

HURRICANE SURVEY

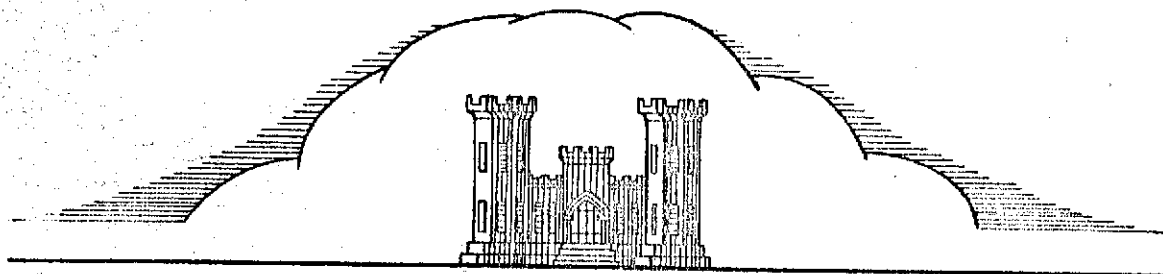
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WASHINGTON, D.C. METROPOLITAN AREA

SURVEY REPORT

~~25 AUGUST 1961~~

15 MAY 1963



U. S. ARMY ENGINEER DISTRICT, BALTIMORE
CORPS OF ENGINEERS
BALTIMORE 3, MARYLAND

HURRICANE SURVEY

WASHINGTON, D. C. METROPOLITAN AREA

U. S. ARMY ENGINEER DISTRICT, BALTIMORE
CORPS OF ENGINEERS
BALTIMORE 3, MARYLAND

S Y L L A B U S

The Washington D. C. Metropolitan area located at the head of tide water on the Potomac River is subject to damages from hurricane tide surges. Large and valuable developments have been located on reclaimed tidal flats and the natural flood plain of the river. These areas would suffer about \$5,000,000 in damages from a recurrence of the 11.0 foot tide as caused by the August 1933 hurricane. The tidal flood that would probably be generated by the most severe hurricane that could reasonably be expected in the Chesapeake Bay region would cause about \$17,000,000 in damages. However, from the present state of knowledge such tidal floods have a very low frequency and therefore the construction of protective works for prevention of tidal flooding only are not justified. The predominant flooding problem in the area is from fluvial floods and this problem would control the design of any local protective works upstream of the National Airport and Bolling Air Force Base. Prevention of tidal flooding would be an additional benefit to accrue to fluvial flood protection. The continuing encroachment on the tidal flats and flood plains of the Potomac River in the Washington area has seriously reduced the capacity of the stream to pass fluvial floods and absorb tidal floods without losses. Zoning regulations to stem the encroachment on the waterfronts and to establish future structures at safe elevations are needed.

The District Engineer recommends that the construction of protective works for tidal flooding only not be authorized at this time.

HURRICANE SURVEY

WASHINGTON, D.C.

METROPOLITAN

AREA

PREPARED BY

U. S. ARMY ENGINEER DISTRICT, BALTIMORE
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U. S. ARMY ENGINEER DISTRICT, BALTIMORE
CORPS OF ENGINEERS
P. O. BOX 1715
BALTIMORE 3, MARYLAND

15 May 1963

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SUBJECT: Hurricane Survey - Washington, D. C. Metropolitan Area

TO: Division Engineer
U. S. Army Engineer Division, North Atlantic
New York, New York

I. AUTHORITY

1. AUTHORITY

This report is submitted in compliance with authorization contained in Public Law 71, 84th Congress, 1st Session, approved 15 June 1955, with reads:

"Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled. That in view of the severe damage to the coastal and tidal areas of the eastern and southern United States from the occurrence of hurricanes, particularly the hurricanes of August 31, 1954, and September 11, 1954, in the New England, New York and New Jersey coastal and tidal areas, and the hurricane of October 15, 1954, in the coastal and tidal areas extending south to South Carolina, and in view of the damages caused by other hurricanes in the past, the Secretary of the Army, in cooperation with the Secretary of Commerce and other Federal agencies concerned with hurricanes, is hereby authorized and directed to cause an examination and survey to be made of the eastern and southern seaboard of the United States with respect to hurricanes, with particular reference to areas where severe damages have occurred.

"SEC. 2. Such survey, to be made under the direction of the Chief of Engineers, shall include the securing of data on the behavior and frequency of hurricanes, and the determination

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of methods of forecasting their paths and improving warning services, and of possible means of preventing loss of human lives and damages to property, with due consideration of the economics of proposed breakwaters, seawalls, dikes, dams, and other structures, warning services, or other measures which might be required."

A survey was recommended for the Washington Metropolitan Area in the Washington District hurricane survey appraisal report dated June 1956. The survey of the Washington Metropolitan Area was approved by the Chief of Engineers 5 December 1956 by letter ENGWD, subject: "Hurricane Appraisal Report" to North Atlantic Division.

II. EXTENT OF INVESTIGATION

2. GENERAL.

This investigation of extended reconnaissance scope concentrates on hurricane effects that are subject to modification by protective works, zoning and evacuation. An inspection of the study area was made by the District Engineer. For the purpose of this report the geographical limits of the Washington Metropolitan Area are considered to include the area subject to significant tidal damages. The upstream limits are Key Bridge on the Potomac River and the Colmar Manor, Maryland flood protection levee on the Anacostia River. Downstream, the area includes the residential areas of Forest Heights, Maryland, and New Alexandria, Virginia. The following studies were made to determine the extent of hurricane induced tides, evaluation of damages for various levels of flooding, the engineering and economic feasibility of protective works, and the need for zoning and evacuation plans.

3. HISTORICAL RECORDS STUDY

A search was made of public and private libraries, newspaper files and similar sources to develop a history of hurricane activity and tidal flooding in the Washington Metropolitan area. These records were used to supplement official observed data in estimating tidal flooding frequency and establishing the maximum tide of record. A summary of the findings are included as Appendix A.

4. FREQUENCY ANALYSIS OF TIDAL FLOODING.

A frequency study of tidal flooding was made on the continuous record from 1931 to 1958, for the U. S. Coast and Geodetic Survey gage at Washington, D. C. and intermittent records extending back to 1858. This hundred year record supplemented by historical data was used to establish the frequency discussed in paragraph 18.

5. STUDY OF PROBABLE SURGES.

As a part of general studies conducted to determine the probable effect of severe hurricanes that could reasonably be expected, the investigation of the Potomac River was included in the report by the Beach Erosion Board, Miscellaneous Paper No. 3-59, "Hurricane Surge Prediction for Chesapeake Bay."

6. DAMAGE SURVEYS.

Detailed damage surveys were made of the study area to determine the probable extent of damage at all levels of flooding up to 20 feet above low water datum. The survey and results are discussed in detail in paragraphs 35 through 37.

7. INVESTIGATIONS OF PROTECTIVE WORKS.

Plans of protective works for the study areas were studied and are discussed in paragraphs 48 through 62.

III. PRIOR REPORTS

8. GENERAL.

There are no prior reports dealing specifically with the hurricane problem in the Washington Metropolitan area. There are numerous reports covering navigation problems in the Potomac and Anacostia Rivers and Reclamation of the Anacostia River Flats. However, none of these deal with problems of storm tide flooding. The following published reports on flood control and allied purposes in the Potomac and Anacostia River basins are the basis for existing flood control projects within the Washington Metropolitan area.

9. POTOMAC RIVER.

Under the provision of House Document No. 308, 69th Congress, 1st Session, a report was submitted 12 April 1932 and published as House Document 101, 73rd Congress, 1st Session, presenting a plan for development of the Potomac River Basin in the interest of navigation, flood control, water power and irrigation. The only feature of the report affecting the Potomac River at Washington is that covering flood control. The existing flood control project for Washington, D. C., as adopted by the Flood Control Act of 22 June 1936, was based on that report. Modifications to the approved flood control project were recommended in the subsequent Survey Report on Potomac River and Tributaries submitted 30 April 1944 and published as House Document No. 622, 79th Congress, 1st Session. The modifications were adopted by the Flood Control Act of 24 July 1946.

10. ANACOSTIA RIVER.

The Survey Report on the Anacostia River Basin in the interest of flood control and navigation dated 31 October 1946, contains favorable recommendations for channel improvement for both flood control and navigation and for local flood protection works. The report served as the basis for the construction of local protection works at Bladensburg, Edmonston, Riverdale, Brentwood, North Brentwood, Colmar Manor and Cottage City, all in the state of Maryland. The report also served as the basis for channel improvements for navigation and flood control from Bladensburg downstream to the Magruder Bridge at the District of Columbia boundary line.

IV. DESCRIPTION

11. GENERAL.

Washington, D. C. is located on the Fall Line at head of tidewater 108 river miles up the Potomac estuary from Chesapeake Bay. The airline distances are 75 miles to the mouth of the Potomac, 140 miles to the mouth of Chesapeake Bay and 265 miles to Cape Hatteras. The drainage area of the Potomac at the head of tidewater is 11,500 square miles and the drainage area of the Anacostia River is 170 square miles. The sections of the Washington Metropolitan area subject to significant tidal damage are located on the characteristic unconsolidated alluvial deposits of gravel, sand and clay. The man-made areas in the tidal area are constructed largely from dredged materials from the alluvial deposits. The study area is covered by maps of the U. S. Geological Survey and Army Map Service and charts of the U. S. Coast and Geodetic Survey.

12. POPULATION.

Preliminary returns of the 1960 census indicate that the population of the Washington Metropolitan Area is about 1,970,000. The population has increased about 30 percent since 1950, largely in suburban communities not affected by tidal flooding. About 80 percent of the population is employed by Federal and local governments, wholesale and retail businesses and service industries. The next three employers in order of size are transportation, contract construction and light manufacturing industries.

13. LAND USE AND DEVELOPMENT.

There are about 48 miles of waterfront in the Washington Metropolitan area of which about 87 percent is owned by the United States. The use of the waterfront is highly diversified and includes park lands, marina facilities, commercial wharfs, airports, power plants, oil terminals, sand and gravel plants, industrial developments and military installations. Redevelopment construction and planning for large sections of the city proper are currently underway. The trend is toward less commercial development in the Washington, D. C. sector and more commercial development in the Alexandria, Virginia sector. A more complete description, by reaches, is included in paragraphs 21 through 34 under the heading "Extent and Character of Flood Area."

V. CLIMATOLOGY

14. The Washington Metropolitan area located on the boundary of the Middle Atlantic Coastal Plain and the Piedmont Plateau about 100 miles from the Atlantic Ocean has a moderate climate under the influence of the Atlantic Ocean. The climate is generally temperate with an average annual temperature of 56 degrees with extremes of 106 and -14 degrees having been recorded. Precipitation averages 42 inches annually. The greatest 24-hour amount recorded was 7.31 inches occurring on 11-12 August 1928 associated with a tropical hurricane crossing the lower Chesapeake Bay. The prevailing winds are northwesterly in the winter and southwesterly in the summer, with an average annual hourly velocity of 7.0 miles per hour. The highest recorded velocity for a 5 minute period was 53 miles per hour in July 1913. Thunder-squalls bring the most frequent high winds and are local in character. Tropical hurricanes or their remnants crossing the Chesapeake Bay or sweeping the Atlantic Coast are attended by heavy rain, but they generally do not have winds of hurricane velocity in the area.

VI. HURRICANES AND TIDES

15. GENERAL.

Records of the U. S. Weather Bureau show that at least 35 tropical hurricanes or remnants of tropical hurricanes have passed through or near the Washington Metropolitan area in the past 100 years. As the hurricane centers approach Washington, the wind velocities are generally reduced to below hurricane velocities as the result of passing overland. The greatest number of hurricanes have occurred during the months of August, September and October. See Figure 5, Plate 6. Tidal flooding in the Potomac River at Washington can be caused by hurricane tidal surges formed in several ways, including in the open sea off the mouth of the Chesapeake Bay, in the lower Bay, in the middle Bay and lower Potomac estuary, or combination of above. The surges produce the highest water levels in the upper Potomac when they are transmitted to arrive at time of astronomical high tides. The mean range for astronomical tides at Washington is 2.9 feet. However, the range is as great as 4.0 feet during the hurricane season. The convergence, or narrowing, of the Potomac tidal estuary contributes to the rise of both normal and storm surges as they reach the Washington area.

16. HURRICANES OF RECORD.

An examination of the hurricanes of record affecting the Washington area disclosed only four with sufficient data for detailed analysis. These are the hurricanes of 23 August 1933; "Hazel"-15 October 1954; "Connie"-13 August 1955; and "Diane"-18 August 1955. Tracks and meteorological data are shown on Plate 7.

a. 23 August 1933. The hurricane of 23 August 1933 was the most destructive on record for the Chesapeake Bay area and the Washington Metropolitan area. The hurricane track entered the mainland near Cape Hatteras, North Carolina, passed slightly west of Norfolk, Virginia, continued north and passed east of the Washington, D. C. area. The storm surge in the Bay and Potomac River was the highest of record and was superimposed on the

astronomical high tide as it proceeded upstream. The combined effects of the storm surge, wind set-up, astronomical high tide and convergence effect caused a tidal flooding elevation of 11.0 feet above low water datum at Washington. In addition, strong winds caused destructive wave action. It is estimated that a recurrence of this storm could conceivably result in damages of approximately \$5,000,000 under existing conditions.

b. Hurricane "Hazel", 15 October 1954. Hurricane "Hazel", the second most destructive of record in the tidewater area of the Washington District, entered the mainland along the Atlantic Coast south of Wilmington, North Carolina and moved rapidly northward over Richmond and Fredericksburg, Virginia, to the Washington area. The northward movement of the storm was accompanied by high winds which contributed greatly to the total damage. The hurricane tidal surge of about 5.6 feet was superimposed on the astronomical high tide and the resultant flood elevation reached 8.7 feet low water datum at Washington. A recurrence of a storm of this magnitude could result in a damage of approximately \$1,300,000 to riverside facilities.

c. Hurricane "Connie" 13 August 1955. The path of hurricane "Connie" through the Washington area was similar to that of the August 1933 hurricane. The maximum tidal surge of about 5.6 feet occurred on astronomical low tide and the level of flooding was 6.6 feet low water datum. Had this storm surge coincided with the normal high tide, the flooding elevation could have reached about 10.0 feet low water datum with a substantial increase in damages. Local damage due to wind, tide and wave action of the storm has been estimated to be about \$100,000.

d. Hurricane "Diane", 18 August 1955. The path of hurricane "Diane" was too far west to cause extensive tide and wave damage to the Washington area. However, heavy rainfall coincident with the storm caused severe damage from fluvial flooding. The rainfall increased the damage to areas subjected to fluvial flooding by hurricane "Connie", six days previous. The maximum surge for this storm in the Potomac at Washington was approximately 4.5 feet and the maximum flooding elevation 7.0 feet low water datum.

VII. HIGHEST TIDES OF RECORD

17. The highest recorded tidal elevations resulting from hurricane activity in the Metropolitan Washington area from 1846 to the present are listed in Table A. These elevations are based on tidal records except for the estimated values which were derived from the Records Study included as Appendix A. Only those elevations equal to or exceeding 6.5 feet low water datum were included. The tracks of the hurricanes producing these high tides are shown on Plate 6. There are numerous references in the historical record prior to 1846 reporting high waters in such terms as "greatest tides remembered by the oldest inhabitants", however, these references are too general to make reasonable estimates of tide heights.

Table A
Hurricane Tidal Flooding Elevations

<u>Date</u>	<u>Elevation Low Water Datum</u>	<u>Remarks</u>
23 August 1933	11.0	Maximum of Record
13 October 1893	9.8±	Estimated
15 October 1954	8.7	"Hazel"
18 September 1876	7.9±	Estimated
30 September 1896	7.0	
18 August 1955	7.0	"Diane"
13 October 1846	6.9±	Estimated
12 August 1955	6.6	"Connie"
29 August 1893	6.5	
1 September 1952	6.5	

18. TIDAL FLOODING FREQUENCY.

The estimate of the frequency hurricane induced tidal flooding was derived from the continuous record for 1931 to 1958 from the U. S. Coast and Geodetic Survey gage at Pier 4, formerly Lighthouse Wharf on the Washington Channel, supplemented by intermittent records, newspaper accounts and other sources. All records of high water due to fluvial flooding were eliminated. The frequency curve shown as Figure 3, Plate 6, was developed by the procedures given in "Statistical Methods in Hydrology" by T. R. Beard. The upper limits of the curve were defined by adjusting the plotting positions of the tide elevations of 23 August 1933 and 15 October 1954 to a 100 year period of record. The lower portion of the curve is essentially a partial duration plot. Based on available data it appears that the maximum tide of record 23 August 1933 has about a one percent chance of annual occurrence.

VIII. STANDARD PROJECT HURRICANE AND RESULTING TIDES

19. The standard project hurricane criteria for the Chesapeake Bay Zone as developed by the U. S. Weather Bureau and Office Chief of Engineers, is considered applicable to the Washington Metropolitan area. The maximum wind and pressure data of the Cape Hatteras hurricane of 14 September 1944, applied to the path and forward speed of the hurricane

of 23 August 1933 are comparable to those of the standard project hurricane, and it appears reasonable to expect that the resulting storm surges would also be comparable. The wind and pressure data developed from the September 1944 hurricane transposed to the Chesapeake Bay were used by the Beach Erosion Board to estimate the storm surge in Chesapeake Bay and Potomac River. The computed surge in the Potomac River at Washington for this condition is 13.6 feet, ± one foot. With the tolerance of one foot and using the full astronomical tide damage, the resulting tide elevation at Washington could range from 12.3 feet to 18.5 feet above low water datum. The average computed surge superimposed on mean tide level would give a water surface elevation of 15.0 feet above low water datum.

IX. MAXIMUM PROBABLE TIDE

20. The Beach Erosion Board study included an estimate of the effect of increasing the wind velocities of the September 1944 transposed hurricane by 5 miles per hour. The resulting surge at Washington would be 14.8 feet, ± one foot. Assuming the upper limit of about 15.8 feet for the storm surge superimposed on the highest astronomical tide to be expected during the hurricane season the resulting tide would be between 19 and 20 feet above low water datum. This is concluded to be the maximum probable tide. However, the probability of the occurrence of such an event is so remote that it is not included in the frequency estimates of this report.

X. EXTENT AND CHARACTER OF FLOOD AREA

21. GENERAL.

The area under consideration includes approximately 48 miles of shoreline consisting of 30 miles of Potomac River shoreline and about 18 miles of Anacostia River shoreline. The area susceptible to flooding lies within the political boundaries of the District of Columbia and the states of Maryland and Virginia and includes a total land area subject to inundation of about 6,000 acres at the tidal flooding elevation of 15.0 feet low water datum. Approximately 87 percent of the shoreline is owned or controlled by the Federal Government. The area subject to flooding includes residential, commercial, industrial and recreational facilities including 2,600 acres of park land. Waterfront development includes power generating stations, sand and gravel plants, oil and bulk goods terminals, commercial and recreational boating facilities and military installations. The area has been divided into 13 reaches as described in detail in the following paragraphs.

22. REACH 1 - GEORGETOWN.

This reach extends along the left bank of the Potomac River from Key Bridge downstream about 0.6 miles to the mouth of Rock Creek. The present development is primarily industrial and commercial and is served

by a branch line of the Baltimore and Ohio Railroad. The limited commercial waterborne traffic is expected to be further reduced by the construction of fixed span bridges downstream. The trend is toward reduction of commercial and industrial activity in this reach. Consideration is being given to location of an express highway in the area. The area is subject to tidal flooding but the greatest damage is caused by fluvial flooding.

23. REACH 2 - WEST POTOMAC PARK.

This reach extends along the left bank of the Potomac River from Rock Creek to the 14th Street highway bridge and consists primarily of parks, memorials, monuments and riverside highways. Primary physical damage is limited mainly to the World War II temporary buildings still being utilized.

24. REACH 3 - DOWNTOWN WASHINGTON.

This important area including the Federal Triangle, other permanent and temporary Government buildings and valuable commercial properties extends from the Capitol building west to the Potomac River and south to "P" Street Southwest near Fort McNair. There are about 450 acres in the area below 15 feet low water datum with some street elevations as low as 8.0 feet. The sector south of Independence Avenue and west of South Capitol Street is being rebuilt by the Redevelopment Land Agency of the District of Columbia. The natural protection for the area is a low ridge extending from the Washington Monument to the vicinity of Fort McNair. The upstream end of the natural protection is supplemented by flood protection works from Washington Monument to Lincoln Memorial. Emergency closures are required for extreme floods at 17th Street and Constitution Avenue and 23rd Street and Constitution Avenue. The area is closed to flooding from the south by the raised grade of "P" Street Southwest.

These protective works shown on Plate 2 provided for fluvial floods are also effective against tidal floods up to about 15 feet low water datum without making the 17th Street Northwest, closure. However, the area could be damaged during tidal floods by failure to make all storm and sanitary sewer closures and by coincident interior runoff flooding.

25. REACH 4 - EAST POTOMAC PARK - WASHINGTON CHANNEL.

This reach extends along the left bank of the Potomac from the 14th Street Highway bridge to the confluence with the Anacostia River. The reach is sub-divided into two damage centers, East Potomac Park and Washington Channel. East Potomac Park is a man-made peninsula between the Washington Channel and the Potomac River with elevations ranging from 6.4 to 14.4 feet low water datum. The area under the control of National Capital Parks, is occupied by motel and trailer park facilities, tennis courts, a public golf course, a restaurant, and repair shop

facilities. The second damage center is the left bank of the Washington Channel, extending from the confluence upstream about 10,000 feet. Prior to the redevelopment program of Southwest Washington, the left bank of this channel had been one of the principal commercial navigation terminals. Future plans are expected to reduce commercial activities and concentrate on recreational facilities. Maine Avenue, a heavily travelled cross town route, parallels the channel and is susceptible to flooding at 12.9 feet low water datum.

26. REACH 5 - BOLLING AIR FORCE BASE.

This airfield is located on the left bank of the Potomac River immediately downstream of the mouth of the Anacostia River. The downstream end of the facility near the river is subject to flooding. Flight operations at the field are to close down in the near future but no definite plans have been announced for the future use of the area.

27. REACH 6 - BELLEVUE-FOREST HEIGHTS.

This reach is adjacent to and downstream of Bolling Field, on the left bank of the Potomac. The area is susceptible to tidal and fluvial flooding and includes the Naval Research Laboratory, the Bellevue Housing Annex for Naval personnel, and the District of Columbia Blue Plains sewage treatment plant. The town of Forest Heights, Maryland, is included in this reach and is susceptible to fluvial flooding by Oxon Run which is influenced by extreme tidal fluctuations of the Potomac River.

28. REACH 7 - KEY BRIDGE TO 14TH STREET.

This area extends along the right bank of the Potomac River for a distance of about 2.5 miles. The land area subject to flooding is occupied by parks and riverside highways which sustain relatively slight physical damage.

29. REACH 8 - NATIONAL AIRPORT.

This reach extends from the 14th Street bridge to Four Mile Run downstream of the airport. The airport, constructed from material dredged from the river occupies about 700 acres. The field is protected by levees on the upstream section to elevation 16.0 feet low water datum and on the downstream section to 11.0 feet. The minimum elevation of the north approach road is 10.5 feet low water datum and of the south approach 8.5 feet. The lowest runway elevation is 12.0 feet and the zero damage elevation of the terminal building is 16.0 feet. The west approach road to the airport via the underpass has a minimum elevation of 8.5 feet low water datum and is also subject to flooding from interior runoff.

30. REACH 9 - FOUR MILE RUN.

Four Mile Run, which drains about 20 square miles, enters the Potomac River downstream of National Airport. The stream is passed under U. S. Route 1 and the Potomac Railroad Yards through a large 3-cell box culvert, and under George Washington Memorial Parkway through an arch bridge. The damage center is a residential and commercial area to the west of U. S. Route 1. The area is not directly subject to tidal flooding, but high stages in the Potomac from tides and fluvial floods interfere with drainage and cause interior flood damages.

31. REACH 10 - FOUR MILE RUN TO ALEXANDRIA.

This reach on the right bank of the Potomac, extends from the mouth of Four Mile Run to the upstream limit of the Alexandria City Reach. The area is lightly developed and damages are limited to the National Capital Park tree nursery and the Washington Sailing Marina.

32. REACH 11 - ALEXANDRIA, VIRGINIA.

This reach along the right bank of the Potomac, is within the city limits of Alexandria, Virginia. Flooding is confined to a narrow strip of waterfront by the natural topography. The area susceptible to damage by tidal flooding is primarily commercial in nature and includes the existing waterfront developments which are in varying degrees of repair. Residential damage is comparatively light and is limited to older residences near the waterfront. A spur track of the Southern Railway along Union Street, parallel to the waterfront is subject to tidal flooding. Plans for expansion and redevelopment of port activities are currently being studied by the city.

33. REACH 12 - NEW ALEXANDRIA - HUNTING CREEK.

This area is located in Fairfax County, Virginia, immediately downstream of Alexandria. New Alexandria occupies a low flat area with an elevation of about 8.0 feet low water datum, and is bounded by Hunting Creek on the north and George Washington Memorial Parkway on the east. The development includes a large garden type apartment project, single family residences, a modern shopping center and a golf course. Tidal floods could enter the area from Hunting Creek or from the Potomac River across the parkway. The area is currently undergoing considerable change by construction of a major highway interchange, channelization and land fills.

34. REACH 13 - ANACOSTIA RIVER.

This reach includes both banks of the Anacostia River and extends from Hains Point at the mouth to the Anacostia River Basin Flood Control levees, at Colmar Manor and Bladensburg, 8 miles upstream. The major installations on the right bank subject to fluvial and tidal flooding are Fort McNair, Government Services Administration, Temporary Building A, B and C, Buzzards Point Power Plant, U. S. Naval Weapons Plant, U. S. Army Engineer Wharf, Pennsylvania Railroad freight line and bridge, oil

terminals, sand and gravel plants, and marinas. On the left bank are the U. S. Naval Air Station, Naval Receiving Station, Anacostia Park and the Benning Power Plant. Also in the area subject to flooding is the partially completed Anacostia River Flats Project which extends from Pennsylvania Railroad bridge upstream to the District of Columbia-Maryland line.

X. HURRICANE FLOOD DAMAGES

35. GENERAL.

Hurricane damages to the Washington Metropolitan area are caused by tidal flooding, limited wave action, high winds and fluvial flooding from hurricane associated rainfall. Since fluvial flood damages also affect the entire study area as defined in paragraph 2, the field survey for tidal flood damages was made in conjunction with the investigation of damages from fluvial flooding conducted as a part of the Potomac River Basin Review Report. Thus the stage-damage estimates as shown on Plates 5 and 6 are applicable to both fluvial and tidal flooding. However, the stage-damage data was applied to tidal flood frequency only in developing benefit-cost ratios in this report. Wind damages are not included in this survey.

36. PROCEDURE.

Damages were assessed for elevations up to 20 feet low water datum for each of the 13 reaches and were compiled in the following categories:

- a. Residential
- b. Industrial
- c. Commercial
- d. Marine and waterway facilities
- e. Land transportation facilities
- f. Communications and utilities
- g. Public properties and services

The physical contents of each reach were inventoried as to type of construction, use, owner or occupant and the zero damage elevation. Tangible primary damages evaluated included physical damages to structures, equipment, machines, household furnishings and non-physical losses such as unreasonable loss of business, wages, salaries and expenses to homeowners for supplemental food shelter and other necessities. The data on probable damages to major items were obtained from the Federal and municipal agencies

responsible for the operation and maintenance of the public facilities and from the owners or operators in case of the larger privately owned facilities. A sampling procedure was used to estimate damages to residential and smaller commercial properties.

37. RESULTS.

The results of the damage survey as shown on Plates 5 and 6 are adjusted to the price level of June 1960 and include estimates based on a projection of the Southwest Washington Redevelopment. It is estimated that a recurrence of the maximum tide of record, 11.0 feet low water datum would cause about \$5,000,000 in damages. The damages from a 15.0 foot tide elevation would be about \$17,000,000. A 15 foot tide elevation might be expected from the tide surge generated by a Standard Project Hurricane in the Chesapeake Bay region. The probable damages from a higher tide would be dependent on making an effective closure at the existing Potomac Park flood control at 17th Street and Constitution Avenue Northwest. For example, damages from a 17 foot tide elevation with all closures not in place, the damages from a 17 foot tide could reach \$60,000,000 for the present state of development and \$95,000,000 with the Southwest Redevelopment fully completed. A greater share of the estimated damage would be to buildings and other facilities now occupying reclaimed tidal flats.

XI. EXISTING CORPS OF ENGINEERS FLOOD CONTROL PROJECTS

38. WASHINGTON, D. C. FLOOD CONTROL PROJECT - ORIGINAL PROJECT.

The local flood protection project as recommended in House Document No. 101, 73rd Congress, 1st Session and adopted by the Flood Control Act of 22 June 1936 consists of levees, walls and grade raisings to protect the downtown portion of Washington completed in 1939 included earth levees, a combination wall and levee and provision for emergency closures at 17th Street Northwest and the entrance into the Navy Building parking area. The total length of protection was about 4,800 feet with a top elevation of 20.5 feet above low water datum. The project for the protection of Bolling Field and the Anacostia Naval Air Station was completed in 1940, and included 12,800 feet of levees, floodwalls and movable closures extending from the U. S. Botanical Gardens to Giesboro Point. The top of protective works is at elevation 16.3 low water datum. The raising of P. Street Southwest and the provision of flood gates on sewer outlets were accomplished by the District of Columbia Government. Local cooperation has been fully complied with except for the Arlington Experimental Farm area where protection is no longer required by reason of elevations of roads obtained during construction of the Pentagon.

39. AUTHORIZED MODIFICATIONS FOR WASHINGTON, D. C. PROJECT.

The local flood protection project was modified by the Flood Control Act of 24 July 1946 in accordance with the recommendations of the Chief of Engineers contained in House Document No. 622, 79th Congress, 2nd

Session. Authorized modifications are in two stages. The first stage includes the raising of a short section of "P" Street Southwest east of 4th Street Southwest, grading in vicinity of Lincoln Memorial and the construction of about 1,200 feet of temporary levee around the temporary buildings T-3, T-4 and T-5 which are situated between 17th Street Northwest and Washington Monument. The second stage of construction includes the regrading of the park area to the maximum elevation of 20.5 feet low water datum after the removal of the temporary buildings and the provision of movable closure gates. The modification by this Act also eliminates the protective work for Arlington Experimental Farm. No construction has been undertaken on these authorized modifications. The present estimated cost is about \$2,200,000.

40. STATUS OF WASHINGTON, D. C. PROJECT.

A considerable portion of the Potomac Park Levee was removed during World War II to construct an additional wing on the Navy Department main building and buildings T-3, T-4 and T-5. In the event of a major fluvial flood, it may be necessary to construct as much as 1,500 feet of temporary levee to provide protection to the height of the permanent works now in place. The Potomac Park project is under the jurisdiction of the National Capital Parks for operation and maintenance. The various reaches of the Anacostia Levee are under the control of agencies having jurisdiction over the lands and include the National Capital Parks, the U. S. Navy, the District of Columbia and the U. S. Air Force.

41. ANACOSTIA RIVER BASIN FLOOD CONTROL AND NAVIGATION PROJECT, D. C. AND MARYLAND.

The project was authorized by the Flood Control Act of 17 May 1950, Public Law 56, 81st Congress, Second Session, substantially in accordance with the recommendation of the chief of Engineers in House Document No. 202, 81st Congress, 1st session. The project completed in 1959 provides a high degree of protection against both fluvial and tidal flooding to the town of Bladensburg, Edmonton, Riverdale, Brentwood, Hyattsville, Cottage City and Colmar Manor, all in Maryland. Since the minimum elevation of top of protective works for this project is 21.3 feet low water datum, it is considered that no modifications are necessary for hurricane protection.

XII. OTHER FLOOD CONTROL PROJECTS

42. NAVAL RECEIVING STATION.

The Naval Receiving Station located on the left bank of the Anacostia River, immediately downstream of the 11th Street bridge, is protected by an 1,800 foot steel sheet pile bulkhead to elevation 15.4 feet low water datum. The project, constructed by the Potomac River Naval Command, has two removable closure structures and ties into the Anacostia levee project.

43. WASHINGTON NATIONAL AIRPORT.

The Washington National Airport has a perimeter levee along the Potomac River at the northern and eastern boundaries. There is no levee along the southern boundary. The levee is primarily for protection against fluvial flooding and the maximum elevation of the northern or upstream section is 16 feet low water datum. The downstream section is exposed to damage for elevations greater than 12.0 feet above low water datum.

XIII. IMPROVEMENTS DESIRED.

44. The study of the Washington Metropolitan Area was undertaken as part of the program to include all major metropolitan areas subject to hurricane damages. "Local interests" in this case are primarily the Federal agencies charged with responsibilities for the properties along the waterfront. There have been no direct requests for hurricane protection in the area and no public hearings were held. Since the preliminary investigations clearly indicated a lack of justification for protective works, the various plans were not formally presented to the Federal and local agencies for comment. In the absence of economic justification for protective works, major purpose of the study is to define the nature and scope of the hurricane problem as a guide to local hurricane preparedness actions such as zoning. This is particularly important in relation to the extensive plans for development and redevelopment of the Washington Metropolitan Area.

XIV. HURRICANE PROBLEMS AND SOLUTIONS CONSIDERED

45. The major hurricane problem in the Washington Metropolitan Area is flooding from wind generated tidal surges. These surges are formed in the open sea off the mouth of Chesapeake Bay and in the lower Bay itself. Generally the convergence of the Potomac River tidal estuary and local wind effects increase the water surface elevation of the surges as they are translated up the river from the Bay to Washington, D. C. The short fetches available in the Washington area and the reduction of wind velocities below hurricane strength reduces the threat of wave damage. The problem of wind damage reduction was not considered.

46. RELATED PROBLEMS.

The problem of fluvial flooding predominates in the consideration of protective works in the Washington Metropolitan area. The drainage area of the Potomac River Basin at Washington is about 12,000 square miles. The maximum discharge of record was about 484,000 cubic feet per second which occurred in March 1936. The flood of June 1889 was about equal in magnitude to that of March 1936 and flooded much of the Downtown Reach referred to in this report. However, the maximum stages were attained during the flood of October 1942 from a discharge of about 450,000 cubic

feet per second. A comparison of the stages of the October 1942 fluvial flood and the August 1933 tidal flood illustrates the difference in damage potential of the two types of flooding. As stated in paragraph 18 the frequency of the 1933 tidal flood is estimated at about one percent chance of annual occurrence, while the 1942 flood is estimated to about a two percent chance of annual occurrence. Included in the following tabulation are the probable effects of the design flood discharge of 700,000 cubic feet for Washington, D. C. as recommended in House Document 622 and adopted by the Flood Control Act of 1946 (See Paragraphs 9 and 39), and the effects of the tide that might be expected from Standard Project Hurricane. The fluvial flood of 700,000 c.f.s. is now estimated to have a larger percent chance of annual occurrence than the 15.0-foot tide.

Table B

Elevations above Low Water Datum

Location	River Mile	<u>Maximum of Record</u>		<u>Considered for Design</u>	
		Fluvial Oct. 1942	Tidal Aug. 1933	Fluvial * 700,000cfs	Tidal Standard Proj.Hurr.
Key Bridge	0	19.5	11.1	27.0 *	15.0
Memorial Bridge	1.4	14.0	11.0	22.0 *	15.0
17th Street	2.0	13.6	10.9	19.6 *	15.0
Hains Point	4.1	12.1	11.0	18.2 *	15.0
Bolling AFB (Downstream)	6.0	10.7	10.7	16.5 *	15.0
Alexandria	8.3	8.4	10.6	-	15.0
New Alexandria	10.0	7.9	10.5	-	15.0

* Subject to Revision.

47. SOLUTIONS CONSIDERED.

The reduction of hurricane tidal flood damages was considered by two structural means; local protection works for the separable areas and by barriers located downstream of the Metropolitan area. Also considered are the reduction of future damages by zoning regulations and by evacuation.

XV. PROTECTION BY STRUCTURES

48. GENERAL.

Protective plans to reduce tidal flooding and wave damages were considered for the various reaches by local protection works, and for the entire area by the construction of a tidal barrier downstream of Washington in the vicinity of Marshall Hall, Maryland. The selected

design tide elevation was 15 feet above low water datum. This is the computed water surface elevation resulting from the storm surge of the Chesapeake Bay Standard Project Hurricane, modified for effects of travel up the Potomac River and arriving at time of mean tide level at Washington, D. C. An addition of 3.0 feet for freeboard to allow for wave action and convergence effect set the top elevation of 18.0 feet above low water datum. The following summary by reaches includes the description and estimate of first cost. References are made to annual charges and annual benefits where applicable. Benefits were claimed for protection up to 15 feet above low water datum on the basis of the stage-damage data and the tidal flooding frequency only. Investigations for protective works for design tides higher than 15.0 feet showed progressively lower benefit-cost ratios as the degree of protection was increased.

49. REACH 1 - GEORGETOWN.

The plan of protection would consist of about 3,600 feet of reinforced concrete floodwall, with permanent type removal closures, and alterations to existing drainage structures. An estimated first cost is over \$1,000,000 and would show a benefit-cost ratio less than 0.1 for tidal protection only. Although a small increment of benefits would accrue for prevention of fluvial flooding, the height of protective works is clearly not adequate for flood protection.

50. REACH 2 - WEST POTOMAC PARK.

Protective works were not considered practical since they would interfere with the use of the land for park purposes. The temporary U. S. Government office buildings remaining in the area are now scheduled for removal by 1965.

51. REACH 3 - DOWNTOWN WASHINGTON.

Protection against tidal flooding up to the design tide for this area is provided by the existing flood control project. The low point in the protective works, without the temporary closures in place, is 15.9 feet above low water datum at 17 Street Northwest. Since this point is in a sheltered location with respect to winds, the 3-foot freeboard is not needed.

52. REACH 4 - EAST POTOMAC PARK AND WASHINGTON CHANNEL.

The protection of East Potomac Park by a floodwall or levee would be neither practical nor desirable since the structures would interfere with the primary purpose of the area. The protection of the north side of Washington Channel against the design tide would require about 4,800 feet of reinforced concrete floodwall and would cost in excess of \$500,000. This would not provide adequate protection against the design

fluvial flood. Since the plans for the redevelopment of this area as a part of the Southwest Redevelopment project are not complete, it is not possible to estimate the benefits.

53. REACH 5 - BOLLING AIR FORCE BASE.

Protection for this facility would require raising that part of the Anacostia River levee that protects the upstream end of the airfield and the extension of these works to the downstream end of the airfield. About 7,900 feet of earth levee and 1,400 feet of reinforced concrete floodwall would be required at an estimated cost of over \$600,000. On the basis of protection of the existing development against tidal flooding only, the benefit-cost ratio would be about 0.2. Additional benefits to be gained by reduction of damages by fluvial floods would increase the benefit-cost ratio to about 1.9. These additional benefits would be substantially reduced, however, if fluvial floods were controlled by retention reservoirs upstream. In a comprehensive study for development of the Potomac River Basin, the District Engineer recommends a plan for a system of headwater and major reservoirs that would provide, among other benefits, protection from floods somewhat greater than the largest flood of record. Ancillary benefits would be insufficient to justify local protection against tidal floods in this area.

54. REACH 6 - BELLEVUE - FOREST HEIGHTS.

Protection for the Bellevue area would tie in with the lower end of the protection for Bolling Air Force Base. Approximately 4,600 feet of earth levee, 2,400 of reinforced concrete floodwall, revisions to drainage structures and closure structures for access to the waterfront are required at an estimated cost of about \$700,000. The benefit-cost ratio for prevention of tidal flooding only is about 0.3. A local flood protection project for the community of Forest Heights, Maryland, is under construction under the authority of Section 205 of the Flood Control Act of 1948, as amended. The works as proposed would provide protection against the Standard Project fluvial flood from Oxon Run and from the maximum fluvial and tidal flood elevation of record on the Potomac River. The proposed project would not prevent flooding by the design hurricane tide. However, the addition of this protection would not be economically feasible.

55. REACH 7 - KEY BRIDGE TO 14TH STREET.

Protective works were not considered for this area due to the relatively light damage that might be expected from tidal flooding.

56. REACH 8 - NATIONAL AIRPORT.

Protective works for the design tide plus freeboard would consist of raising about 14,600 feet of the perimeter road-levee. Drainage modifications would be needed and closures would be required at each end of the three runways. The estimated cost of the work is about \$400,000

and the benefit-cost ratio is about 0.1. There would be added benefits from fluvial flood control. Any modifications of the existing work should be on fluvial flood control requirements.

57. REACH 9 - FOUR MILE RUN.

Protective works were not considered for this reach since the flooding damages are primarily from interior drainage.

58. REACH 10 - FOUR MILE RUN TO ALEXANDRIA.

Protective plans were not considered for this reach due to the relatively light damages.

59. REACH 11 - ALEXANDRIA.

Elimination of tidal flood damages from this reach to the design tide elevation would require about 7,900 feet of reinforced concrete floodwall with numerous emergency closures to permit access to loading and docking facilities. The estimated cost of the works is over \$2,000,000 and the benefit cost ratio for prevention of tidal floods is about 0.3. Additional benefit would accrue from fluvial flood protection since the design height for tidal flood protection would be adequate for fluvial flood protection in this reach. The City of Alexandria has under consideration plans for developing the waterfront for a deep water port.

60. REACH 12 - NEW ALEXANDRIA - HUNTING CREEK.

Protection for this area against the design hurricane tide would require about 12,400 feet of earth levee, 400 feet of reinforced concrete floodwall, a pumping station for interior drainage channel outside the levee and several other drainage structures at an estimated cost of about \$1,500,000. The benefit-cost ratio would be about 0.8. To protect the area against damages from a recurrence of the record tidal flood of about 10.6 feet, would require essentially the same elements with the top of protective works at 14.0 feet above low water datum. The cost of this protection would be about \$1,200,000. The benefit-cost ratio would be about 0.6. Additional benefits to be gained by reduction of damages by fluvial floods would increase the benefit-cost ratio to about 1.5. These additional benefits would be substantially reduced, however, if fluvial floods were controlled by retention reservoirs upstream. In a comprehensive study for development of the Potomac River Basin, the District Engineer recommends a plan for a system of headwater and major reservoirs that would provide, among other benefits, protection from floods somewhat greater than the largest flood of record. Ancillary benefits would be insufficient to justify local protection against tidal floods in this area.

61. REACH 13 - ANACOSTIA RIVER.

The protection of the Federal and private facilities along the Anacostia River against the design hurricane tide would require

extensive works with the total estimated cost exceeding \$4,000,000. The right bank structures, including protection for Fort McNair and the U. S. Naval Weapons Plant, would include 12,500 feet of floodwall, changes to drainage structures and numerous closures to allow access to the waterfront. The left bank protection would include 2,000 feet of earth levee between the Pennsylvania Avenue and 11th Street bridges and modification of the existing protection works for the U. S. Naval Receiving Station, National Capital Park lands, and the U. S. Naval Air Station. The benefit-cost ratio for prevention of tidal flood damage to the existing development would be about 0.1. Obviously the consideration of protection works should be on the basis of probable effect of future fluvial flooding and the type of development to be undertaken.

62. PROTECTION BY BARRIERS.

As an alternate to providing protection by means of walls and levees, the use of tidal barriers located downstream of the Washington Metropolitan area was investigated. The two types considered were a rock-fill barrier with a fixed opening and a concrete barrier with crest gates and a gated navigation opening. A rock barrier, with a top elevation of 18.0 feet above mean low water and a fixed 175-foot opening for navigation, would be effective in reducing tide surge damages in the Washington area. However, such a barrier would increase the level of fluvial floods in the area and thereby increase the damages. Additional damages would result from the increased pollution due to reduction of the tidal exchange. A concrete barrier with crest gates and sector type navigation gates would eliminate the tidal flood damages in the Washington area. A structure of this type with the crest gates and navigation gates normally open, would allow the daily tidal exchange and would not significantly affect the fluvial flood stages. The estimated cost of a gated tidal barrier is over \$35,000,000 and the benefit-cost ratio is about 0.2. A more detailed study of the effects on pollution conditions and the fish and wildlife interests might further reduce the benefit-cost ratio.

XVI. ESTIMATES OF FIRST COSTS AND ANNUAL CHARGES

63. The estimates of first costs and annual charges for the New Alexandria-Hunting Creek reach only are shown on Table C. Costs estimates and annual charges for the sub-marginal plans considered for the other reaches are not included in this report. Construction costs are based on the July 1960 price level and include appropriate contingency allowances. Federal annual charges are based on 70 percent of the first cost of construction, plus the preauthorization study costs. Non-Federal annual charges are based on 30 percent of the first costs of construction plus the cost of operation and maintenance.

Table C

Estimates of First Costs and Annual Charges

(July 1960 Price Level)

Principal Features	Degree of Protection	
	Design Hurr. Tide (15.0 Ft. L.W.D.)	Max. Tide of Record (10.6 Ft. L.W.D.)
	\$	\$
Lands and Damages	58,000	46,000
Levees and Floodwalls	609,000	379,000
Pumping Station	276,000	276,000
Drainage System	303,000	303,000
Engineering and Design	75,000	60,000
Supervision and Administration	119,000	96,000
Total Estimated Construction Costs	1,440,000	1,160,000
Pre-Authorization Studies	5,000	5,000
TOTAL ESTIMATED FIRST COSTS	1,445,000	1,165,000
Distributed Costs:		
Federal: 70% of Estimated Constr. Cost	1,008,000	812,000
Pre-Authorization Studies	5,000	5,000
TOTAL (Federal)	1,013,000	817,000
Non-Fed: 30% of Est. Constr. Costs	432,000	348,000
Estimated Annual Charges:		
Federal: Interest at 2.625%	26,600	21,500
Amortization at 2.625% at 50 yrs.	10,000	8,100
TOTAL (Federal)	36,600	29,600
Non-Fed: Interest at 3.5%	15,100	12,200
Amortization at 3.5% at 50 yrs.	3,300	2,600
Operation & Maintenance	10,000	10,000
TOTAL (Non-Fed)	28,400	24,800
TOTAL ESTIMATED ANNUAL CHARGES	65,000	54,400

XVII. ESTIMATES OF BENEFITS

64. The benefits for the protection of the New Alexandria-Hunting Creek area were computed on the basis of reduction of damages due to tidal flooding. The average annual benefits for protection up to the 15.0-foot design tide are \$55,500 and for the 10.6-foot maximum of record are \$34,200.

XVIII. COMPARISON OF BENEFITS AND COSTS

65. The benefit-cost ratio for the protective works for the New Alexandria-Hunting Creek area are shown in the following tabulations:

<u>Degree of Protection</u>	<u>Annual Benefits</u>	<u>Annual Charges</u>	<u>Benefit/Cost Ratio</u>
15.0-foot design tide	55,500	65,000	0.8
10.6-foot tide (max. of record)	34,200	54,400	0.6

The benefit-cost ratios for local protection works in the remaining upstream reaches range from 0.1 to 0.3, and the ratio for protection by a tidal barrier is about 0.2.

XIX. PROPOSED LOCAL COOPERATION

66. NEW ALEXANDRIA - HUNTING CREEK.

The local cooperation for the New Alexandria-Hunting Creek or other non-Federal areas where tidal flooding predominates would be based on the cost sharing formula adopted by the Flood Control Act of 1958, Public Law 85-500, 85th Congress for Narragansett, New Bedford and Texas City projects where local interests are required to pay at least 30 percent of the first cost of construction. Included in the 30 percent would be the costs of lands, easements and rights-of-way, highway revision and utility changes. The operation and maintenance would also be a local responsibility.

67. OTHER AREAS.

In other non-Federal areas where an appreciable portion of the benefits would accrue from reduction of fluvial flood damages, the local cooperation formulas would be applied in proportion to the benefits to accrue for each purpose. The local costs allocated for tidal flooding only would be based on the formula adopted by Public Law 85-500 as described above, while the cost for allocation for fluvial flooding would be based on the local cooperation requirements for flood control as established by the Flood Control Act of 1936, as amended. The operation and maintenance would be a local responsibility. In areas of mixed Federal and non-Federal responsibility, local cooperation requirements would depend on allocation of costs among the various purposes and apportionment of costs among interests on the basis of benefits derived.

XX. APPORTIONMENT OF COSTS AMONG INTERESTS

68. The apportionment of costs among interests for the New Alexandria-Hunting Creek area is based on the cost sharing formula as stated in paragraph 66.

<u>Degree of Protection</u>	<u>Federal First Cost</u>	<u>Non-Federal First Cost</u>	<u>Non-Federal Annual Operation & Maintenance</u>
15.0-foot design tide	1,013,000	432,000	10,000
10.6-foot tide (Max. of Record)	817,000	348,000	10,000

XXI. COORDINATION WITH OTHER AGENCIES

69. All Federal and local agencies involved cooperated in furnishing information for the damage survey. The U. S. Fish and Wildlife Service has been apprised of the survey. The interest of this agency in the protective works considered is confined to the barrier, which is the only feature which, if constructed, would have a significant effect on the fish and wildlife resources. Since the barrier was not proposed for construction, no study was made on the effects on fish and wildlife. Comments are included in Appendix B.

XXII. DISCUSSION

70. THE TIDAL FLOOD PROBLEM.

The Washington, D. C. area, located at the head of tidewater on the Potomac River, is subject to significant tidal actions. Normal astronomical tides have a mean range of about 3.0 feet and an extreme range of about 15.0 feet, from a high of 11.1 feet observed during the 1933 hurricane to a low of minus 4.8 feet observed in March 1888. Since the observed high tide of 1933 was the result of a comparatively weak hurricane, the effects of more severe hurricanes must be taken into account when considering the possible means of preventing loss of lives and damages to property. The encroachment on the tidal flats and flood plains of the Potomac River by the development of Washington, D. C. and adjacent communities has made a sizable segment of the area subject to high property damages. The extent of this problem is indicated by the estimate of \$5,000,000 in damages that would result from a recurrence of the 1933 hurricane tide. Because of the probability of much more severe hurricanes attacking the Chesapeake Bay region, protection against tidal flooding up to the maximum tide of record would not constitute adequate protection for an area as important as the National Capital.

71. SELECTION OF A DESIGN TIDE.

The selection of a design hurricane tide for consideration of protective works in the Washington Metropolitan area was based on the probable effects of the most severe hurricane that is reasonably characteristic of the region. This is analogous to the "Standard Project Storm" and "Standard Project Flood" which usually serve as the basis for design of fluvial flood protection for large urban areas. The Cape Hatteras Hurricane of September 1944 transposed to a path similar to that of the August 1933 hurricane meets the requirement for a "Standard Project Hurricane" for the region as established by the U. S. Weather Bureau and the Office Chief of Engineers. From the data developed from this hurricane, the Beach Erosion Board estimated that the probable storm tide surge in the Potomac River at Washington would be in the order of 13.6 feet + one foot. This surge occurring at time of ordinary mean tide would raise the water level to 15.0 feet above low water datum. The selected design tide of 15.0 feet, about 4.0 feet above the maximum of record, provides an adequate standard for evaluating the need for protective works in the Washington Metropolitan area.

72. RELATED FLUVIAL FLOOD PROBLEMS.

The problem of fluvial flooding controls the consideration of protective works in the Washington Metropolitan area from Bolling Air Force Base and the National Airport upstream. The existing flood protection project for the downtown area is based on a design flood of 700,000 cubic feet per second, which is roughly equivalent to the Standard Project Flood for the region. However, part of the levee has been removed for the construction of temporary Federal office buildings requiring emergency closures during major floods. The Anacostia River levees for protection of the U. S. Naval Air Station and other facilities were designed for a flood of 500,000 cubic feet per second. Recommendations for modification of the existing flood control projects for Washington, D. C. is included in the Review Report for the Potomac River Basin.

73. PROTECTIVE WORKS CONSIDERED.

Protection by levees and floodwalls for the separable reaches and for the entire area by tidal barriers were investigated and found to be economically unjustified. The low benefit-cost ratios were the result of including only benefits for the prevention of tidal floods.

74. NEED FOR ZONING REGULATIONS.

There is an urgent need for zoning regulations to deter encroachment on the Potomac River waterfront in the Washington area. The only controls now available are the regulations with regard to interference to navigation which are wholly inadequate for protecting the river from encroachment.

Since the last major flood in October 1942, four new bridges with attendant approaches have added restriction to the waterway. It is believed desirable zoning regulations with respect to both elevation and exposure are needed for the projected redevelopment of such areas as the Bolling Air Force Base and U. S. Naval Air Station.

75. SENATE RESOLUTION NO. 148.

Additional information on considered alternatives, called for by Senate Resolution No. 148, 85th Congress, adopted 28 January 1958, is contained in a supplement attached to this report.

76. ADDITIONAL STUDIES NEEDED.

Additional studies are needed to establish the waterway requirements for passing fluvial floods and for more precise estimates of the tidal flooding potential. The requirements for fluvial flood control is defined in the Potomac River Basin Report in which upstream control by reservoirs is investigated. However, more intensive investigations, including model studies, are needed to firmly establish limits for zoning regulations.

XXIII. CONCLUSIONS

77. The Washington Metropolitan area is vulnerable to severe damages from hurricanes. However, the construction of protective works for elimination of tidal flooding is not economically justified. The damages from fluvial flooding are far more serious than damages from tidal flooding. The relief from tidal flooding by structural means could be accomplished by the protective works needed for fluvial flood control. The most important need with respect to flooding hazards in the Washington Metropolitan area is effective zoning. Since the basic data now available is not adequate, additional studies are needed to establish more firmly the physical requirements for such zoning, including waterway capacity and safe elevation.

XXIV. RECOMMENDATIONS

78. It is recommended that protective works for the reduction of hurricane damages in the Washington Metropolitan area not be authorized at this time. It is recommended that zoning and regulations to reduce tidal and fluvial flood damages be considered by the responsible Federal and local agencies.

ROY S. KELLEY
Colonel, Corps of Engineers
District Engineer

GLOSSARY

ASTRONOMICAL TIDE - See PREDICTED NORMAL TIDE

FETCH - The continuous area of water over which the wind blows in essentially a constant direction. Often used synonymously with FETCH LENGTH.

FLUVIAL FLOOD - River flows or stages created by excessive rainfall or snowmelt beyond the absorptive capacity of the ground. With respect to the Washington Metropolitan area, fluvial floods are caused by excess water from upstream sources while tidal floods are caused by disturbances created downstream of Washington.

FREEBOARD - The difference in elevation between the design tide level and the top elevation of a water-restraining structure.

HURRICANE PATH (OR TRACK) - The line connecting successive locations of central pressure of the hurricane.

HURRICANE SURGE - The mass of water causing an increase in elevation of the water surface above predicted normal tide at the time of a hurricane.

HURRICANE TIDE - The actual measured rise and fall of the still water surface at a given point during a hurricane (exclusive of wave action).

PREDICTED NORMAL TIDE - The predicted still water elevation of the ocean and its tidal arms at a given time and place when unaffected by abnormal phenomena, i.e., resulting only from the gravitational attraction of the moon, sun, and other astronomical bodies acting upon the rotating earth.

STILLWATER LEVEL - The elevation of the water surface if all wave action were to cease.

STORM SURGE - Same as HURRICANE SURGE, except that it may be caused by storms not of hurricane characteristics as well as by hurricanes.

STANDARD PROJECT HURRICANE - A hurricane that may be expected from the most severe combination of meteorological conditions that are considered reasonably characteristic of the region involved.

TRANSPOSED HURRICANE - A storm transferred from actually observed location to another location for the purpose of study, with appropriate changes in storm characteristics.

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1. The preparation of this report was administered by:

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- * Robert L. Wadsworth, former Chief, Planning and Reports Branch

2. The preparation of this report began in the Planning and Reports Branch of the Washington District under the direction of Floyd B. Morris. It was completed in the Baltimore District under the direction of Michael A. Kolessar. Principal authors were James B. Clark and Gordon F. Johnson.

3. The United States Army Engineer District, Baltimore, acknowledges with appreciation the cooperation and assistance rendered in connection with these studies by personnel of a number of other offices and agencies, particularly the following:

The Beach Erosion Board

United States Army Engineer Division, North Atlantic

United States Weather Bureau

United States Fish and Wildlife Service

- * Of the former Washington District

NADEN-R (15 May 63)

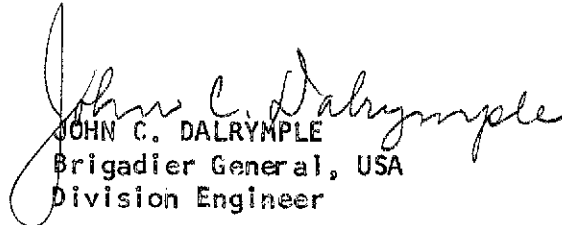
1st Ind

SUBJECT: Hurricane Survey - Washington, D. C. Metropolitan Area

U. S. Army Engineer Division, North Atlantic, New York 7, N. Y.,
26 June 1963

TO: Resident Member, Board of Engineers for Rivers and Harbors,
Washington, D. C.

I concur in the conclusions and recommendations of the District Engineer.


JOHN C. DALRYMPLE
Brigadier General, USA
Division Engineer

HURRICANE SURVEY

WASHINGTON METROPOLITAN AREA

Additional information called for by Senate Resolution 148,
85th Congress, 1st Session, adopted 28 January 1958.

1. The information contained in this supplement is furnished in response to Senate Resolution 148, 85th Congress, 1st Session, adopted 28 January 1958.

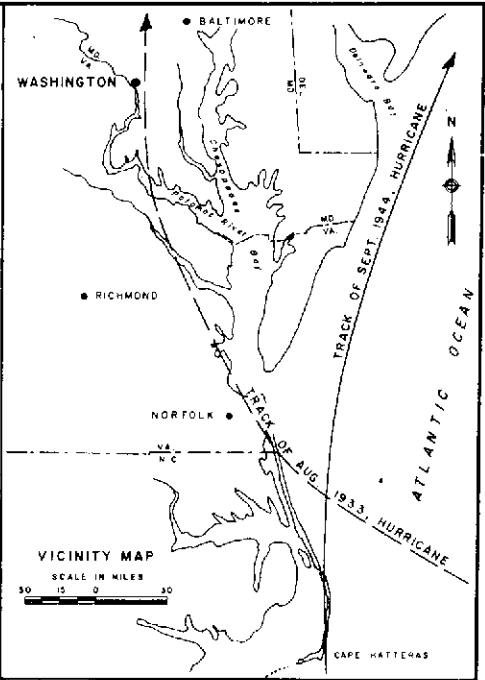
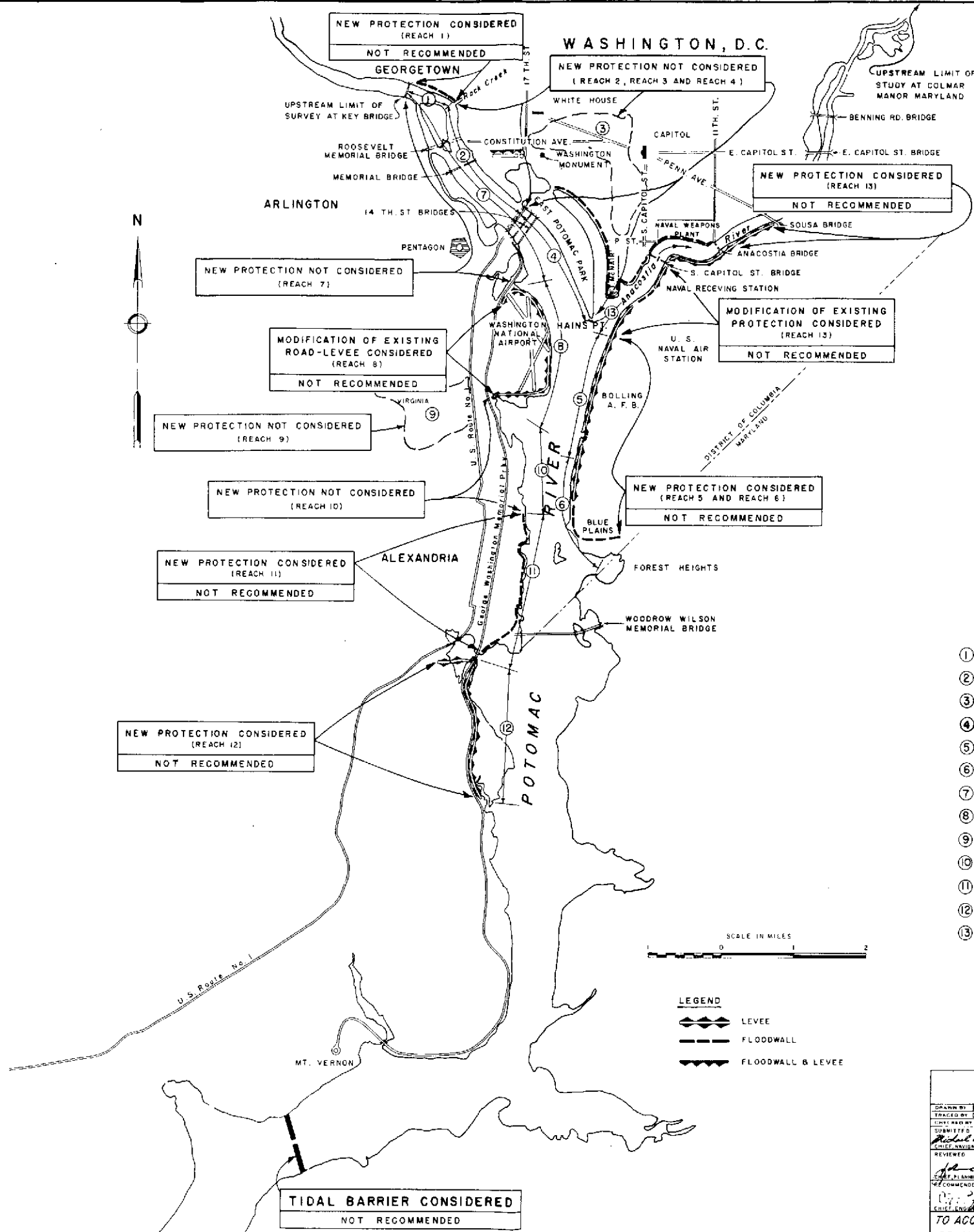
2. The geographical limits of the Washington Metropolitan Area Hurricane Survey considered that area subject to significant tidal damages. The upstream limits are Key Bridge on the Potomac River and the town of Colmar Manor, Maryland, on the Anacostia River. The downstream limit, south of Alexandria, Virginia, included the residential areas of Forest Heights, Maryland, and New Alexandria, Virginia. There are about 48 miles of waterfront in the study area subject to tidal flooding. The plans of protection as described in the basic report and shown on the plates therein, considered protection by walls and levees to exclude a design tidal flood of 15.0 feet above low water datum. An economic life of 50 years was used in determining project economics. The cost of providing protection by this means would be on the order of \$10,000,000 with an estimated annual charge of about \$450,000, based on July 1960 prices.

3. Annual benefits which would accrue to the considered protective works were based solely on exclusion of tidal flooding from the affected areas. No benefits were claimed for fluvial flood exclusion. Annual benefits to exclude the design tidal flood are estimated to be about \$150,000. The benefit-cost ratio would be 0.3. Extension of the economic life to 100 years does not appreciably influence the benefit-cost ratio.

4. There have been no direct requests for hurricane protection in the study area and no public hearings were held.

5. As an alternate structural protective plan, consideration was given to a downstream tidal barrier to reduce tidal surge damages in the area. Though this plan would be effective in reducing tidal damages, the plan is not economically feasible. In lieu of protective structures, recommendations are contained in the basic report that zoning and building regulations by responsible Federal and local agencies be considered.

6. Application of the standards contained in Senate Resolution 148, do not affect the recommendations of the basic report.



- LIST OF REACHES**
- ① GEORGETOWN
 - ② WEST POTOMAC PARK
 - ③ DOWNTOWN WASHINGTON
 - ④ EAST POTOMAC PARK - WASHINGTON CHANNEL
 - ⑤ BOLLING FIELD
 - ⑥ BELLEVUE - FOREST HEIGHTS
 - ⑦ KEY BRIDGE TO NATIONAL AIRPORT
 - ⑧ NATIONAL AIRPORT
 - ⑨ FOUR MILE RUN
 - ⑩ FOUR MILE RUN TO ALEXANDRIA
 - ⑪ ALEXANDRIA
 - ⑫ NEW ALEXANDRIA - HUNTING CREEK
 - ⑬ ANACOSTIA RIVER

CORPS OF ENGINEERS U. S. ARMY
OFFICE OF THE DISTRICT ENGINEER
BALTIMORE DISTRICT, BALTIMORE 3, MARYLAND

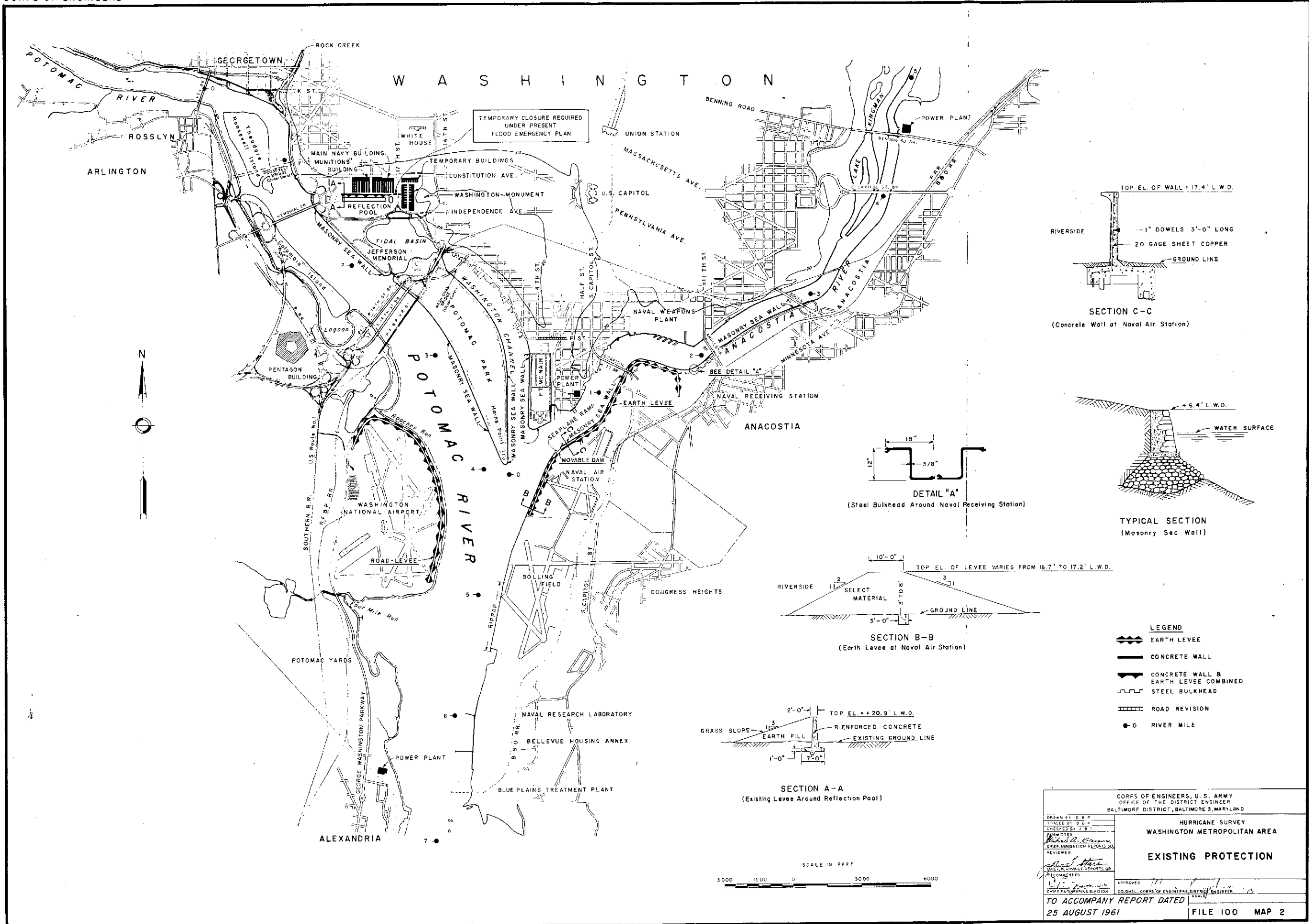
HURRICANE SURVEY
WASHINGTON METROPOLITAN AREA

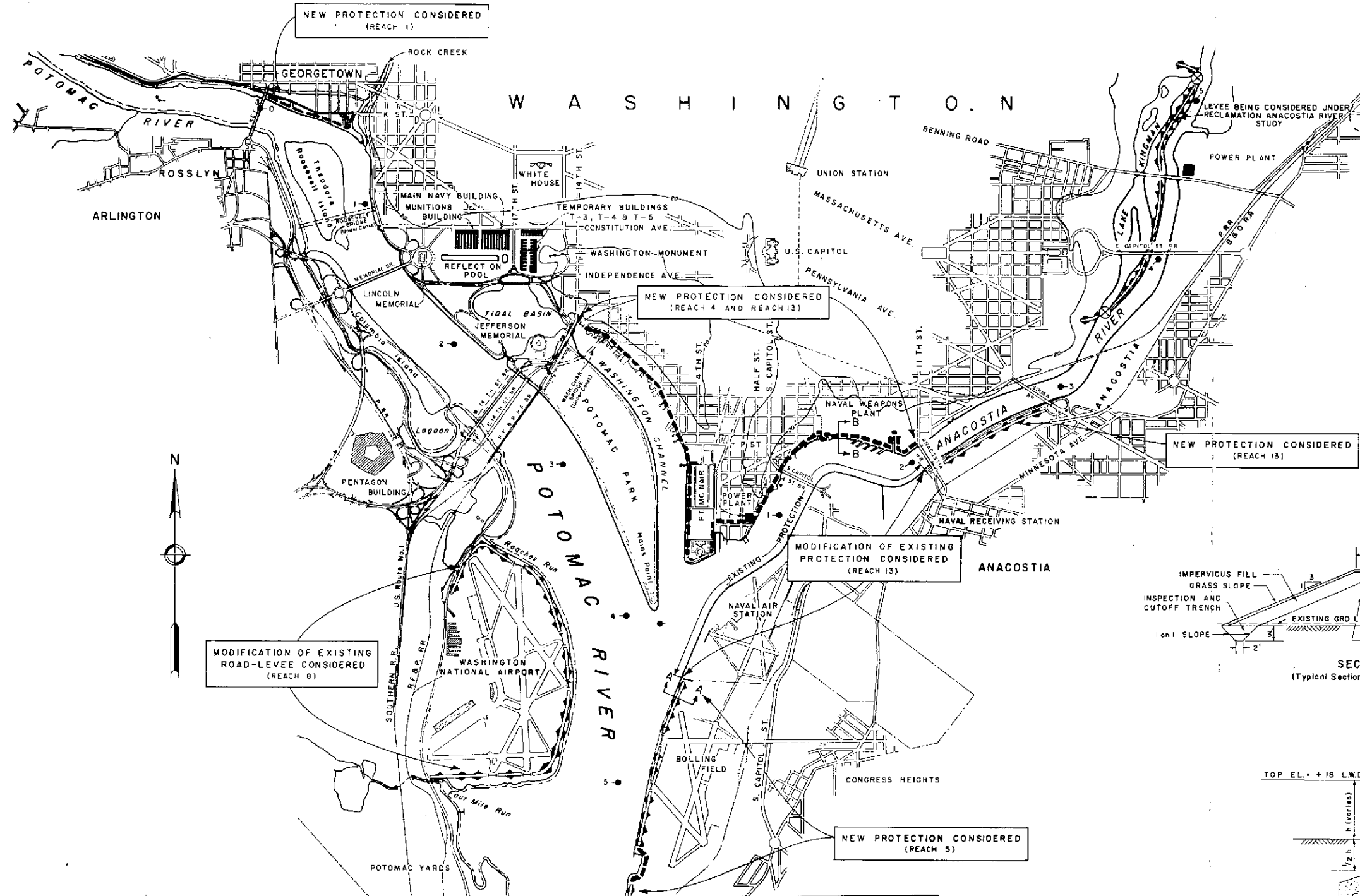
GENERAL PROJECT MAP

DRAWN BY: D. B. P. TRACED BY: D. B. P. CHECKED BY: F. B. M. SUBMITTED: <i>Richard R. Johnson</i> CHIEF, DIVISION REPORTS SEC. REVIEWED: <i>John A. Johnson</i> CHIEF, PLANNING REPORTS BR. RECOMMENDED	APPROVED: <i>William J. Johnson</i> COLONEL, CORPS OF ENGINEERS, DISTRICT ENGINEER
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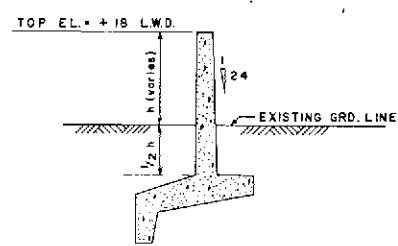
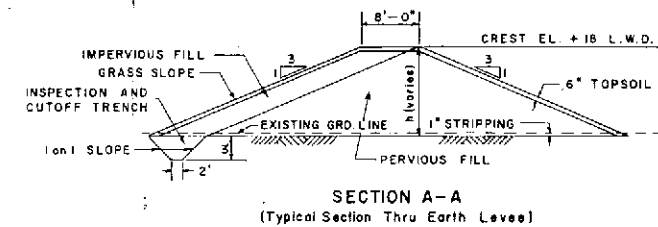
TO ACCOMPANY REPORT DATED 25 AUGUST 1961

FILE 100 MAP 1





PLAN OF PROTECTION CONSIDERED



- LEGEND**
- EARTH LEVEE
 - CONCRETE WALL WITH MOVABLE CLOSURES
 - DRAINAGE STRUCTURE
 - MOVABLE CLOSURE

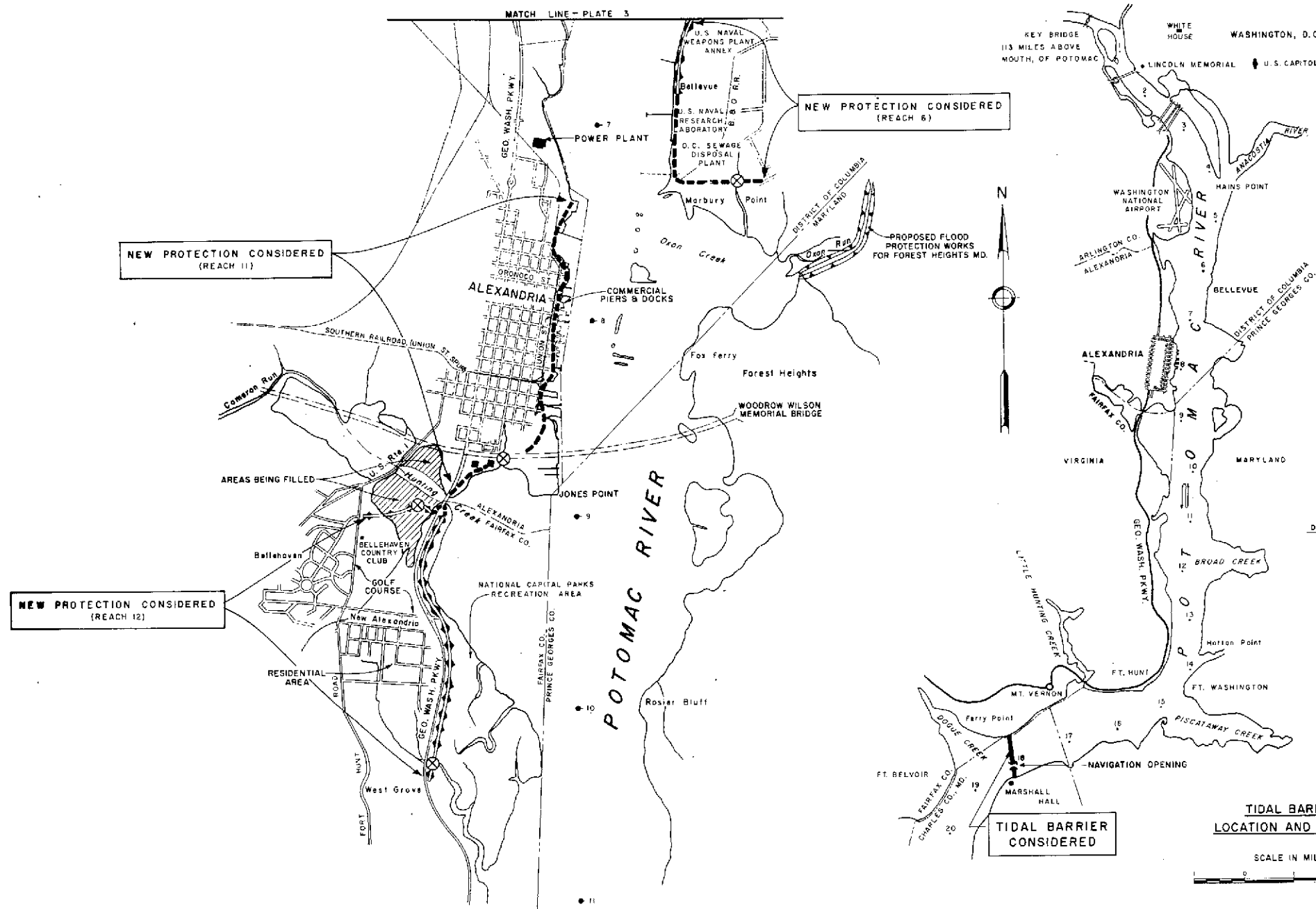


U. S. ARMY ENGINEER DISTRICT, BALTIMORE
CORPS OF ENGINEERS
Office of the District Engineer
Baltimore District, Baltimore 3, Maryland

HURRICANE SURVEY
WASHINGTON METROPOLITAN AREA
**PROTECTIVE PLAN CONSIDERED
BUT
NOT RECOMMENDED**

APPROVED: *[Signature]*
COLONEL, CORPS OF ENGINEERS
TO ACCOMPANY REPORT DATED 25 AUGUST 1961

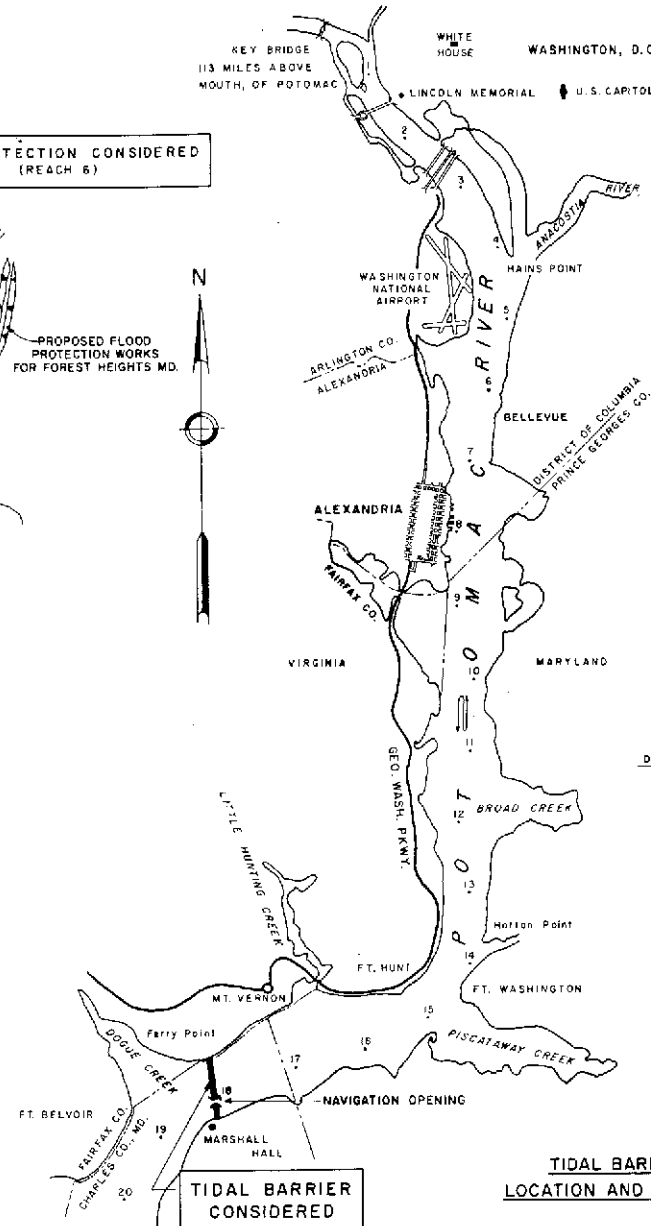
FILE 100 MAP 3



PLAN OF PROTECTION CONSIDERED

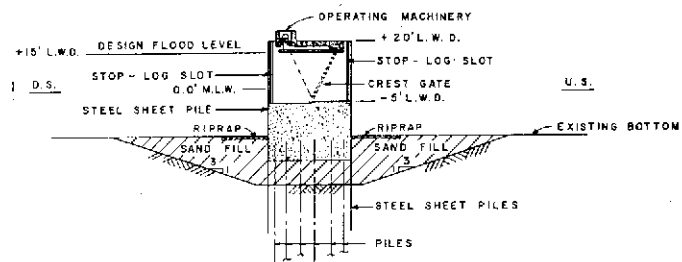


- LEGEND**
- EARTH LEVEE
 - CONCRETE WALL WITH MOVABLE CLOSURES
 - DRAINAGE STRUCTURE

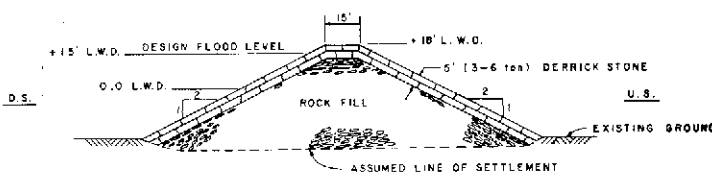


TIDAL BARRIER LOCATION AND DETAILS

SCALE IN MILES

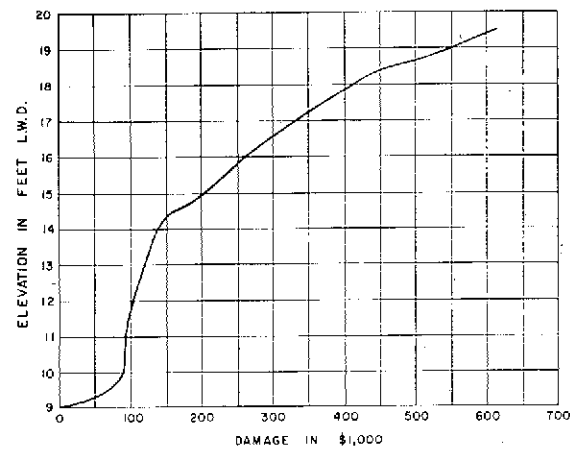


SECTION GATED CONCRETE TIDAL BARRIER

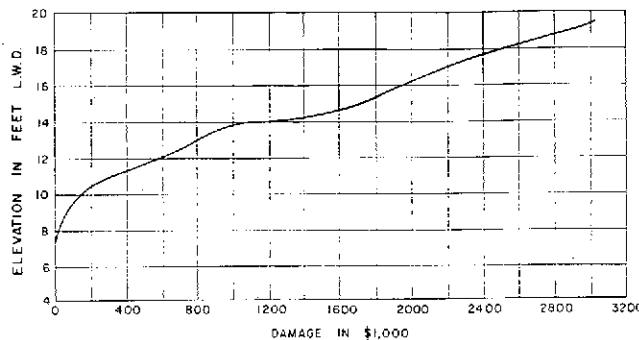


SECTION FIXED ROCK DAM TIDAL BARRIER

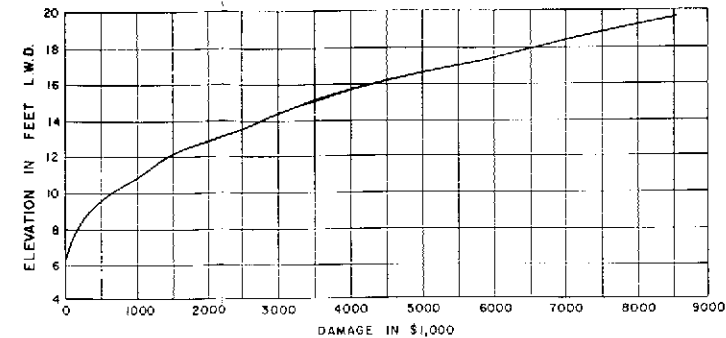
U. S. ARMY ENGINEER DISTRICT, BALTIMORE CORPS OF ENGINEERS Office of the District Engineer Baltimore District, Baltimore 3, Maryland	
DRAWN BY: D.B.P. CHECKED BY: J.B.C. SUBMITTED: REVIEWED:	HURRICANE SURVEY WASHINGTON METROPOLITAN AREA PROTECTIVE PLANS CONSIDERED BUT NOT RECOMMENDED
APPROVED: TO ACCOMPANY REPORT DATED 25 AUGUST 1961	FILE 100 MAP 4



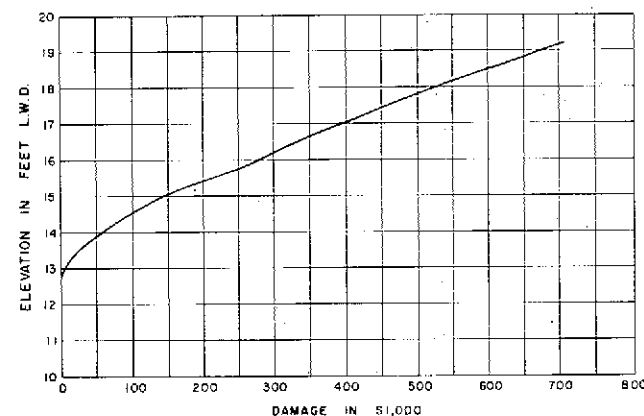
GEORGETOWN (REACH 1)



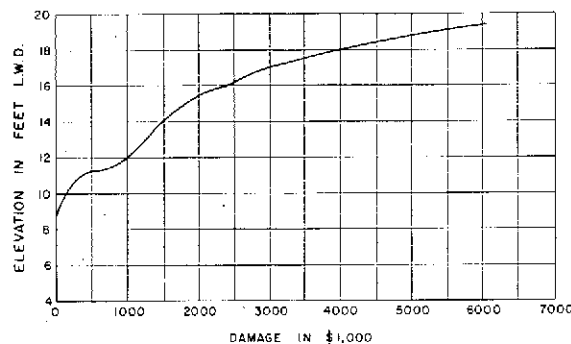
BOLLING FIELD (REACH 5)



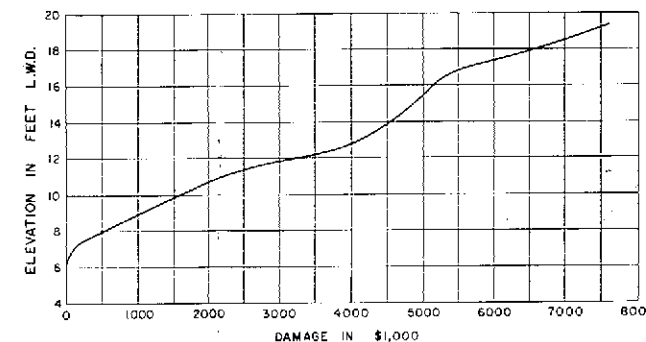
ALEXANDRIA (REACH 11)



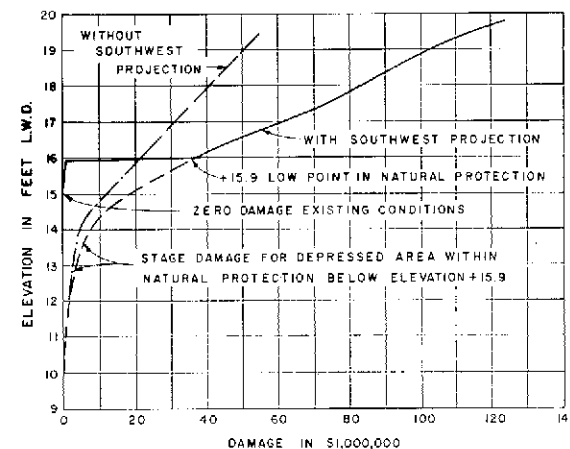
WEST POTOMAC PARK (REACH 2)



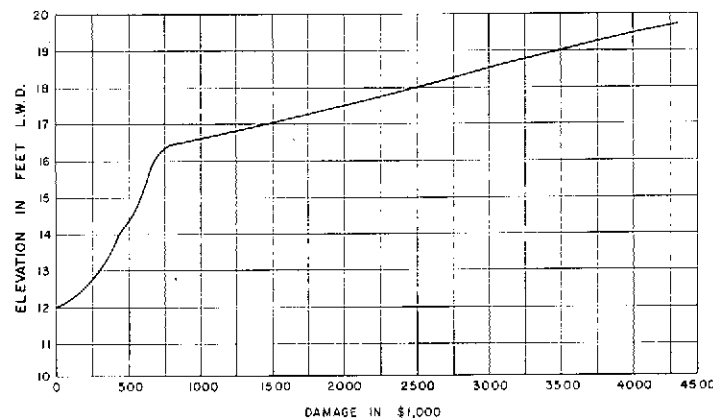
BELLEVUE-Forest HEIGHTS (REACH 6)



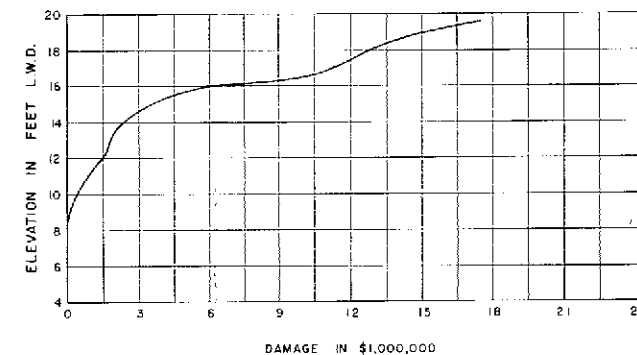
NEW ALEXANDRIA-HUNTING CREEK (REACH 12)



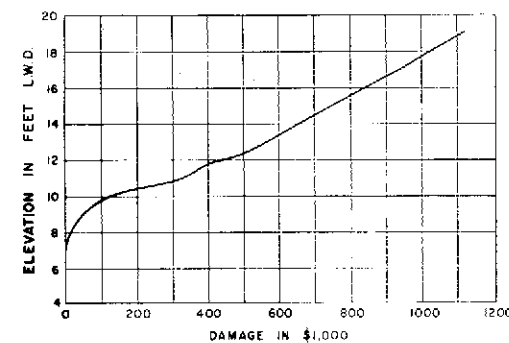
DOWNTOWN WASHINGTON (REACH 3)



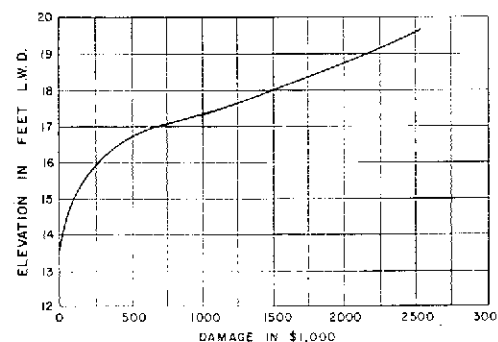
NATIONAL AIRPORT (REACH 6)



ANACOSTIA RIVER (REACH 13)



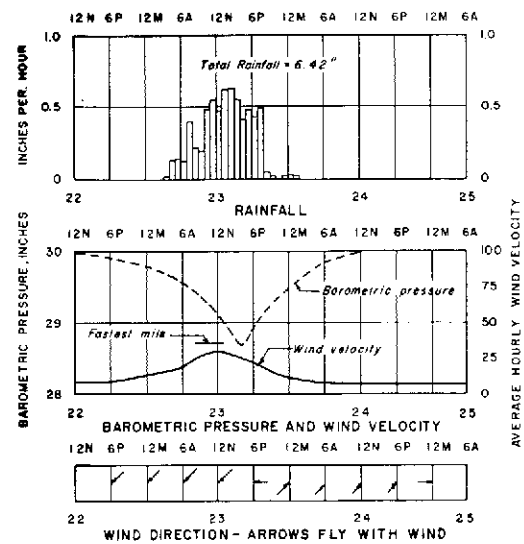
WASHINGTON CHANNEL (REACH 4)



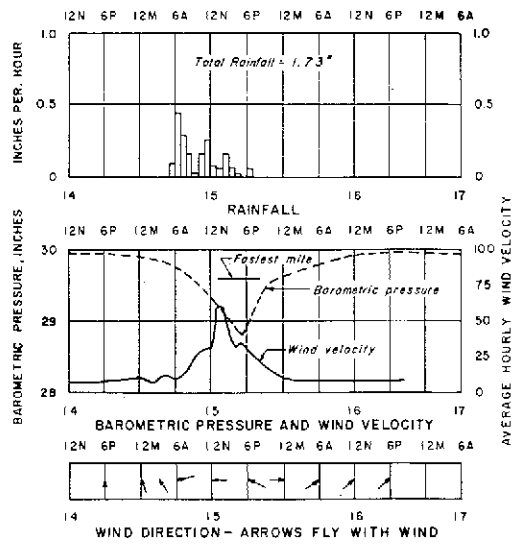
FOUR MILE RUN (REACH 9)

PRICE LEVEL - JUNE 1960 (ENRCCI-826.24)

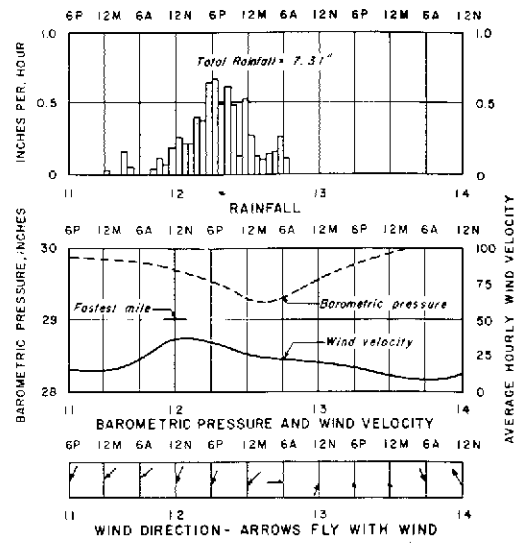
CORPS OF ENGINEERS, U. S. ARMY OFFICE OF THE DISTRICT ENGINEER BALTIMORE DISTRICT, BALTIMORE 3, MARYLAND	
DRAWN BY: K.W.B. CHECKED BY: D.B.P. SUBMITTED BY: [Signature] REVIEWED BY: [Signature] RECOMMENDED BY: [Signature]	HURRICANE SURVEY WASHINGTON METROPOLITAN AREA STAGE-DAMAGE DATA
APPROVED: [Signature] COLONEL, CORPS OF ENGINEERS, DISTRICT ENGINEER	TO ACCOMPANY REPORT DATED: 25 AUGUST 1961 SCALE: FILE 100 MAP 5



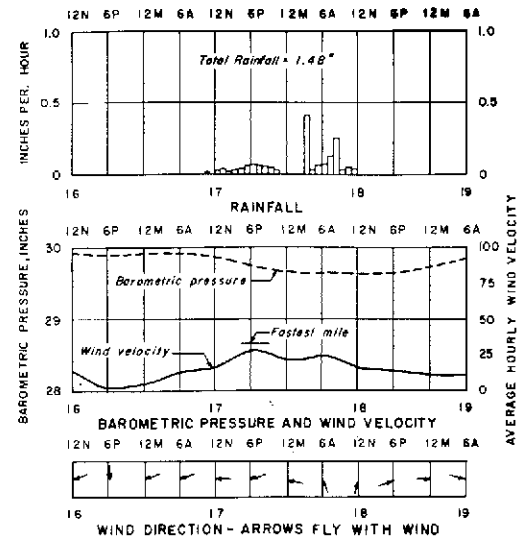
METEOROLOGICAL DATA



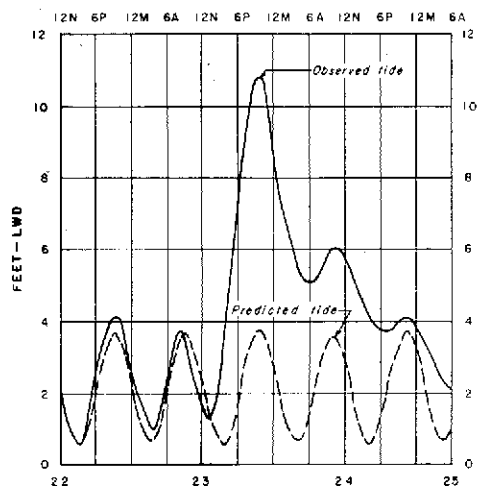
METEOROLOGICAL DATA



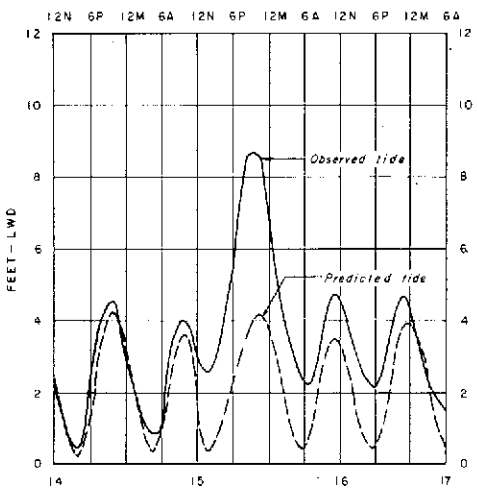
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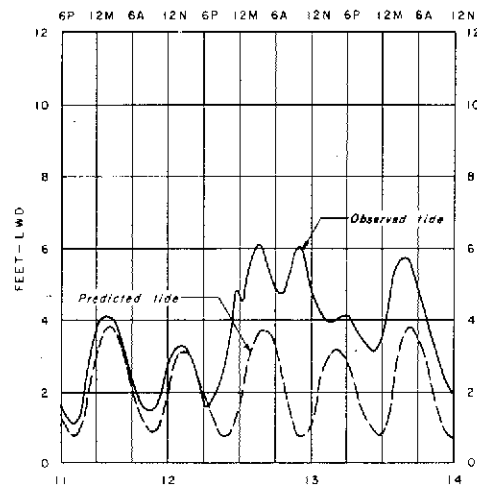
METEOROLOGICAL DATA



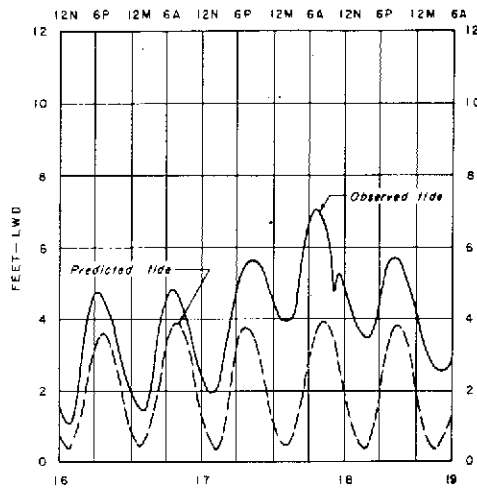
TIDE RECORD



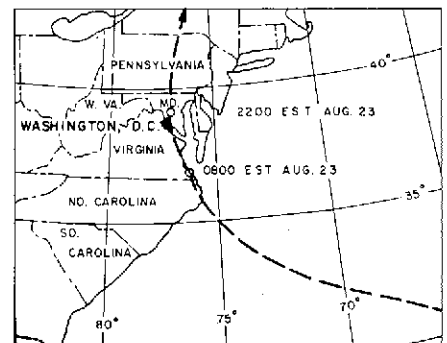
TIDE RECORD



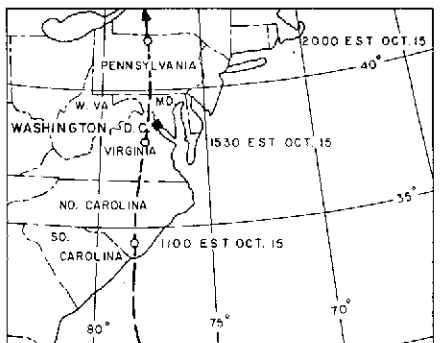
TIDE RECORD



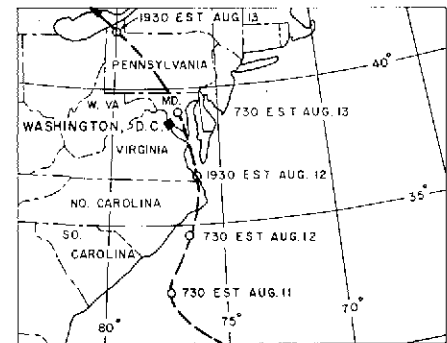
TIDE RECORD



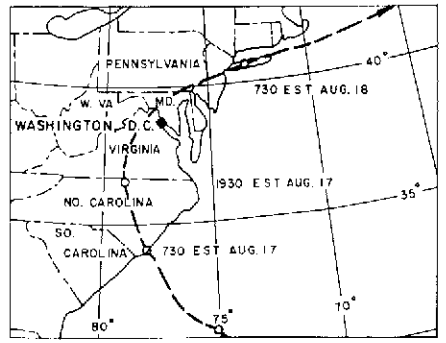
TRACK OF HURRICANE
AUGUST 1933



TRACK OF HURRICANE
OCTOBER 1954
"HAZEL"



TRACK OF HURRICANE
AUGUST 1955
"CONNIE"



TRACK OF HURRICANE
AUGUST 1955
"DIANE"

CORPS OF ENGINEERS, U. S. ARMY
OFFICE OF THE DISTRICT ENGINEER
BALTIMORE DISTRICT, BALTIMORE 3, MARYLAND

HURRICANE SURVEY
WASHINGTON METROPOLITAN AREA
METEOROLOGIC & HYDROLOGIC DATA
STORM OF RECORD

DRAWN BY: D.B.P.
CHECKED BY: D.B.P.
SUBMITTED: [Signature]
REVIEWED: [Signature]

APPROVED: [Signature]
COLONEL, CORPS OF ENGINEERS

TO ACCOMPANY REPORT DATED
25 AUGUST 1961

FILE 100 MAP 7

APPENDIX A

History of Hurricane Occurrences

Appendix A

The following accounts of hurricane activity, relative to the Washington Metropolitan area, were extracted from the Historical Record Study Report. Pertinent information contained in the Hurricane Survey Reports for Garden Creek and Norfolk, Virginia, has been extracted and is included:

1609 - July 28 From: "Swem: Some Notes on Shipbuilding and Shipping in Colonial Virginia"

"On June 7, 1609, a fleet of seven ships and two pinnaces left Plymouth, England, for Jamestown...On July 28, a violent storm arose which separated the Sea Venture from the rest of the fleet. This "dreadful tempest" was the tail of a West Indies hurricane and lasted four days and nights...The storm drove the ship toward the dangerous and dreaded islands of Bermuda."

From: "Jamestown, Virginia (handbook)"

"It resolved to send a much larger expedition to Virginia than the three sent prior to this date (1609)...It went out in June...the voyage was uneventful until they ran into a stiff hurricane that broke up the fleet and cast ashore in the Bermuda Islands the flagship..."

1667 - August From: "Andrews, Matthew: History of Maryland, p.150"

"...1667 was long remembered in Maryland and Virginia as 'the year of the hurricane' which...from contemporary accounts, was the worst that had visited the Atlantic seaboard..."

From: "Virginia Mag. History and Biography, Vol. XIX
p. 255."

Letter of William Jones to James Hicke at the Post Office in London:

"...the storms and floods last year made great destruction in Virginia and Maryland so that...ships now in the Country will be necessitated to stay until next Season for want of freight ..." Virginia, May 8, 1668."

From: "Middleton: Maritime History of Tobacco Coast
p. 46."

"The worst (storm) was the great "hurry-cane" of August, 1667. Hailstones as large as turkey eggs pelted the countryside, destroying the fruit, beating down the grass; the hurricane itself, which lasted twenty-four hours, began at northeast, gradually backed into the north, and finally to southeast...heavy rain caused...floods...raised the water even in the lower estuaries to a destructive height. Fields...inundated, crops torn to shreds...and even the largest vessels washed up on the beach. Philip Ludwell estimated that some ten thousand houses were ruined in Virginia alone."

From: "Norfolk in By-Gone Days," Rev. W.H.T. Squires, D.D.
(Vol. I, Norfolk Public Library) (Hurricane Survey,
Norfolk, Virginia, Norfolk District)

"It was the same terrific storm that obliterated Fort George at Old Point Comfort, washing it almost entirely away. What the furious storm snatched from Old Point, it seems to have piled upon the southern shore as "Willoughby Spit." (Page 22).

"Samuel Barron recently arrived from Bristol was appointed to this command (1737). Though apparently strong and ready to resist the assaults both of nature and of man, another terrific storm (1749) swept in from the ocean and destroyed Ft. George. Only by the greatest exertion was Samuel Barron able to save the garrison and his family...." (Page 90).

1754 - October 24 From: "Maritime History of the Tobacco Coast, p. 85."

"In 1754 a violent storm from the southeast "swell'd the Tide" at Annapolis to a height never before known by the oldest inhabitant. The water at the town dock rose fourteen or fifteen inches higher than the normal tide of twenty-four inches."

Tannehill lists two September storms in 1754.

1769 - September 8-14 From: "William and Mary Quarterly, Vol. 14, p. 165."

"Last Friday morning, about one o'clock, came on at northeast a most dreadful hurricane, attended with rain, which came down in torrents. It blew most violently from that quarter until between ten and eleven o'clock, and then shifted to the northwest, when the storm increased, and continued without any abatement until about dinner time. The damage done in the country must be inconceivable...The farther up the country the fiercer the storm was and most of the mills are destroyed; upwards of fifty, we hear, between this and Newcastle..."

From: "Middleton, Arthur: Maritime History,
p. 47, Fredericksburg."

"A more serious storm attended by torrents of rain in 1769 leveled houses and crops, spoilt tobacco, blew down trees, blocked roads, and destroyed mills. Four ships in the York River were driven aground; another ship, lately arrived from London, successfully rode out the storm only by cutting away both main and mizzenmasts. The smaller vessels grounded; one sank at Gloucester Point, another went ashore, and a third was stove to pieces. Moreover, the top of a wharf at Yorktown was carried away, and a schooner ran her bowsprit into a nearby storehouse. Perhaps the most destructive storm since 1667, it was called "a most dreadful hurricane"..."

From: "Martin: A New and Comprehensive Gazetteer, p. 475".

"... (In August, 1814) many houses were blown down and trees laid prostrate..."

From: "Records Columbia Historical Society, Vol. 2, p. 258".

This number of the paper (September 1st edition of the National Intelligencer) also mentions

"that on Thursday evening last while our devoted city was in possession of the Enemy, it was visited by a tremendous hurricane, which did great damage to the houses, blowing off the roofs of many, destroying chimnies, fences, etc.

In some parts of the City every house was more or less injured."

From: "Smith, Mrs. S.H.: The First Forty Years of Washington Society".

"(Brookville, Maryland) Just as we were going to dinner a tremendous gust arose, it has broken the trees very much... On Thursday the hurricane which blew down houses, tore up trees and spread terror around, pass'd in a few minutes and nature recovered her tranquility... and the vestige... of the hurricane of Thursday which had blown down fences and trees..."

1830 - August 17 From: "Alexandria Gazette".

"...the Storm was very violent at Georgetown; (it) occasioned but little damage on Sullivan's Island; its safety is, however, attributed to the change of wind from South East to North. Only a few fences and out buildings were blown down..."

"a dreadful hail storm" with wind from W.N.W. passed over Loudoun County; loss of glass very great."

1840 - June 6 From: "Clipping File, Washingtoniana Div., D.C. Pub. Lib."

"About 6 o'clock, p.m., on the 6th of June 1840, Washington and the surrounding country was visited with a gust of unusual violence and duration, accompanied by severe lightning, heavy thunder, and copious rain, the latter continuing throughout the night and part of the ensuing day. The wind blew a perfect hurricane, tearing down fences, signs, etc. damaging whole fields of grain, uprooting the largest sized trees. All the creeks, branches and streams near the city rose to an unusual height, overflowing their banks and doing great damage to the meadows."

1896 - September 29 From: "Alexandria Gazette".

Climatic Handbook supplies the following data:

Date	Lowest Pressure (inches)	Total Rainfall (inches)	Highest Wind (mph)	Direction	Highest Tide (feet)
Sept. 29	29.14	.68	80	se	6.7

Local documentation asserts:

"Alexandria passed through an experience last night which will be remembered so long as the present generation lives - The easterly wind of yesterday had several times assumed a velocity which caused some apprehension...the wind was whistling through the city... swaying the lights...Half an hour later the wind was shifting. It passed from northeast to east then to southeast and to south... Chimneys were falling, roofs...carried from houses...Two people had been killed outright...There was some damage around the wharves... the steam yacht Cecile had her upper works carried away and the yacht Samuel Sutton was sunk...The steamer Florence was badly damaged..."

From: "Hurricane Survey, Norfolk, Virginia, Norfolk District".

"...Increased in intensity as it reached Florida and moved through Atlantic states, inside coast line. Center passed over District of Columbia....".

APPENDIX B

Comments of the
Fish and Wildlife Service



UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
BUREAU OF SPORT FISHERIES AND WILDLIFE
PEACHTREE-SEVENTH BUILDING
ATLANTA 23, GEORGIA

SOUTHEAST REGION

(REGION 4)

NORTH CAROLINA
SOUTH CAROLINA
GEORGIA
FLORIDA
KENTUCKY
TENNESSEE
ALABAMA
MISSISSIPPI
ARKANSAS
LOUISIANA
VIRGINIA
MARYLAND
PUERTO RICO
VIRGIN ISLANDS

ADDRESS ONLY THE
REGIONAL DIRECTOR

April 13, 1961

District Engineer
U. S. Army, Corps of Engineers
Washington, D. C.

Dear Sir:

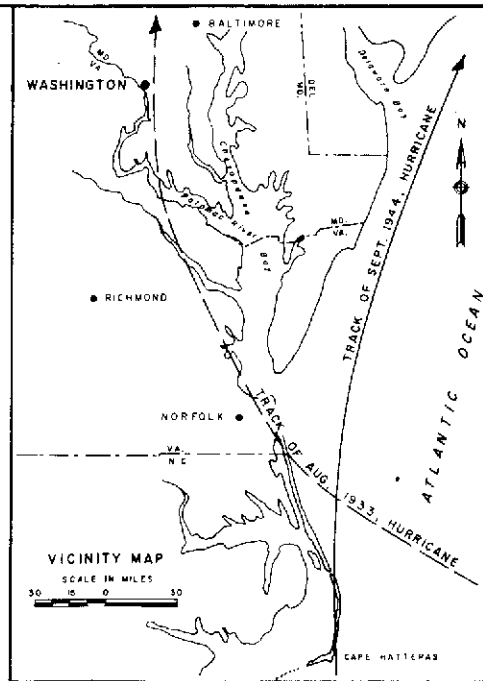
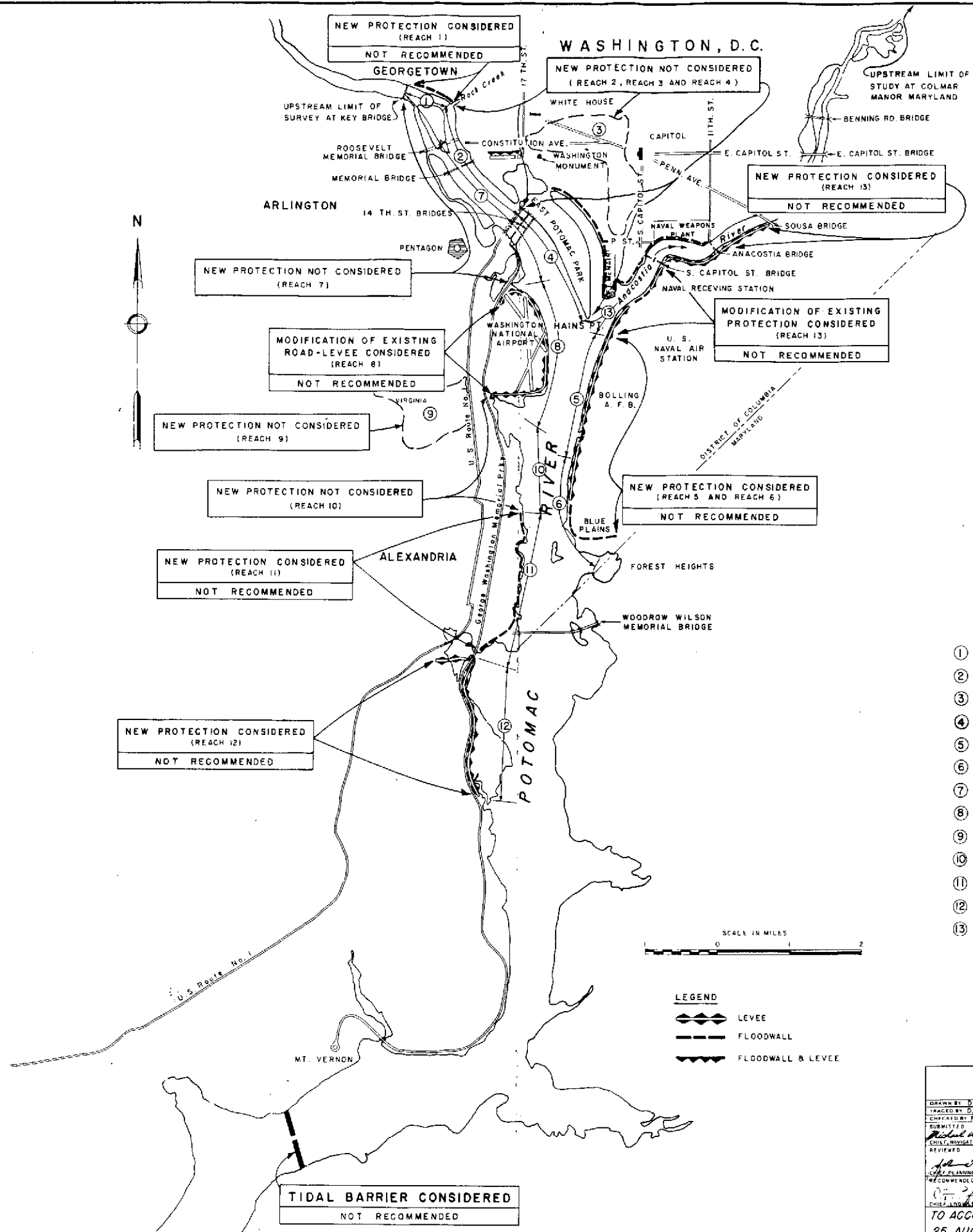
We have reviewed the plans of improvements to provide hurricane protection for the Washington Metropolitan Area, which were furnished with Major Smith's letter of April 4, 1961. He advised that the plans as shown were not economically feasible and are not recommended for construction.

Based on our general knowledge of the area, the only feature of the considered plans that would have a significant effect on fish and wildlife resources is the construction of a tidal barrier in the Potomac River below Mt. Vernon, Virginia. Since the plan is not recommended for construction, we will not undertake a study to determine the effects on fish and wildlife resources.

Thank you for the opportunity to comment on these plans.

Sincerely yours,

Walter A. Gresh
Regional Director



LIST OF REACHES

- ① GEORGETOWN
- ② WEST POTOMAC PARK
- ③ DOWNTOWN WASHINGTON
- ④ EAST POTOMAC PARK - WASHINGTON CHANNEL
- ⑤ BOLLING FIELD
- ⑥ BELLEVUE - FOREST HEIGHTS
- ⑦ KEY BRIDGE TO NATIONAL AIRPORT
- ⑧ NATIONAL AIRPORT
- ⑨ FOUR MILE RUN
- ⑩ FOUR MILE RUN TO ALEXANDRIA
- ⑪ ALEXANDRIA
- ⑫ NEW ALEXANDRIA - HUNTING CREEK
- ⑬ ANACOSTIA RIVER

CORPS OF ENGINEERS, U. S. ARMY OFFICE OF THE DISTRICT ENGINEER BALTIMORE DISTRICT, BALTIMORE 3, MARYLAND	
HURRICANE SURVEY WASHINGTON METROPOLITAN AREA	
GENERAL PROJECT MAP	
DRAWN BY: D. B. P. CHECKED BY: F. B. M. SUBMITTED BY: Richard H. Johnson CHIEF, NAVIGATION REPORTS SEC. REVIEWED BY: J. C. Harn RECOMMENDED BY: J. C. Harn	APPROVED: [Signature] COLONEL, CORPS OF ENGINEERS, DISTRICT ENGINEER
TO ACCOMPANY REPORT DATED 25 AUGUST 1961	
FILE 100 MAP 1	