The Virginia Tidal Riverbank Erosion Survey

Virginia Agricultural Experiment Station
Virginia Polytechnic Institute
Blacksburg, Virginia

In cooperation with

Virginia State Soil Conservation Committee

and

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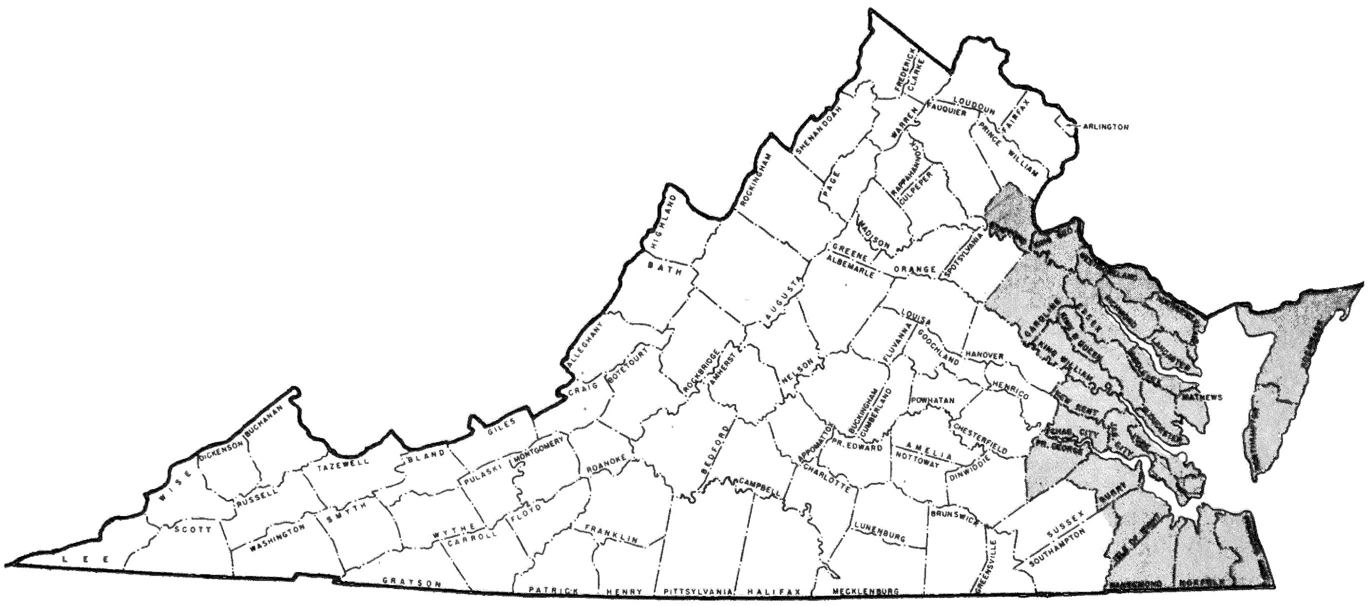


Shaded counties indicate extent of tidal riverbank erosion problem area in Virginia

All photos used in this publication were provided by the Soil Conservation Service, U. S. Department of Agriculture

PREFACE

This publication is the report of a limited tidal riverbank erosion survey in Virginia supported by the Virginia State Soil Conservation Committee, the Virginia Agricultural Experiment Station and the Soil Conservation Service, USDA.

The field surveys were conducted by David H. Pugh, Jr., Agricultural Engineer, Soil Conservation Service; and Z. M. K. Fulton, Agricultural Economist, Virginia Agricultural Experiment Station, under the general direction of an advisory committee, composed of W. A. Phillips, SCS, Chairman; J. H. Lillard, Virginia Agricultural Experiment Station, Vice Chairman; A. D. Williamson, SCS, Secretary; W. A. Allaband, SCS; R. E. Blaser and W. L. Gibson, Jr., Virginia Agricultural Experiment Station. Their field reports have been consolidated for the Committee and for this publication by J. H. Lillard and W. L. Gibson, Jr.

The Committee expresses its sincere appreciation to Dr. C. Y. Kramer and Professor D. C. Hurst, VPI Department of Statistics, for their assistance in planning the survey, for developing the sampling procedure and for programming the data computations. Thanks are due also to Mr. John W. Clay, Soil Scientist, SCS, who prepared the section on the general and local geology of the area.

The Virginia Tidal Riverbank Erosion Survey

The value of the land along the tidal rivers of Virginia is very high and continues to rise at a rapid rate. The land is in great demand for both seasonal and permanent homesite development, for light industries, particularly those pertaining to seafood and farm product processing, and for agricultural production.

The erosion of these valuable riverbanks by tides and storms is a matter of extreme concern throughout the Tidewater region. The supervisors of the Northern Neck Soil Conservation District in recent years received requests from several hundred landowners for technical assistance on riverbank erosion problems. As a result, that District made urgent pleas to State and Federal agencies for appropriate assistance. Additional requests for similar help came from all the other Districts in the Tidewater region.

In response, the Virginia State Soil Conservation Committee assumed the initiative in working out a cooperative agreement with the Virginia Agricultural Experiment Station and the Soil Conservation Service to survey the problem. The agreement stipulated that the field survey would be conducted by a team of 2 men. One of them would be an Agricultural Engineer provided by the Soil Conservation Service and the other would be an Agricultural Economist supplied by the Agricultural Experiment Station. The work was to commence as early as possible in 1960 and be completed within one year. The cooperative agreement also provided for establishment of a 6-man Advisory Committee composed of appropriate Agricultural Experiment Station and SCS technical people to assist with the planning of the project, guidance of the survey team, and preparation of this final project report.

PURPOSE

Fund and time limitations made it necessary for the Advisory Committee to limit the project to an exploratory type of survey on the Rappahannock and part of the South bank of the Potomac Rivers. Attempts to measure objectively the relationships between riverbank erosion and overall physical factors suspected of influencing it were not successful with the extensive generalized type of information collected in such a survey. Likewise, the data were not intended to provide a basis for designing corrective measures — engineering or otherwise.

Rather, it is the purpose of this manuscript to report upon the nature and extent of the riverbank erosion and deposition problems in tidewater Virginia; and the economic importance of these problems to the affected areas as revealed by the survey data. On the basis of these findings certain recommendations are made which should contribute toward the organization and development of an effective long range corrective program.

METHODS

A 3-step procedure was adopted for making the survey. First, a composite map was prepared to show the extent of changes in the shorelines of the Rappahannock and south bank of the Potomac and their tidal tributaries. United States Coast and Geodetic Survey hydrographic maps of these shorelines made in 1909 were superimposed on maps of a 1956 re-survey. The difference between these lines on the composite map provided a means for determining the extent of shoreline change during the 47-year period between surveys.

The total area of change along both banks of the Rappahannock from Port Royal to the Chesapeake Bay and along a corresponding area of the south bank of the Potomac, together with their tributaries, was carefully measured. Accretion and recession were totaled separately. From these data Dr. C. Y. Kramer and Prof. D. C. Hurst of the Department of Statistics at VPI performed step 2 of the study; that of developing a suitable site sampling procedure. It was estimated initially that only about 350 sites could be sampled in the allotted time. The statisticians felt that with so few samples it would be necessary to limit the survey to the Rappahannock River in order to have sufficient density of sampling to be reliable. Based on this decision, the proper spacing and location of the sample points along both banks of the Rappahannock were made. Subsequently, when it became evident that an additional 100 sites could be surveyed, the same procedure was used to locate these additional sample sites along that portion of the south bank of the Potomac between Pumpkin Creek in King George County and Walnut Point in Northumberland County. Researchers hoped that the survey could cover all of the south bank of the Potomac in addition to the Rappahannock, but it soon became evident that the approximately 450 sample sites could not be spread that thin and still provide a reliable representation of conditions.

The third step in the procedure required on-the-site study of each sample point. It involved collection of the physical data required to characterize the erosion problem and the economic information necessary to formulate an economic appraisal of its effect. Thus, 2 rather distinct types of surveys had to be made. The survey team was composed of an agricultural engineer and a man with a background in agricultural economics.

Each of these surveyors, with the assistance of the Advisory Committee, statisticians, and others, prepared suitable schedules or work sheets for recording the desired survey information at each sample point. These data summaries were designed to facilitate transfer of the data to punch cards for electronic machine tabulation.

The engineering data sheet was concerned mainly with a description of the erosion problem, characteristics of the site such as length of shoreline represented, erosion, near-shore gradient, rate of shoreline recession or accretion, storm damage, exposure, fetch length and direction, riverbank soil type and drainage, bank height and slope, beach width and type of material; and whether the beach is starved or nourished.

The economic data sheet was concerned with the detailed characteristics and ownership of the land unit at each site and all useful indices related to values which might be affected by the erosion problem. Other observations and data pertinent to the problem were recorded by both surveyors, including opinions and facts obtained from people at the sample sites and throughout the area.

The information from these survey work sheets taken at each of the 450 sample sites was placed on punch cards and certain machine tabulations performed. From these summaries each of the surveyors prepared draft reports for study and consolidation by the Advisory Committee.

DESCRIPTION OF AREA

The Rappahannock and Potomac Rivers are located in the northeastern part of Virginia known as the "Northern Neck" and "Middle" peninsulas. The "Northern Neck" is the peninsula in the Coastal Plain Province lying between the Potomac River on the north and the Rappahannock River to the south. The "Middle" peninsula is south of the Rappahannock River. The area extends eastward from U. S. Route 301 at Dahlgren and Port Royal to the Cheasapeake Bay. Riverbanks along part of the southern shore of the Potomac River, and both shores of the Rappahannock River and their numerous estuaries, were studied during the survey. The entire shoreline is subject to tidal action.

General Geology

Geologically, the area is a part of the Columbia Group of Pleistocene Age. The Columbia Group deposit averages 30 or 40 feet thick, but varies from 1 to approximately 75 feet. This group is on all 5 terraces. The land, consisting of 5 Coastal Plain terraces, was developed at a time when the entire area was inundated by the sea. The land area is the product of water deposited material. The sea has receded and flooded the land repeatedly over a long period of time. At present, the elevation relationship between the water and land is slowly changing in such a way as to very gradually submerge the lower lying land area.

The water deposited soil material is composed of stratified gravel, sand, silt, and clay; usually combinations of these materials. The uppermost stratum usually was originally a relatively homogeneous mixture of sand, silt, and clay. Through chemical reactions and physical downward movement of the fine clay and silt particles by percolating waters, the surface soil became coarser textured and the subsoil finer textured.

The substrata have been subjected to this process to a much lesser degree and remain much more like they were when originally deposited. In addition to gravel, sand, silt, and clay deposits, the substrata often contains thin layers of ferruginous sandstone and marl beds. The marl beds are deeply embedded and are exposed only in some places along streams. The sandstone layers are nearer the surface and are exposed in road cuts; although usually thin, they are in some places 2 feet thick.

Local Geology

The 5 Coastal Plain Terraces may be likened to stairsteps with the highest step to the west and extending eastward in the central portion of the peninsulas, with descending steps toward the rivers and the Chesapeake Bay. The Sunderland Terrace at an elevation of 100-200 feet is the highest and most extensive. It extends continuously from U. S. Route 301 to State Route 200 along which it follows southward from U. S. Route 360 to Carlson's Store and to East Corrotoman River. The Wicomico is the next lower terrace with elevations from 60-90 feet. It is a triangular shaped area adjacent to the Sunderland Terrace from Carlson's Store to East Corrotoman River, to Kilmarnock and back to Carlson's Store. Another portion of this terrace is located south of this area on the Tidewater or Middle Peninsula between the Rappahannock and Piankatank Rivers from Gray's Point along State Route 3 to the Riankatank River.

The Chowan Terrace (30-45 feet), Dismal Swamp (10-25 feet) and the lowest, Princess Anne (0-15 feet) are on the river flats or "neck" lands bordering the Potomac and Rappahannock Rivers.

The Sunderland Terrace borders the rivers in a few places for short distances only, such as on the Potomac at Westmoreland State Park, and eastward through Stratford to Currioman Bay,

An unsuccessful attempt by the landowner to control bank erosion by sloping and reseeding. Most of this damage was done by a single storm.

on the Rappahannock at King George-Westmoreland County Line, just south of the Westmoreland-Richmond County Line at Carter's Warf vicinity, and at Butylo at the Essex-Middlesex County Line. Some riverbanks at these places are approximately 100 feet high, but in most places they range from 1 to 40 feet in height.

The average height ranges from 10 to 20 feet, but there are significant stretches with heights of less than 10 feet along the lower Potomac in Northumberland County and on the Rappahannock in Essex and Richmond Counties.

The mechanical composition of the Sunderland Terrace is essentially a sandy loam containing some small gravel. Gravel content and size of gravel increases westward while increasing quantities of finer materials with decreasing size and content of gravel is found eastward. Most grains are poorly sorted and are angular and subangular, indicating fluvial origin.

On the lower terraces river deposited materials are found generally below Port Royal but in decreasing quantities from northern Essex and Richmond Counties to Tappahannock where these deposits are only on the lowest (Princess Anne) terrace adjacent to the Rappahannock River. Below Tappahannock, the low terraces are thought to be principally of marine origin. The low terraces on the Potomac River are also thought to be mainly of marine origin.

Most river banks are characterized by alternating strata of coarse and fine textured materials. Typically, the surface soil to a depth of about one foot is composed of sandy loams, the subsoil to a depth of 3 feet consists of clay loams. Below 3 feet there is a stratum of coarse textured material which, with depth, alternates with strata of fine textured materials. These strata are of variable thickness. On some banks, only fine textured materials are exposed. Gravel sandstone, marl, and diatomaceous earth strata and lenses are present in some places.

Rivers

The Rappahannock River, rising in the foothills of the Blue Ridge Mountains near Front Royal, Virginia, is the longest river rising in the Piedmont Plateau. It has a drainage area of 1,590 square miles and has tidal flows inland to the fall line. Running in a southeasterly direction, it passes through the towns of Fredericksburg, Port Royal, and Tappahannock; and enters the Chesapeake Bay near Deltaville. It ranges in width from about 0.3 mile at Port Royal to more than 3.5 miles at its mouth.

The Potomac River, having a total drainage area of 14,550 square miles, is the largest eastern seaboard river south of the Saint Lawrence. However, that part of its drainage basin which lies in the Virginia Coastal Plain is limited to a relatively narrow strip along the south and west sides of the river. At Washington the Potomac is about one mile wide with a central channel 25 to 60 feet deep. It gradually widens downstream until it is 6 miles wide at its mouth with an average depth of about 50 feet.

The banks of both rivers are generally vertical and range in height from 4 to 20 feet on the Rappahannock and from 14 to 18 feet on the Potomac. However, there are limited distances where the banks reach cliff heights of more than 120 feet on the Rappahannock and more than 180 feet on the Potomac.

From Rappahannock upstream to Port Royal there are at least 10 large marshes ranging in size from 1.0 to 3.0 square miles which occur mainly in sharp bends of the river. Downstream from Tappahannock the marshes are less frequent, smaller, and occur generally along straight bank sections. Tidal marshes along the south bank of the Potomac occur less frequently.

Texture of the material along the river banks varies from silt to coarse gravel, with the coarse gravel usually occurring in the upstream areas. Generally the material along the south bank of the Potomac is somewhat coarser than it is on the Rappahannock.

Normal tides will cause water level fluctuations in these rivers of about 2 feet. High winds and storms may increase these tidal fluctuations to 6 feet or more. It is under these extreme conditions that shore and riverbank erosion is most severe.

The shoreline of both rivers is indented with numerous guts and creeks, most of which are less than 10 miles in length. These inlets often afford good harbors for small pleasure and commercial boats. Siltation at their mouths is often a problem, sometimes requiring periodic dredging. It is believed that the siltation material comes mainly from main river banks and is transported and deposited by littoral currents.

Land use along the tidal portions of these rivers consists mainly of (1) farming, with corn, small grain, and soybeans the principal crops; truck cropping, dairying, and beef cattle are also important, (2) subdivisions for summer and permanent homes, and (3) small industries pertaining mainly to the seafood and food processing businesses. The rate of subdivision development and home construction along the rivers has increased very rapidly during the last decade.

The Potomac River, serving Washington, D. C., Alexandria, Virginia and numerous other smaller Maryland and Virginia cities and towns, is an important commercial waterway. The Rappahannock is used to a lesser extent for commerce but does provide an important waterway for the transportation of sand, gravel, pulpwood, gasoline, fuel oil, farm crops, and other commodities produced or used in the area.

The seafood industry is active along both rivers. Fish, crabs, and oysters are harvested, processed, and marketed in large quantities.

Both rivers are used extensively for recreation by the local people and by visitors from neighboring states and nearby cities. Boating, fishing, water skiing, and swimming abound during the warm seasons. In the fall and winter, many sportsmen are attracted to the rivers for excellent duck hunting and game fishing.

RESULTS

Erosion of the banks along these tidal rivers is the result of infinite combinations of the tremendous natural forces of water, waves, winds, and tides. Except for minor good and bad influences exerted by landowners, the overall rate of riverbank change probably has remained nearly constant for centuries. Many areas of active erosion, however, are constantly shifting and sometimes changing from recession to accretion. Long reaches of shoreline remain virtually stable over very long periods of time, but they cannot be considered immune to future erosion. Small changes in shoreline characteristics in one area will often alter the resultant effect of wind and tides enough to cause active erosion to commence at another.

Shoreline Changes. Measurements from the composite map of the 1909 and 1956 U. S. Coast and Geodetic Surveys reveal the distribution and magnitude of shoreline changes during that 47-year intervening period. These changes are summarized in Tables 1 and 2. The first table deals with the extent and rate of riverbank erosion and the second with the extent and rate of shoreline accretions. In both cases, data for the north and south banks of the Rappahannock and the south bank of the Potomac are summarized separately. Then the data are further subdivided according to main rivers and tributaries, with the solid banks and marshes shown separately for each.

Table 1.—Summary of riverbank erosion on portions of main rivers and tributaries, Rappahannock and Potomac Rivers, 1909-1956

LOCATION	Length of River Bank Surveyed	EXTENT OF EROSION: Length of Riverbank Affected		Area Lost Annually	Average Bank Recession
	Miles	*Miles*	*% of Total*	*Acres*	*ft/yr*
North Bank Rappahannock					
Main River					
Solid Banks	54.7			3.78	
Marshes and Sand Spits	35.8	....	....	5.77	....
Total	90.5	24.2	26.8	9.55	3.25
Tributaries					
Solid Banks	155.5		....	4.53	
Marshes and Sand Spits	122.3	....	....	2.22	....
Total	277.8	38.4	13.8	6.75	1.45
North Bank Rappahannock Total	368.3	62.6	17.0	16.30	2.15
South Bank Rappahannock					
Main River					
Solid Banks	52.3			7.37	....
Marshes and Sand Spits	46.1	....	....	7.30	....
Total	98.4	41.5	42.1	14.67	2.92
Tributaries					
Solid Banks	81.0			3.61	
Marshes and Sand Spits	111.4	....	....	3.28	....
Total	192.4	41.8	21.7	6.89	1.36
South Bank Rappahannock Total	290.8	83.3	28.6	21.56	2.14
South Bank Potomac					
Main River					
Solid Banks	39.8			3.36	
Marshes and Sand Spits	11.6	....	....	1.57	....
Total	51.4	17.3	33.7	4.93	2.35
Tributaries					
Solid Banks	173.5			5.78	
Marshes and Sand Spits	67.4	....	....	1.30	....
Total	240.9	58.4	24.2	7.08	1.00
South Bank Potomac Total	292.3	75.7	25.9	12.01	1.31
GRAND TOTAL	951.4	221.6	23.3	49.87	1.86

Table 2.—Summary of rivershore accretion on portions of main rivers and tributaries, Rappahannock and Potomac Rivers, 1909-1956

LOCATION	Length of River Bank Surveyed	EXTENT OF DEPOSITION: Length of Riverbank Affected		Area Gained Annually	Average Bank Accretion
	Miles	*Miles*	*% of Total*	*Acres*	*ft/yr*
North Bank Rappahannock					
Main River					
Solid Banks	54.7			2.28	
Marshes and Sand Spits	35.8	....	....	2.00	....
Total	90.5	13.8	15.3	4.28	2.55
Tributaries					
Solid Banks	155.5			2.98	....
Marshes and Sand Spits	122.3	....	....	3.61	....
Total	277.8	18.4	6.6	6.59	2.96
North Bank Rappahannock Total	368.3	32.2	8.7	10.87	2.78
South Bank Rappahannock					
Main River					
Solid Banks	52.3			1.58	
Marshes and Sand Spits	46.1	....	....	3.77	....
Total	98.4	20.9	21.3	5.35	2.11
Tributaries					
Solid Banks	81.0			3.15	
Marshes and Sand Spits	111.4	....	....	1.49	....
Total	192.4	28.4	14.7	4.64	1.35
South Bank Rappahannock Total	290.8	49.3	16.9	9.99	1.67
South Bank Potomac					
Main River					
Solid Banks	39.8			0.57	
Marshes and Sand Spits	11.6	....	....	0.79	....
Total	51.4	6.4	12.5	1.36	1.75
Tributaries					
Solid Banks	173.5			2.82	
Marshes and Sand Spits	67.4	....	....	0.87	....
Total	240.9	14.4	6.0	3.69	2.12
South Bank Potomac Total	292.3	20.8	7.1	5.05	2.01
GRAND TOTAL	951.4	102.3	10.7	25.91	2.09

On the main riverbanks only 26.8% of 90.5 miles of the north bank of the Rappahannock showed a recession during the 1909-1956 period, while 42.1% of the 98.4 mile south bank was affected. On the south bank of the Potomac 33.7% of the 51.4 miles surveyed showed losses from erosion. The percentage of the total tributary banks affected was just slightly over half that of the main rivers.

Bank recession rates were highest on the main rivers, ranging from 2.35 feet per year on the Potomac south bank, to 2.92 on the Rappahannock south bank, to 3.25 on the Rappahannock north bank. In the same order, their tributaries had rates of 1.00, 1.36, and 1.45 feet per year. All of these rates are based on the portions of the rivers and tributaries which actually showed a recession in shoreline during the 1909-1956 period.

There was a grand total of 951.4 miles of shoreline included in the study. From this total, 221.6 miles or 23.3% suffered some degree of erosion. The average annual loss totaled about 50 acres per year and the overall bank recession rate was 1.86 feet per year.

From the data in Table 2 similar comparisons can be made about the extent of deposition and rate of bank accretion along portions of the same rivers and tributaries. In general, only about half as much shoreline received depositions and accretions as were affected by erosion. However, where depositions occurred the average annual rate of shoreline accretion was not greatly different on most streams from the bank recession rates on the eroding areas.

Out of the total of 951.4 miles of shoreline investigated, 102.3 miles or 10.7% received depositions during the 1909-1956 period. The average shoreline area gained annually was about 26 acres and the bank accretion rate was 2.09 feet per year.

The data presented in Tables 1 and 2 are based upon the location of the shorelines, revealed by the 1956 U. S. Coast and Geodetic Survey, compared with their location when previously surveyed in 1909. Since no intermediate surveys were made during this 47-year period, it was necessary to assume uniform bank movement throughout the period in establishing the yearly changes. Likewise, it was necessary to assume that the entire length of banks affected were actively changing at a constant rate throughout the period. Obviously, these are hypothetical assumptions, but they do not alter the fact that the data presented are a true representation of average long-term gross bank changes expressed in annual loss or gain terms.

It was not possible to determine the periodic changes in shoreline activity from one location to another. Neither was it possible to establish the maximum annual or single storm bank change rates. At many of the survey sample points, bank recession rates of 5 to 10 feet per year, based on the 47-year period, were measured. Rates of shoreline accretion at some points were almost as high. With such high annual rates over a 47-year period, it is logical to assume that in certain years the bank changes at these most active locations were many times greater than the long-time averages. Local residents testify that such is the case, and there are numerous landmarks to substantiate their statements. Hence, the average data presented fail completely to reflect the severity of the problem at specific locations in the more actively eroding areas. While these critical areas tend to shift somewhat through the years, they unfortunately, usually constitute those vantage points along the rivers which are most valuable for private and public development.

Factors Affecting Shore Movement

It was not possible to relate bank erosion and shoreline accretion to selected physical factors which might influence them with the survey data collected. Shore movement is the resultant effect of a great number of widely different, but strongly interdependent forces and conditions acting together in highly variable and complex combinations. Because of this, the various groupings of the limited collected data, designed to show possible relationships, were variable and indecisive. However, when the data are considered in the light of general knowledge and conclusions reached from careful study of each sample site, certain generalized observations can be made.

In most cases, the rate of shoreline recession is about twice as great under starved beach conditions as it is where the beach is continually nourished. The opposite situation usually prevails in regard to accretion.

The rate of shoreline movement seemed to have little relationship to the direction of bank exposure. However, 63.4% of the south bank of the Rappahannock had some degree of bank movement during the 47-year period while only 42.1% of the north bank was affected. This strongly indicates that exposure direction increases the vulnerability to shoreline change.

No relationship was indicated between shoreline movement and near shore gradient. This factor seems to be generally the resultant of all other forces and represents a result rather than a cause.

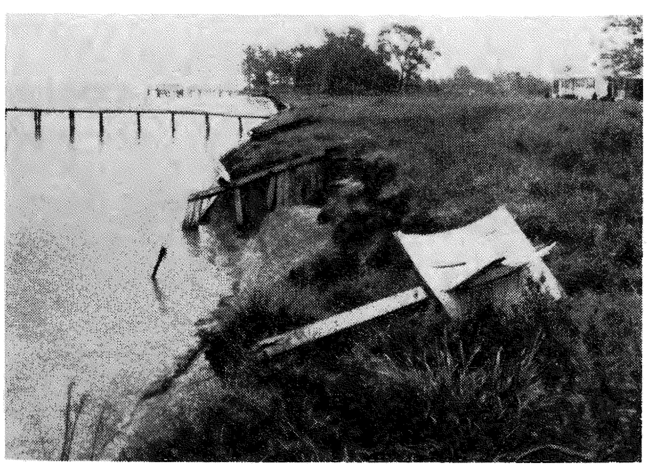
There was some indication that the banks with good substrata drainage provided more protection against bank erosion than the poorer drained soils, but the relationship was not so pronounced as might be expected.

The wider the beach, the more protection it affords the banks. Also, the coarser beach materials tend to be more stable, but no significant relationship was found between composition of beaches and bank movement.

In general, rates of bank movement decreases with increasing bank heights. The effect of texture of the soil banks was not clearly indicated, but there was some tendency toward higher rates of recession on the coarser textured soils. Shoreline movement was greatest along the wider areas of open water where winds, waves, and tides had time and distance to build up maximum forces.

The amount of material carried in the littoral drift determines to a large extent whether the beach is starved or nourished and, therefore, affects shoreline movement. Where large amounts of materials are available beaches build up with surprising rapidity, but so do silt deposits in the navigation channels of the inlets. The amount of material transported generally increases with increasing distance between deep water estuaries.

All of the data clearly indicate the extreme complexity of the shore erosion problem and that the combination of forces acting in a particular area are constantly shifting. In studying the composite map prepared from the 1909 and 1956 U. S. Coast and Geodetic Surveys, and comparing it with some maps which are still available from an 1855 survey, numerous examples can be found where long reaches of the shore recessed during one period and accreted during the next, or vice versa. The maps seem to indicate that generally a convex shape shoreline will recede most rapidly along the center of the curve. This often continues until the shoreline becomes straight and finally concave. In doing so, recession is likely to slow down, then stop, and finally accretion may begin.



Typical failure of an inadequately designed timber bulkhead. Accelerated bank erosion has commenced.

The interrelated forces which affect shoreline movement occur in much more forceful combinations on the wider main rivers than they do on the narrower tributaries. This is evidenced by the data in Tables 1 and 2 for both rates and extent of bank changes.

ECONOMIC APPRAISAL

The study extended to making a limited economic appraisal of beach erosion. In order to complete this phase of the study, data on land use, size of ownership unit, length of tenure, distance of buildings from the river, and value of real estate were compiled for each property adjoining the sample points. These data provide a basis for making a limited appraisal of the economic importance of shore-erosion losses.

Two values were calculated for each ownership unit. First, the assessed values of land and buildings for each property were obtained from the 1960 Land Book in the respective counties. These assessed values were converted to sale values through use of a conversion factor (ratio of assessed value to sale value) provided by the Research Division, State Department of Taxation. It is generally thought that waterfront properties are undervalued for tax assessment and, for this reason, the sale values as determined are probably somewhat conservative. Second, a frontal value per acre was estimated for each ownership unit to represent the value of that portion of the property along the waterfront. Where the ownership unit was a lot or small tract, the frontal value per acre was obtained by converting the sale value (determined from tax assessment records) to an acreage figure. On large acreages, the frontal value per acre was determined by estimating the sale value of the waterfront extending to a depth of 300 to 600 feet. These estimates were on-site appraisals and the appraiser used the converted assessed values as a guide. It is important to note that frontal value per acre includes both the value of land and buildings, where buildings are present.

It was not possible within the limits of the study to enumerate data on the actual value of property losses due to recession. To do so would require a detailed survey of the value of buildings and other improvements either damaged or destroyed, the cost of moving buildings to prevent destruction, and declines in the value of waterfront land due to changes in beach condition. The only feasible alternative was to assume the value of the acreage lost was equivalent, on a per-acre basis, to the present frontal value of properties subject to recession. Undoubtedly, this overvalues the losses where buildings were moved to prevent a complete loss of the investment. Likewise, it also overvalues the losses in areas where many of the improvements were constructed in recent years.

Within the 951.4 miles of riverbanks included in the study, the annual losses during the 47-year period amounted to 14.51 and 13.92 acres, respectively, on the solid banks of the rivers and their tributaries (Table 3). In addition, 14.64 and 6.81 acres were lost annually along banks classified as marsh and sand spits. The value of the annual losses on the latter was relatively small and somewhat insignificant because of the low per-acre value of many of the properties. The value of the annual losses along the solid banks was more substantial, amounting to $86,668 for the rivers and $30,262 for the tributaries. These annual losses were not large per mile of riverbank; however, beach erosion is highly localized in its intensity and where several feet of riverbank are lost per year, the importance of economic losses increases rapidly.

The high values per acre indicate the importance of buildings and other improvements in the beach-erosion problem. Along the south bank of the Rappahannock and Potomac Rivers, the proportion of ownership units with buildings was much greater than on the north bank of the Rappahannock (Table 4). Furthermore, on the own-

Table 4.—Average Distance from Riverbank to Nearest Building

Location	Sample units	Proportion of ownership units: Absence of buildings	Buildings 300 feet or less from riverbank	Buildings more than 300 feet from riverbank	Average distance ([1])
	(*No.*)	(%)	(%)	(%)	(*Ft.*)
North Bank Rappahannock					
Main River	79	25.3	24.1	50.6	133
Tributaries	82	34.2	32.9	32.9	135
South Bank Rappahannock					
Main River	118	5.9	69.5	24.6	92
Tributaries	69	14.5	36.2	49.3	91
South Bank Potomac					
Main River	38	18.4	63.2	18.4	105
Tributaries	62	9.7	61.3	29.0	88

[1]Average distance for ownership units with buildings 300 feet or less from the riverbank.

Table 3.—Acreage and Value of Shoreline Lost Annually through Recession

Location	Solid Bank: Length of riverbank	Annual recession	Value[1]: Total acres	Per acre	Marsh and sand spits: Length of riverbank	Annual recession	Value[1]: Total acres	Per acre
	(*Miles*)	(*Acres*)	($)	($)	(*Miles*)	(*Acres*)	($)	($)
North Bank Rappahannock								
Main River	54.7	3.78	3,754	993	35.8	5.77	883	153
Tributaries	155.5	4.53	5,468	1,207	122.3	2.23	653	293
South Bank Rappahannock								
Main River	52.3	7.37	64,510	8,753	46.1	7.30	8,103	1,110
Tributaries	81.0	3.61	10,740	2,975	111.4	3.28	692	211
South Bank Potomac								
Main River	39.8	3.36	26,695	7,945	11.6	1.57	75	48
Tributaries	173.5	5.78	12,560	2,173	67.4	1.30	247	190
Grand Total								
Main Rivers	146.8	14.51	86,668	5,973	93.5	14.64	10,350	707
Tributaries	410.0	13.92	30,262	2,174	301.1	6.81	1,764	259

[1]Value of annual recession expressed in terms of frontal value of properties subject to recession.

ership units with buildings, the location of the buildings was generally closer to the riverbank. This difference in the number of buildings and location of buildings is reflected in the per-acre values of annual losses through recession. Although the values are somewhat high for appraising past recession, they do indicate the importance of homes and building sites in the beach-erosion problem. The magnitude of potential losses through recession and, consequently the concern of land owners, will increase significantly as more buildings are built near the riverbanks.

The 448 sampling points established for the study fell on 302 ownership units, of which approximately half were farms and part-time farms (Table 5). The farms averaged 467 acres of land and those along the main riverbanks were more than twice the size of farms located on the tributaries. The influence of the water on the land use is strikingly shown by the fact that 1/3 of the sample points fell on lots and small acreages (averaging 26 acres per unit) used by owners and lessees on weekends and holidays for boating, swimming, fishing, and hunting. The average length of riverbank frontage was large for all classes of properties—even the residences averaged 492 feet of riverbank. It was estimated that recession occurred during the 47-year period on 23.3% of all the riverbanks included in the study. Some idea of the magnitude of the protection problem can be obtained by applying this percentage to the average riverbank footage for the various classes of properties. However, care must be exercised in interpreting such estimates because averages tend to destroy the localized nature of severe recession.

The average value of the various properties is shown in Table 6. Like the average size of the properties, the estimates are substantial investments both in land and buildings. Although some properties have only modest shelters for non-permanent housing, others include expensive structures which derive part of their value from their location on the river. Occasionally, farms and other properties include several rental cottages among their buildings, but most of the properties have only one dwelling.

Over the years the ownership of properties on the rivers has not changed frequently; some have remained in the same family for several generations. Since World War II, the tempo for living on the rivers has increased and considerable development has occurred. As a result, properties or parts of properties have changed ownership more frequently as people have purchased tracts on the rivers for homesites, recreational lands,

Table 5.—Number and Average Size of Properties Adjoining Rivers at Sample Points[1]

Item	North Bank Rappahannock		South Bank Rappahannock		South Bank Potomac		Total		
	Main river	Tributaries	Main river	Tributaries	Main river	Tributaries	Main river	Tributaries	All properties
Farms:									
Number	24	18	27	18	8	21	59	57	116
Acres per farm	473	273	819	303	772	198	672	255	467
Riverbank footage	8,177	5,462	12,530	5,393	13,103	5,657	10,837	5,512	8,220
Part-time farms:									
Number	6	20	2	4		11	8	35	43
Acres per farm	156	76	36	56		30	126	59	72
Riverbank footage	2,933	2,930	264	3,493		2,109	2,266	2,735	2,649
Forest tracts:									
Number	6	8				2	6	10	16
Acres per tract	271	264				177	271	247	256
Riverbank footage	4,501	5,353				6,150	4,501	5,512	5,233
Residences:									
Number	2	7	8	4		3	10	14	24
Acres per unit	14	10	1	4		6	4	8	6
Riverbank footage	850	900	160	410		297	298	630	492
Seasonal:[2]									
Number	11	13	24	21	14	16	49	50	99
Acres per unit	66	34	22	21	6	25	27	26	26
Riverbank footage	5,490	2,558	1,016	1,595	1,071	1,345	2,036	1,765	1,899

[1]Sample points fell on four ownership tracts of commercial properties, churches, and government property.

[2]Properties used seasonally. Most of these units were lots or small acreages with waterfront residences used by owners or lessees on weekends or holidays. A few provided only overnight shelters for fishing, boating, and hunting and several were waterfowl hunting grounds.

Table 6. The Average Value of Properties Adjoining Rivers at Sample Points[1]

Item	North Bank Rappahannock		South Bank Rappahannock		South Bank Potomac		Total
	Main river	Tributaries	Main river	Tributaries	Main river	Tributaries	All properties
	($)	($)	($)	($)	($)	($)	($)
Farms:							
Land	26,003	14,395	56,375	33,751	78,488	19,874	34,984
Buildings	11,786	9,784	32,648	20,846	46,879	22,979	22,183
Total	37,789	24,179	89,023	54,597	125,367	42,853	57,167
Part-time farms:							
Land	8,743	6,113	21,855	6,846		3,186	6,532
Buildings	18,198	7,370	24,150	13,907	....	6,883	10,145
Total	26,941	13,483	46,005	20,753		10,069	16,677
Forest tracts:							
Land	7,239	9,990				8,621	8,725
Buildings	661	....	....	....	....	....	248
Total	7,900	9,990				8,621	8,973
Residences:							
Land	2,643	3,039	5,698	4,343		853	3,836
Buildings	13,298	14,434	19,611	2,785	....	5,509	13,008
Total	15,941	17,473	25,309	7,128		6,362	16,844
Seasonal:[2]							
Land	6,788	5,786	6,390	11,219	4,697	5,954	7,069
Buildings	11,554	14,839	9,826	8,678	7,834	8,518	9,940
Total	18,342	20,625	16,216	19,897	12,531	14,472	17,009

[1]Blanks indicate either no properties in sample or an absence of buildings on the properties.

[2]Properties used seasonally. Most of these units were lots or small acreages with waterfront residences used by owners or lessees on weekends or holidays. A few provided only overnight shelters for fishing, boating, and hunting and several were waterfowl hunting grounds.

and similar uses. In general, from 1/3 to 1/2 of the ownership units had the same owners for 25 years or longer, and those who had owned their properties less than 25 years had an average duration of tenure of 10.5 years (Table 7). Thus, the majority of the residents had lived on the river long enough to be familiar with the erosion problem. Newcomers are increasing, however, and at best they usually have only a vague understanding of recession along the rivers. Slightly over 15% of the present owners had owned their properties less than 6 years. Increased immigration and the corresponding development have intensified the problem and will continue to do so unless careful planning is done to prevent the location of improvements where they will be subject to damage or destruction from the water within a few years.

Data on a number of physical factors, such as near shore gradient, fetch length, and height of riverbank, were correlated with the annual rate of recession and frontal value per acre. In all except one of the relationships, significant correlation was absent. Whether the beach was starved or nourished was highly related to value; the frontal value per acre on starved beaches was only 1/3 of the value of nourished beaches (Table 8).

Broadly speaking, the major economic loss from beach erosion accrues to the homeowner, rather than posing any serious threat to agricultural production. The homeowner's vulnerability to such losses is often intensified by the features he values most in a homesite. The survey indicates he is willing to pay the highest price for a waterfront site on a well-drained, solid, main riverbank with a wide nourished beach and a northerly exposure. Such locations are necessarily exposed to storms and often have the higher rates of bank recession. Thus, we have a combination of factors—highest land values, expensive homes and other improvements, and locations vulnerable to severe bank erosion — working together to maximize the economic impact of the problem for the homeowner. The real loss to farmers and other large landowners usually can be most realistically estimated by considering the effect of such losses on the potential value of the shoreline for homesites and similar developments rather than for agricultural uses.

Table 7.—Duration of Tenure on Ownership Units

Location	Solid bank				Marsh and sand spits			
	Ownership units with tenure of less than 25 years		Ownership units with tenure of 25 years or more		Ownership units with tenure of less than 25 years		Ownership units with tenure of 25 years or more	
	Size of sample	Average tenure	Size of sample	Proportion of all units	Size of sample	Average tenure	Size of sample	Proportion of all units
	(No.)	*(Years)*	*(No.)*	(%)	*(No.)*	*(Years)*	*(No.)*	(%)
North Bank Rappahannock								
Main River	22	9.5	26	54	17	8.6	14	45
Tributaries	25	12.7	18	42	20	11.9	19	49
South Bank Rappahannock								
Main River	44	10.1	20	31	30	9.7	24	44
Tributaries	39	10.3	13	25	9	6.5	8	47
South Bank Potomac								
Main River	26	10.2	5	16	7	11.1	....	....
Tributaries	34	11.5	20	37	3	14.0	5	62
Grand Total								
Main Rivers	92	10.0	51	36	54	9.6	38	41
Tributaries	98	11.4	51	34	32	10.6	32	50

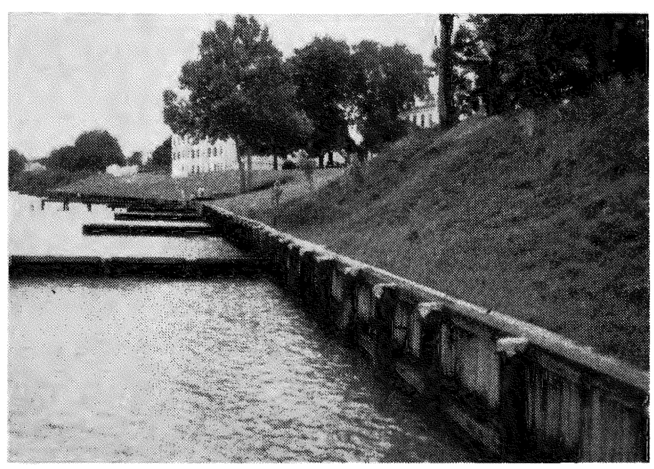
Table 8.—Relation of Condition of Beach to Frontal Value of Properties

Location	Starved beach		Nourished beach	
	Size of sample	Frontal value per acre	Size of sample	Frontal value per acre
	(No.)	($)	*(No.)*	($)
Solid bank				
Main rivers	74	4,354	69	7,710
Tributaries	86	1,583	63	2,982
Marsh and sand spits				
Main rivers	75	148	17	2,350
Tributaries	58	254	6	302
Grand Total	293	1,653	155	4,913

Corrective Measures

In the course of this survey, it was possible to observe the performance of a wide range of corrective measures. These ranged from cheap to very expensive structures employing materials ranging from used automobile tires to pressure-creosoted timber, from loose rock to concrete, and from steel piling to concrete drain pipe sections. Bank sloping, along with various kinds of salt-tolerant vegetation, has also been tried. Many of these works of improvement have been successful, others have provided some protection, many have failed completely, and some have even accelerated losses. Overall, the record has been a gloomy one, and the costs a real burden on the landowners. But out of these experiences much technical knowledge and practical know-how have been gained. The real challenge is to effectively organize and apply this accumulation of knowledge and to continue learning from experience.

The landowners must be impressed with the tremendous forces with which they are dealing and the hazards involved in attempting corrective measures without adequate design. Each landowner must realize also that the kind of construction which will provide the most effective shoreline protection on his property depends on many factors. Chief among these are the amount and nature of shoreline movement taking place, exposure to seasonal winds and storms, tide levels, composition of the beach, and direction and character of the littoral drift. The relation of the local erosion problem to up-and-down shore conditions is another factor to consider.



An example of effective erosion control which can be achieved with properly engineered structures, bank sloping, and vegetation.

These and other factors can work together in many combinations to present a wide range of shore erosion conditions, requiring in turn, many types of control structures. A study of shore erosion in Tidewater Maryland, published as Bulletin 6 of the Maryland Department of Geology, Mines and Water Resources in 1949, revealed similar conditions in that State.

More recently, the Governor of Maryland appointed a special committee to study shore erosion and to make recommendations for a shore erosion policy. The committee report entitled, "A Shore Erosion Policy for Maryland," dated December, 1961, treats the mechanics of shore erosion and the methods of controlling shore erosion in full detail. This excellent discussion is fully applicable to Virginia conditions and is recommended as a valuable reference for users of this report.

SUMMARY

This survey has been limited to a study of shoreline erosion along both banks of the Rappahannock and a 51.4-mile section of the south bank of the Potomac in Tidewater Virginia, together with their tidal tributaries. As a whole, the average rate of bank recession along these rivers and tributaries is not too alarming. It is the fact that the rate varies so much from site to site and from year to year that adds so much to the seriousness of the problem. So often the most desirable locations for homes and other developments are the most vulnerable sites. Even so, there has been a large population increase along the tidal rivers in recent years, and a real population explosion is predicted for the area in the future. As a result, the value of waterfront property is increasing at a very rapid rate and the trend is expected to continue.

The shore erosion problem is becoming increasingly important to both the landowner and the public. While the landowner suffers the direct loss of property, the deposition of eroded materials often blocks or impairs the use of navigable streams, thereby affecting the public interest. In both cases, remedial measures are costly and technically complicated. It will be necessary to develop a comprehensive shore erosion control program which will meet the needs of both the private landowner and the public in order to cope successfully with the problem.

The very foundation of the program must be firm community organization and effort, so that corrective measures incorporating the most advanced technical knowledge can be applied to natural physiographic units of shoreline rather than to short reaches defined by individual property lines.

The erosion-causing forces of waves, winds, and tides are so enormous and act in such a wide range of complex combinations that even the best designed control measures utilizing the latest scientific knowledge sometimes fail. Any structure less carefully designed can be expected to fail; and poor designs often actually aggravate the problem.

Fortunately, research by the Beach Erosion Board, the Corps of Engineers of the U. S. Army and other agencies, both in this country and abroad, are continually supplying new technical knowledge and advancing the overall science of shore erosion control. In addition, much valuable information, both positive and negative, is being obtained from the efforts of landowners to solve their bank erosion problems on these rivers.

Many states have already adopted various programs and policies for dealing with the shore erosion problem. Others are in the process of formulating policies and procedures. Virginia has assisted several municipalities on shore erosion control but has not formulated a definite policy or action program to combat the problem.

RECOMMENDATIONS

This survey of the nature, extent and economic importance of shore erosion on the Rappahannock and portions of the Potomac River systems in Tidewater Virginia clearly establishes the problem as one of great importance to the area. It is the opinion of the Advisory Committee that these findings are representative of the conditions prevailing throughout Tidewater Virginia; and that, with the rapidly expanding population and its correspondingly heavier demands on the shore areas, the problem of shore erosion is becoming increasingly critical year by year.

It is the further consensus of the Committee that a coordinated, well-defined action program should be developed to deal with shore erosion; and that such a program should be a cooperative endeavor between all appropriate public agencies and private landowners, with the public agencies providing the necessary technical assistance.

Accordingly, this Committee makes the following recommendations for developing and executing such a program:

I. That the Boards of Supervisors of the several Soil Conservation Districts affected assume leadership for the program and organize themselves for maximum regional coordination of effort through the establishment of a shore erosion advisory committee to formulate, direct, and establish priorities for the project. Also, the Committee should make recommendations to the local governments involved of the need for shore property development regulations.

II. That the Boards of Supervisors of the affected Soil Conservation Districts petition the public agencies concerned to assign to the project a well-trained engineer, together with such assistants as he may require, who is competent to conduct an effective educational program, to coordinate individual and community efforts, and to provide consultant service on the design and construction of control measures; and, also, to serve as the Executive Officer of the Shore Erosion Advisory Committee.