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# THE FLOOD PLAIN OF THE RARITAN RIVER, NEW JERSEY

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## INTRODUCTION

The flood plain of the Raritan River in New Jersey is usually less than 0.5 mi. in width and occurs throughout much of the length of the river. It has been extensively used for cultivation or for pasture, leaving little or no woodland entirely free from disturbance. At a few places along the river there are areas which give some indication as to the natural composition of flood plain and adjacent terrace forests. Some of these forests have been described by Buell & Wistendahl, 1955. At other places successional trends on islands, river banks, and abandoned fields are evident. This study includes several aspects of the flood plain and its vegetation, ranging from early successional stages to the most mature forests as found here.

The Raritan River drains about 1,105 sq. mi. of central New Jersey (Vermeule 1894). Its numerous branches and tributaries extend into three of the four geologic provinces of the state: namely, the Coastal Plain, The Piedmont, and the Highlands (Fig. 1). Two major branches of the river originate in the Highland Province on or near the Wisconsin terminal moraine. The North Branch, which joins with the Lamington River near Burnt Mills (elev. 60 ft), flows southward from the Highlands onto the Piedmont. The South Branch, originating in Budd Lake (elev. 933 ft) about 5 mi. west of the source of the North Branch, flows southwesterly and then loops easterly joining the North Branch near Raritan, New Jersey (elev. 50 ft), where they then form the main easterly flowing river. Near Manville the north flowing Millstone River joins the main body of the Raritan which continues easterly, passing New Brunswick and emptying into the Raritan Bay.

At the confluence of the Lamington River with the North Branch at Burnt Mills a flood plain has developed which has some relatively undisturbed wooded areas. Where the North Branch joins the South Branch, a similar but more extensive flood plain has developed at Raritan, New Jersey. The forests on these two flood plain areas contain the oldest trees. Along the north side of the lower part of the Raritan River near New Brunswick there is a rather extensive flood plain. The south side of the river has been used for the construction of the Delaware-Raritan Canal and flood plain areas there have thus

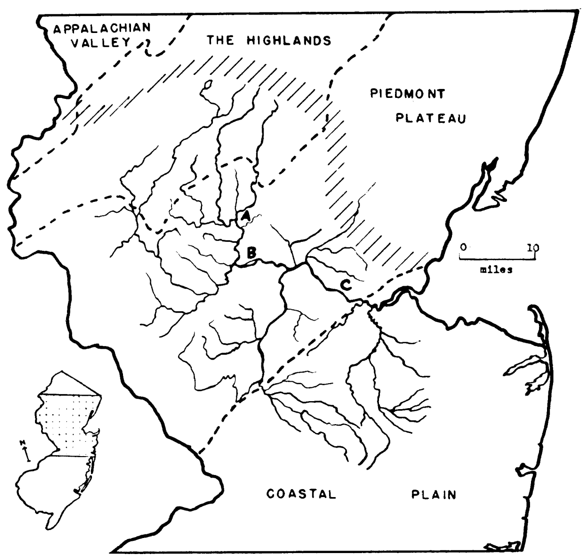


FIG. 1. Drainage pattern of the Raritan River Valley with respect to the geologic provinces of the State of New Jersey and the Wisconsin terminal moraine (hatchings). Three flood plains studied are indicated by: A—Burnt Mills; B—Mertensia Woods; and C—Raritan Landing.

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been cut off from the river. The flood plain on the north side at this vicinity has been used in the past as mill, warehouse, docking, and agricultural sites (Vermeule 1936). At present recreational parks occupy some of the area, while other portions are in various stages of revegetation.

The two principal branches of the Raritan River flow over geological formations which are similar (Lewis & Kümmel 1912). They both arise on or near the terminal moraine of the Wisconsin glacier. At their sources glacial drift covers much of the underlying Pre-Cambrian gneisses. Flowing down from these resistant ridges, the branches cut across or follow occasional beds of Cambrian sandstone and Cambro-Ordovician limestone. Drainage from small areas of Ordovician shale and Silurian conglomerate flows into the North and South Branches. Before flowing onto the extensive Triassic red shale and sandstone valley, the South Branch and the Lamington River cross a small section of Triassic conglomerate. Once on the Triassic shales and sandstones the river remains on such material to its mouth, except for some drainage from old glacial drifts (Jerseyan?) which form high river-terrace deposits. The river ultimately flows into an estuary which has developed on Cretaceous materials.

The Millstone River originates partly on Cretaceous and partly on Triassic deposits. It cuts across a ridge of diabase of Triassic age and, flowing northward, joins the Raritan River near Manville. Other tributaries of the Raritan River drain some areas of both diabasic and basaltic igneous rocks of the same age (Triassic). These rocks are, for the most part, the Cushetunk and Watchung Mountains. Because the river cuts across a variety of bed rock types, some dating back to Pre-Cambrian time and some as recent as the Cretaceous. There is a great variety of source materials for the alluvium of this relatively short system.

Investigation of the flood plain was made during the years 1952, 1953, and 1954. Three general areas were studied in detail (Fig. 1). These were on the flood plain below the junction of the North Branch and the Lamington rivers, which will be referred to as Burnt Mills area (lat. 40° 37.2′ long. 74° 40.5′); on the flood plain below the junction of the North and South Branches of the Raritan near the town of Raritan which will be referred to as Mertensia Woods (lat. 40° 31.1′ long. 74° 39.5′); and on the flood plain near New Brunswick, which is part of an area known as Raritan Landing (lat. 40° 31.3′ long. 74° 28.5′). A flood plain, although a single physiographic feature, possesses a varied topography with equally varied local vegetational patterns. These patterns intergrade from place to place but nevertheless are distinctive enough to be recognized as composed of plant communities. Several such plant communities were sampled independently to bring out vegetational differences which would be lost in less discriminate sampling.

I wish to express my appreciation to Dr. Murray F. Buell for his guidance of this study and to Mr. Malcolm J. Smith of South River, New Jersey, for his assistance in the field obtaining transit data. For the use of unpublished data, I am grateful to Messrs. A. E. White, O. W. Hartwell, E. G. Miller, and O. Lauterhahn of Trenton, New Jersey.

## DISCUSSION OF THE LITERATURE

Flood plain forests possess luxuriant vegetation (Cowles 1901, Nichols 1916, Humphrey 1924, Gordon 1936, Lee 1945). Changes in composition are frequent although the same general list of species prevails throughout a river flood plain system. Lee (1945) found that even though the flood plain of the White River system in Indiana dissected different geologic provinces, each with its own characteristic vegetation, the same flood plain species persisted. He concluded that dominance of one or a few species was not evident. Turner (1936) found that the flood plain forest of the lower Illinois River had more tree species with a dominance index (frequency multiplied by density) over 100 than any other forest he studied in the lower Illinois valley, although silver maple *(Acer saccharinum)* and American elm *(Ulmus americana)* were the chief dominants. Core (1929) considered the herbs of West Virginia flood plains to be "mainly Carolinian (Upper Austral), with a good sprinkling of Alleghenian (Transitional) species." Oosting (1942) summarizes that "slight variations in topography and drainage have pronounced effects upon moisture conditions in bottomlands" and that bottomland communities are ". . . often made up of mixtures of species . . ."

Cribbs (1917) called the flood plain forest of western Pennsylvania a mesophytic forest. Cowles (1901) saw no reason why mesophytic forests should not develop on the flood plains in the Chicago area, with a trend toward retrogression with terrace formation. He was impressed by the number of kinds of trees such as tulip tree *(Liriodendron tulipifera)* which were not common in the Chicago district. Braun (1916) refers to the "high level flood plain" of the Cincinnati region as bearing a mixed mesophytic forest. The continual formation of new surfaces led Shelford (1954) to believe that flood plains are "exceptionally useful, and perhaps as important as sand areas in the study of ecological principles."

The various and variable habitats of river flood plains, bottomlands, and terraces where differences of topography, drainage, light and other factors are interacting present interesting ecological problems. Oosting (1942) recognized that moisture relations on bottomlands influence stand development. Controlled experiments by McDermott (1954) on the "effects of saturated soil on seedling growth" show that the bottomland species which were observed by Oosting recover from the effects of soil saturation at varying rates. Illickevsky (1933) refers to the importance of rivers in controlling distribution of plants. He lists species which are restricted to regularly flooded zones or to higher grounds along various rivers in Russia. The successional trends found on the upper Missis-

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sippi River by Barclay (1924) were observed by Hefley (1937) on the Canadian River. Russell (1953) in studies of the Apple River Canyon of Wisconsin states that "almost every step along the bank of the river took one into a different society." Hefley (1937), Goff (1952) and Shelford (1954) worked out interesting studies of flood plain animal communities, based largely upon the developmental aspects of flood plains within the areas studied.

Many of the aspects of flood plains have been studied by various workers, investigating the effects of silting on tree development (Harper 1938) and on forest succession (Featherly 1941); island formation and development (Shull 1922, 1944); permanent flooding (Yeager 1949); vegetation (Stallard 1929, Hotchkiss & Stewart 1947, Penfound & Hall 1939, Burns 1941, Ware & Penfound 1949, Turner 1930, 1934, Conard 1952, and Griggs 1914) and geographical aspects (McGee 1891).

## METHODS

Quantitative data for the herb layer at Burnt Mills were obtained from forty 0.5 x 2 m quadrats in each of 3 plant communities, the outer flood plain, the inner flood plain and the terrace. These quadrats were located at 10 m intervals along 4 transect lines at each unit. The herbaceous cover in Mertensia Woods was studied in the same manner. The percent cover for herbs, mosses and litter was estimated for each quadrat. Lack of cover was recorded as space. Seedlings (less than 1 ft tall) of tree species were counted on all quadrats. Data were obtained during late May and early June and again in late August and early September.

Several transects cutting across the flood plain perpendicular to the river at Burnt Mills, Mertensia Woods and Raritan Landing were studied. Data for descriptive purposes and for comparing vegetation on various parts of the flood plain were obtained along these lines. Cover was estimated for each 10 m segment of the line and at 10 m intervals a careful search was made for tree seedlings as well as noting the size and abundance of saplings and trees.

The methods described below apply to the study of 3 revegetated fields at Raritan Landing. These fields were covered by different densities of woody species and had obviously ceased to be used agriculturally at different dates. The line intersect method was used (Buell & Cantlon 1950). A 400 m line was used on the youngest or most recently revegetated field but a 200 m line was used on the other fields because of their smaller size. The transects traversed the length of the fields and consequently ran parallel to the direction of the river. Two or three parallel lines were used, depending on the size of the field.

Tree cover and sapling and shrub cover were determined along the entire length of each transect. (The term sapling is used for individuals of tree species which are less than 1 in. d.b.h. and over 1 ft. tall.) At 5 m intervals along each transect line the percent cover was estimated for herbs and tree seedlings were counted on ½ x 2 m quadrats. The diameters of all trees greater than 1 in. d.b.h. were measured within 1 m of each side of the transect lines. Data were recorded for successive 10 m segments of transect. Similarly the number of saplings within ½ m of the lines were counted for each 10 m segment of line. This, in effect, resulted in a series of nested quadrats which were 2 x 10 m in size for trees and 1 x 10 m for saplings, with two ½ x 2 m herb quadrats per nest.

The river bank vegetation bordering the fields at Raritan Landing was sampled at two areas by a combined quadrat-cover transect method. One series of 15 quadrats and cover transect was obtained adjacent to the youngest and intermediate revegetated fields. The second series was of 5 quadrats adjacent to the oldest field, which was farther upstream.

The 10 x 10 m quadrats were placed so that they lay entirely on the bank sloping down to the river or to the reed canary grass *(Phalaris arundinacea)* fringe along the river. In each 10 x 10 m quadrat on the upper part of the bank one 2 x 10 m and two ½ x 2 m quadrats were included. Tree diameters (d.b.h.) were recorded for each 10 x 10 m quadrat. Tree saplings were counted in the 2 x 10 m quadrat, and tree seedlings were counted in the ½ x 2 m quadrats. The percent herbaceous cover was estimated in each of the smallest quadrats.

Cover of trees, saplings, and shrubs were obtained by the line intersect method. A 20 m tape was extended diagonally across each 10 x 10 m quadrat. Thus each line crossed the bank at an angle of about 45° to the river.

The transect method was also used for sampling the reed canary grass area which borders the river between the water and the bank of the natural levee at Raritan Landing. About midway between the bank and the water a 200 m line was established. Details for sampling were the same as those described above for transects cutting across the flood plain.

Heights of trees were determined with the use of an Abney level. Ring counts were determined from borings or from freshly cut saplings and recently cut trees.

Cover values obtained by use of transects can be expressed as the percent of the length of transect covered by the total crown spread of individuals of one species, or by the percent each species contributes to the total cover (length of transect minus unoccupied space) of all species along the transect. Because of the overlap of crowns, the former method of expression may, when the percentages of all species are added, total greater than 100%. However, the latter method of expression will total 100%. Thus, cover computed on the basis of the length of transect covered by the total crown spread of individuals of one species will be referred to as actual cover, and cover computed on the basis of total cover of all species will be referred to as relative cover. Relative cover values will be used in this paper unless stated otherwise.

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Soil on flood plains is extremely variable in texture from one area to another. To bring out the difference in soil composition with increased distance from the river, 3 series of 4 samples each from the upper 10 cm were obtained at points across the Raritan Landing area near New Brunswick for mechanical analysis (Bouyoucos 1936). Thus 4 came from the natural levee close to the river, 4 from the marshy area behind the levee, and the others from about half way between.

Near the middle of the levee at Raritan Landing a soil pit was dug to the water table, which at the time was at a depth of about 6 ft. The thickness of deposits of gravel, sand, silt, and clay were measured. Notes were made on soil color, pebble content, and root penetration.

Three cross section profiles of the flood plain were obtained by use of an engineer's transit. These profiles were taken at the Burnt Mills area, Mertensia Woods and Raritan Landing.

## GENERAL FEATURES OF FLOOD PLAINS

The dynamics by which fertile flood plains are developed have been frequently described (von Engeln 1948, Longwell *et al.* 1948, Cribbs 1917, Nichols 1916, Sallards *et al.* 1923). Basically two main processes are concerned: degradation—the eroding of river beds and banks—and aggradation—the desposition of eroded materials at some point farther downstream. During floods, especially during the falling stages, as the velocity of the river decreases, the heavier particles of sand are deposited near the river's edge, and the lighter particles of clay and silt are deposited a greater distance from the river's edge. This sorting out of materials results in differential rate of flood plain development so that a natural levee builds up near the river's edge and a lower area develops behind it.

The valley slope, bed-load, discharge, bed resistance and the transverse oscillation of the water at the surface of a river greatly influence the meander pattern of a river. The inability of a river to adjust its width in accordance to its velocity leads to alternate deposits of sand bars, first on one side of the river and then on the other. These deposits cause the river water to be diverted first toward one bank and then toward the other, developing a serpentine course or meander pattern (Matthes 1941). The meander of a river across resistant bed rock or across previously deposited flood plain materials gives a usually slow changing but nevertheless dynamic aspect to flood plain communities.

Samples of river bank, field, and marsh soils taken at Raritan Landing show remarkable differences in composition upon mechanical analysis (Fig. 2). These differences reflect the dynamics of deposition during floods.

Certain soils of the flood plains of the Raritan River are mapped as a Bermudian silt loam (Patrick *et al.* 1923), a fertile, well-drained soil. A more recent survey shows the flood plain soil to be a catena

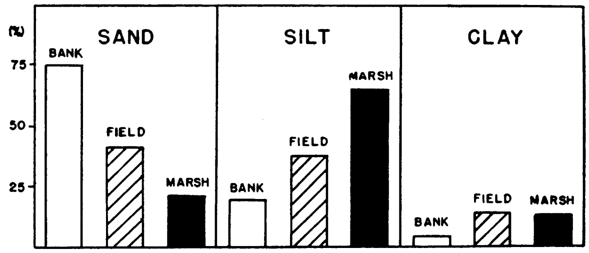


FIG. 2. Results of the mechanical analysis of soil sampled at 3 distances from the river at Raritan Landing: river bank 10 m, field 80 m, marsh 170 m. Each value is the average of 4 samples from the upper 10 cm at each location.

ranging through the well-drained Bermudian, imperfectly drained Rowland[2] and poorly drained Bowmansville[2] soil series. Although only at Raritan Landing was the soil studied intensely for this present study, observations at other places along the river showed similar variations. The large variety of geologic material from which this soil was derived and the differences in degree of flooding at various places along the river result in soils heterogeneous in composition.

The flood plain areas along the Raritan River have been mapped from aerial photographs (Fig. 3). The meander pattern of the river is irregular due to resistant red shale outcrops and glacial drift deposits which are encountered at various places along the river. This irregularity tends to make each flood plain area different in size from the next, as the height of the river banks and thus the intensity of flooding vary greatly.

The soil pit dug in a field at Raritan Landing shows in its vertical profile the development of the flood plain of the Raritan River at that point (Fig. 4). The ancient river bed encountered at the bottom of the pit was of rocks similar in size and shape to those of the present day river bed (Fig. 5). This would suggest that, at the point where the pit was dug (about 80 m from the edge of the river) the river used to flow at about the same rate as it does today. As the course of the river moved farther from this point, stream velocity decreased and first gravel, then sand, became deposited over the large river bed materials. When the deposit was built to a depth of about 2 ft, a thin layer of silt and clay was laid down. This indicates the possibility of a continued migration of the stream away from the site of the pit. The deposition of gravel and sand above this layer could mean that the stream meandered slightly back toward the site of the pit, or that the velocity of the stream increased, carrying coarser particles farther back on the then existing flood plain. Deposits lying on top of this sand and gravel show a decrease in sand and an increase in silt and clay to the surface of the present day flood plain. Occasional larger-sized pebbles in the

[2] Local names not officially correlated by the soil survey division of the U.S.D.A.

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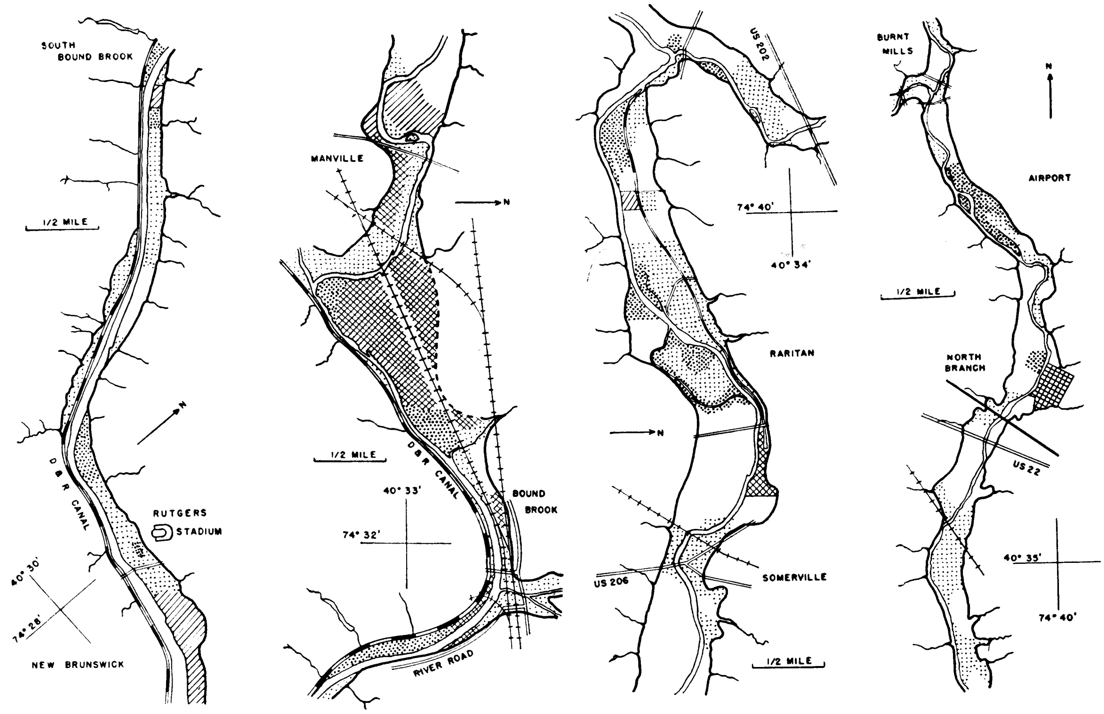


FIG. 3. The flood plain of the Raritan River between New Brunswick and Burnt Mills showing location of agricultural land (blank spaces), heavily wooded areas (heavy dots), sparsely wooded areas (light dots), industrial sites (cross hatching), and recreational areas (diagonal hatching). Mapping is continuous, progressing upstream from the lower left hand corner to the upper right.

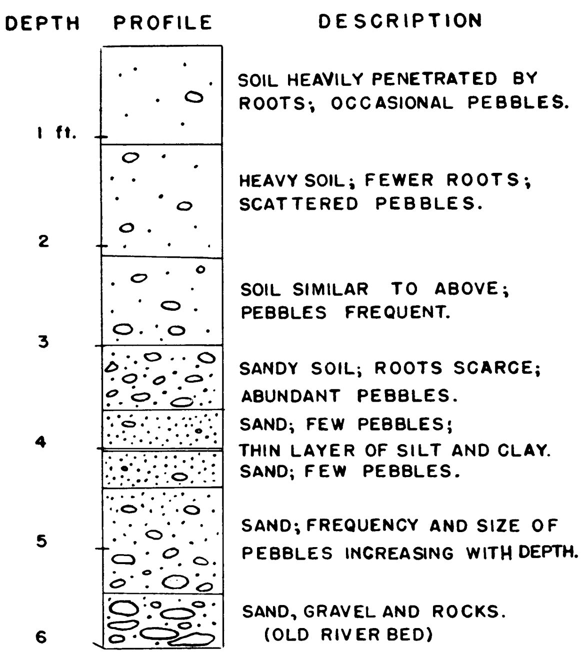


FIG. 4. Diagrammatic interpretation of soil profile 80 m from the river at Raritan Landing.

upper part of the profile may be the result of sporadic heavy floods.

At Raritan Landing the developmental history of the existing flood plain seems to be one of almost constant deposition as the river meandered in a southerly direction away from the resistant red shale outcrop upon which the Rutgers Stadium has been built. One period of meander reversal or of increased river velocity seems evident.

Vermeule (1894) indicated that a river discharge of 7,000 cu ft per sec (sec-ft) was considered a full bank stage at Bound Brook. By interpolation this is equal to a discharge of about 4,000 sec-ft at the Manville station which is 4.5 mi below the confluence of the North and South Branches. This station has the longest and most complete records of daily discharges. On the basis of Vermeule's statement, discharges over 4,000 sec-ft or their equivalent in gage height are considered floods.

Although the patterns of flooding, precipitation, and temperature show great irregularity from one year to the next, certain trends are evident (Fig. 6a). There were usually more days of flooding and longer periods of flooding prior to 1921. During that period many of the early yearly averages of temperature fall below 52°F which is the 1930 average. The total yearly precipitation was generally greater prior to 1921 than later. On the other hand the trend since 1921, even though slight, is toward higher temperature, lower rainfall, and fewer floods. Nevertheless, the yearly number of floods on the Raritan River is extremely variable and unpredictable, sometimes totalling 16, more frequently much less, and sometimes none.

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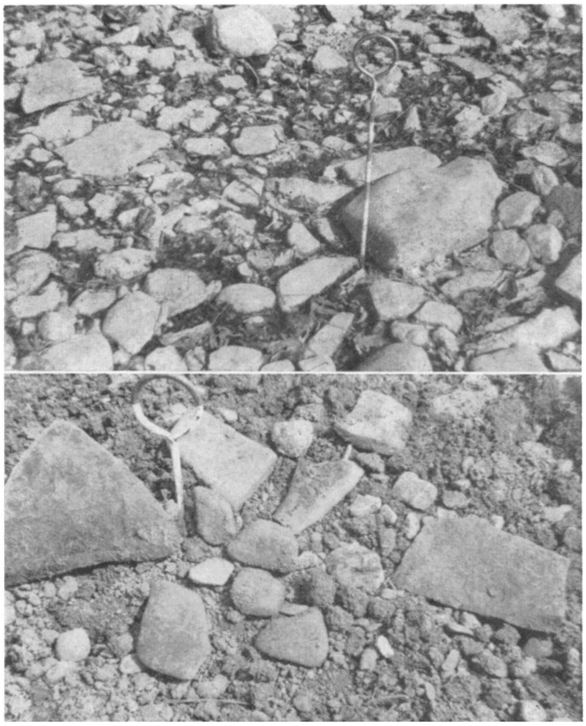

FIG. 5. The upper photograph shows the river bed of the present course of the Raritan River near Raritan Landing. The lower photograph shows material of an ancient river bed removed from the bottom of the soil pit on the natural levee at Raritan Landing.

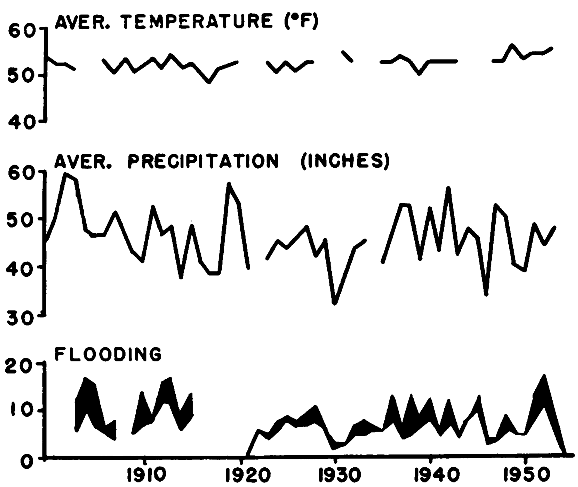


FIG. 6a. Temperature, precipitation, and flooding by year in the Raritan River Valley. The width of the darkened band in the curve for flooding indicates the intensity of flooding. The upper limit of the band represents the number of days of flooding; the lower limit, the number of floods for each year of record. When the band narrows to its thinnest width, floods were only one day in duration. Data from published and unpublished records at Trenton, N. J.

The seasonal distribution of floods (Fig.6b) on the Raritan River shows that the season with the greatest number of floods is not during the months with the highest average monthly precipitation (July and August, 4.8 in.). Rather, the number of days of flooding is at a maximum in March and the floods are often a few days in duration. This is undoubtedly the result of spring rains, sometimes on frozen soil and in some years with melting snow.

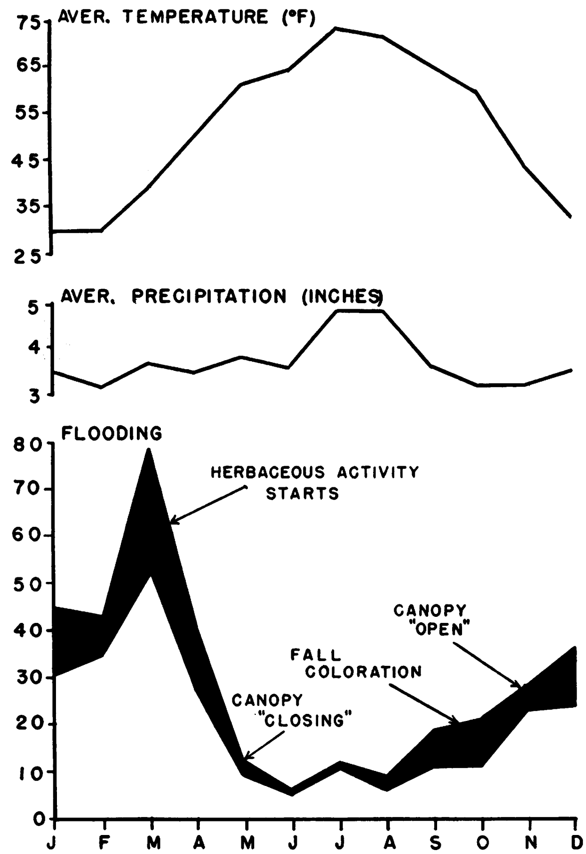


FIG. 6b. Temperature, precipitation, and flooding by month in the Raritan River Valley. The width of the darkened band in the curve for flooding indicates the intensity of flooding. The upper limit of the band represents the number of days of flooding; the lower, the number of floods for each month for the length of record, 1903 to 1955. For example, there were 80 days of flooding occurring in March since 1903 and during that time there were 51 floods. See Fig. 6a for source of data. Phenology from Cantlon (1953).

As the season progresses from spring to summer, there is a sharp drop in the number of floods to a yearly low in June and August. During this time less water is available for runoff, as much soil water is utilized by actively growing plants. In addition, there is an increase in the interception of rainfall by foliage as the tree canopy closes, which might average as much as 20%-30% in forested sections of a watershed (Kittredge 1948). Also higher temperatures increase the rate of water loss by evaporation. A reduction in the number of floods occurs, despite the fact that the average monthly precipitation is greater during the summer.

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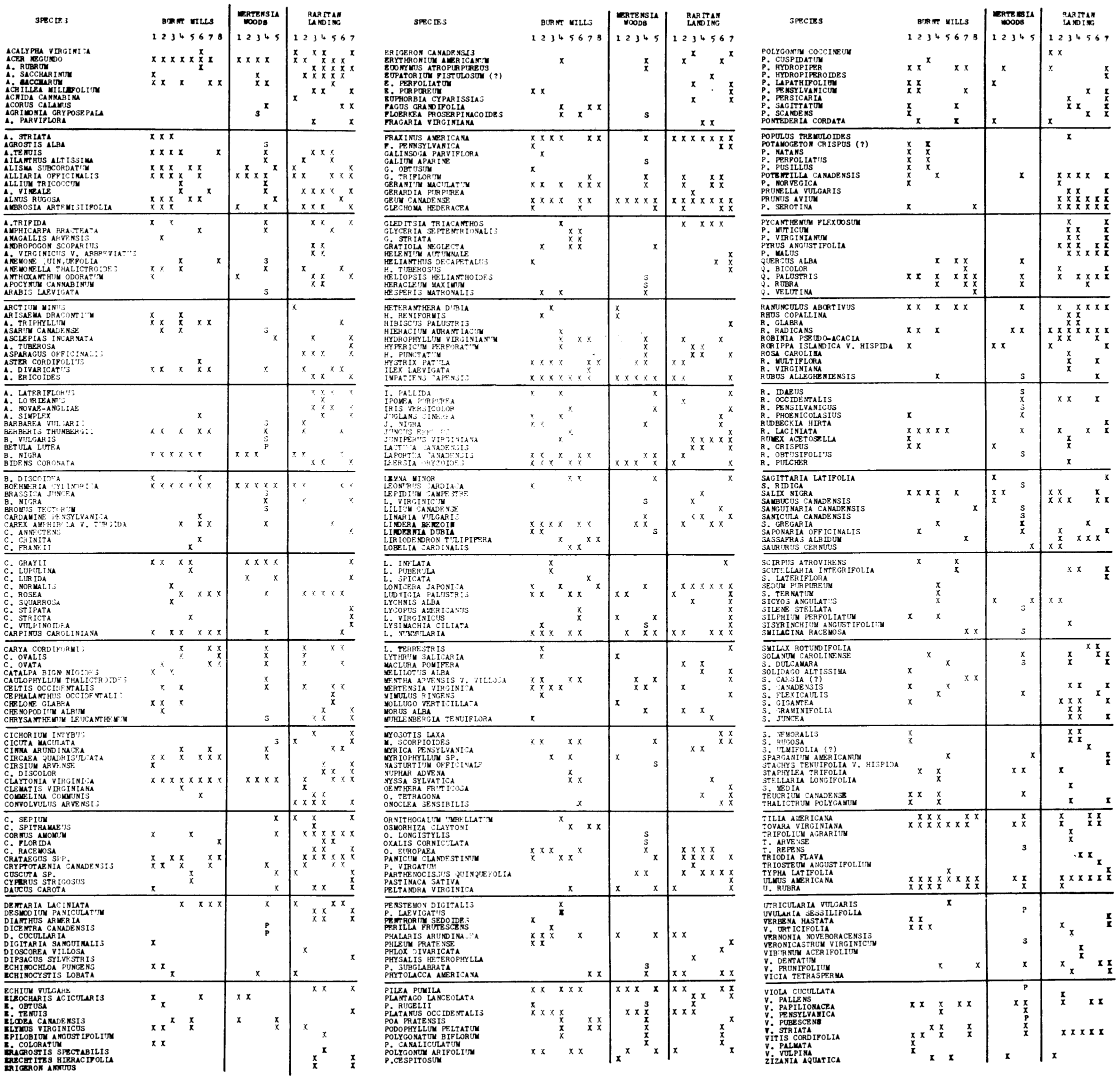


FIG. 7. General distribution of species according to habitat on 3 areas of detailed study, omission of species from any one habitat does not preclude its presence. Habitats and occurrence based on quadrat, transect, and reconnaissance data. Species marked S are from a species list contributed by Dr. J. A. Small of Douglass College; those marked P, by Dr. Grace A. Petersen of Brooklyn Institue of Arts and Science. Habitats for the Burnt Mills area are: 1—Island A, 2—Island B, 3—River banks, and river margins, 4—Outer flood plain, 5—Deep sloughs, 6—Shallow sloughs, 7—Inter-sloughs and 8—Terrace. Habitats for Mertensia Woods (Mertensia "island") are: 1—River bank, and river margins, 2—Sloughs near the river, 3—Inter-sloughs, 4—The Woods and 5—Deep slough behind the Woods. Habitats for Raritan Landing are: 1—Reed canary grass area, 2—Levee bank, 3—Youngest field, 4—Intermediate field, 5—Oldest field, 6—Fencerows and wooded areas and 7—Marsh area.

As fall approaches, the temperature decreases and the hurricane season usually brings heavy rain. Floods, therefore, increase and are longer in duration than those of the summer months. With the opening of the tree canopy in November and lower temperatures, the number of floods increases and they may last longer than one day. The winters are not uniformly cold in this area, so there are periods of thaw which also contribute to the number of winter floods.

Although the average pattern of flooding is a maximum in March and a minimum in June and August, the records show that flooding is very irregular and unpredictable. For example, major floods have been recorded for November 1810, July 1865, September 1882, and October 1903 (Vermeule 1894). A more recent record flood occurred in August 1955 following two successive hurricanes.

## FLORA

The species observed on the flood plain of the Raritan River are listed in Figure 7. It is not presumed that this list is all inclusive, but all species predominating in the vegetation are included as well

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as numerous others. Nomenclature follows that of Gray's Manual (8th ed. Fernald 1950). Voucher specimens have been deposited in the Chrysler Herbarium at Rutgers University.

One of the most important tree species in flood plain succession is ash. An attempt by the author to separate white ash (*Fraxinus americana*) from red ash or green ash (*F. pennsylvanica*) proved difficult if not impossible with young trees, saplings, and seedlings since fruits having one of the most reliable characters, were generally absent. Proper identification of these species often requires special techniques since there occurs within the genus ecotypic and genotypic variations (Wright 1944a, 1944b, Anderson 1949). The variation found at Raritan Landing made it necessary to lump the species together as *Fraxinus*. Some of the mature trees, however, were definitely identified as *Fraxinus americana* or *F. pennsylvanica*. *Fraxinus* regardless of species will be referred to as ash except where identification was reasonably certain.

## AREAS OF DETAILED STUDY

### Burnt Mills

The influence of slight differences in topography on flood plain vegetation is well illustrated near Burnt Mills (Fig. 3). The flood plain at this location was studied critically at several places: a well-developed flood plain with adjacent terrace, river banks of the erosional and depositional types, and two islands along the margin of the river (Fig. 8). The following account of these areas is based upon transect, quadrat and reconnaissance data.

#### THE FLOOD PLAIN AND TERRACE

Most of the uplands at the Burnt Mills location are or have been used agriculturally. However, below the Somerset Airport there is an especially wide area of woodland extending from the river well on to the upland. The presence of some multi-trunked trees and cattle fences in the woods suggest past cutting, followed by a period of pasturing. Nevertheless, some trees 100 ft tall and some with trunk diameters as great as 38 in. d.b.h. indicate that disturbance had not been severe nor had it been recent. The lower portion of the woods where occasional flooding occurs might generally be designated as a flood plain forest. When studied critically smaller plant communities become apparent.

Near the river there exists one such community, partly cut off from the mainland by a slough which is about 10 m wide and deep enough to retain water during periods of drought. This community will be referred to as the outer flood plain (Fig. 8). Inland from the slough there is a low area which has been dissected by an irregular pattern of shallow sloughs. The community occupying this area will be referred to as the inner flood plain community. Farther inland there is a terrace which is only about 110 m wide which floods on rare occasions, such as the flood of August 1955 (personal communication, M. F. Buell). The vegetational differences allow the recognition of a third community, the terrace community. These communities are the same as those studied for their woody species composition by Buell & Wistendahl (1955).

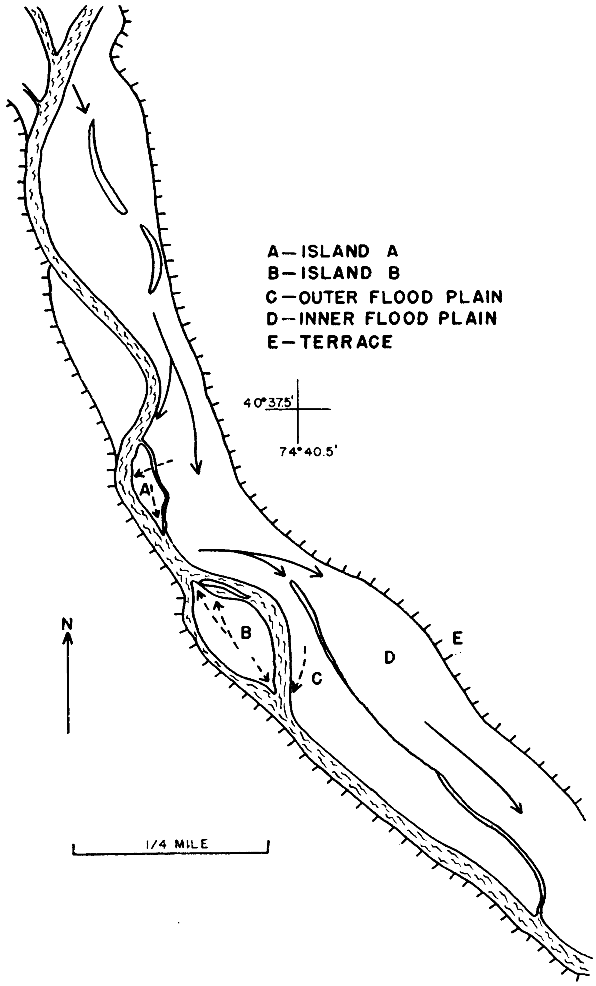


FIG. 8. Detail map of Burnt Mills area showing locations of study areas, the general flooding path in the inner flood plain, and the direction of island growth.

From quadrat and line intercept studies Buell & Wistendahl (1955) determined that the forest of the outer flood plain was heterogeneous in tree composition with beech (*Fagus grandifolia*), sugar maple (*Acer saccharum*), tuliptree, slippery elm (*Ulmus rubra*), and basswood (*Tilia americana*) contributing conspicuously to the data. The forest of the inner flood plain was composed of species of trees more characteristic of moist areas: elm, red maple (*Acer rubrum*) and others. The forest of the more mesic terrace suggested a trend toward maple-beech-basswood. In the present study, data from a line transect extending from the river to the upland show differences in the herb, shrub, and tree species composition in each of the three communities and in transitional areas between them.

Variation in species composition of the 3 plant

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communities was evident along the transect (Fig. 9). River birch *(Betula nigra)*, ironwood *(Carpinus caroliniana)*, slippery elm and boxelder *(Acer negundo)* appeared only on the outer flood plain, although away from the transect some individuals were found on the inner flood plain. Elsewhere along the edge of the river but not along the transect the same general pattern of tree distribution occurs, except for local dominance of beech or less frequently sycamore *(Platanus occidentalis)*. Several species—American elm, bitternut hickory *(Carya cordiformis)*, tuliptree, ash *(Fraxinus americana)*, and sugar maple were also on the outer flood plain.

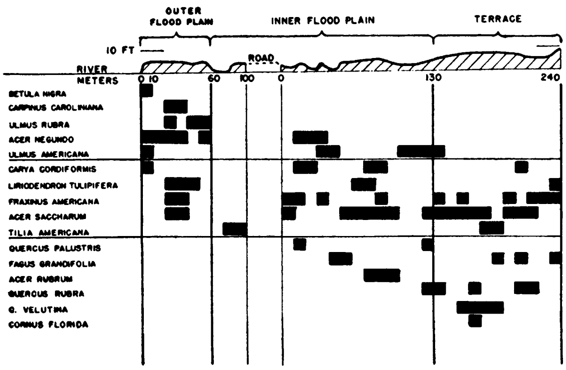


FIG. 9. Distribution of tree species along the transect line extending from the river to above the terrace at Burnt Mills area. Data based on presence of species within 10 m segments of transect. Vertical profile exaggerated about six times.

Throughout much of the inner flood plain there are series of shallow sloughs, most of which are more or less connected with each other forming a network of low areas. These areas vary in width and depth but are all the result of erosion. The species composition of the slough and interslough areas differ. In general, trees do not occur on the slough itself but occupy the interslough areas. Noticeable exceptions are boxelder and river birch which are occasionally in low areas. Trees, undercut by the erosion process, have fallen or are leaning over the sloughs. The general lack of trees in these wet areas has resulted in openings in the canopy. However, trees on the borders shade much of the slough areas.

The interslough areas of the inner flood plain varied greatly in width. One area through which the transect line passed, although only 2 or 3 m wide, supported mature trees. A red oak *(Quercus rubra)* 15.6 in. d.b.h. formed the obstruction which caused an erosion pattern that created two sloughs downstream from it, separated by an uneroded, wedge-shaped interslough below the tree (Fig. 10). Sugar maple, American elm, beech and a large white oak *(Quercus alba)*, 30.1 in. d.b.h., occurred on this interslough area in the vicinity of the transect line. Other interslough areas were much wider—up to 40 m. The vegetation of these wider areas was much more mesophytic and bore some similarity to that of

FIG. 10. Photograph of inner flood plain taken March 1955 looking "upstream." Wedge shaped interslough was formed by the deflection of flood water by red oak at the point.

the outer flood plain and the terrace. On the entire inner flood plain, including the sloughs and intersloughs, there were 17 tree species; 13 species occurred along the transect and among these were mature individuals of tuliptree, bitternut hickory, basswood, beech, elm, red maple, pin oak *(Quercus palustris)*, white oak and red oak.

On the terrace, the highest and best drained habitat, sugar maple, although not the largest tree, contributed the most cover. It also had the greatest tree density, sapling cover, and seedling density (Table 2, also Buell & Wistendahl 1955). Associated with the sugar maple were tree species which indicate a difference in conditions here as compared to the outer flood plain and the lower, wetter, inner flood plain. Black oak *(Quercus velutina)* for example, present only on the terrace, was quite abundant and attained sizes as great as 19.8 in. d.b.h. Red oak and flowering dogwood *(Cornus florida)* were also found in greater abundance than anywhere else. Missing were the boxelder, river birch, and occasional black gum *(Nyssa sylvatica)* of the lower areas.

Seven species of shrubs and lianas were present on the outer flood plain of which spicebush *(Lindera benzoin)* had the highest cover value along the transect. This species was also common on the inner flood plain. Saplings of sugar maple occupied the better drained interslough areas and contributed heavily to the shrub-sapling cover values. Over considerable stretches along the transect, shrubs were sparse especially on the terrace.

Slight undulations of topography on the outer flood plain influenced the distribution of the herbaceous species. Viola, *Alliaria officinalis*, and *Impatiens capensis* were abundant in the moist, shaded areas. *Aster divaricatus* was common on the higher ground. The outer flood plain had many species in common with the inner flood plain but few in common with the terrace.

The deep slough between the outer and inner flood plain is pond-like most of the year and has flowing water only during floods. The eroding action of floods has undercut trees on the inner or main-

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land bank exposing their roots and causing some trees to lean or fall across the slough. The bank on the outer flood plain side is less steep, as some soil from the outer flood plain has been washed into the slough. Both banks, except where erosion is severe, support a rich mixture of plants with large stands of *Impatiens capensis*, some heavily infested with Cuscuta, masses of *Boehmeria cylindrica, Pilea pumila, Panicum clandestinum* and *Myosotis scorpioides*. An occasional stand of *Lobelia cardinalis* adds color to the area. In the water one may find *Nuphar advena*, Myriophyllum, Potamogeton, and an almost complete cover of *Lemna minor*, depending upon the location and time of the year. The water is rich in algae.

Although 43 species of herbs were recorded along the transect which extended across the inner flood plain, and despite the fact that there are many more than that number in the area, single species often dominated parts of the sloughs. *Glyceria septentrionalis* and *G. striata* covered large areas in early summer, and in other parts of the same slough, *Myosotis scorpioides* grew in profusion. Other species which were conspicuous are listed in Figure 7.

As a result of the low terrain and the shading by trees, the slough areas remain moist for most of the year. Only during the dry summer months do some of them become free of standing water. In winter they are almost all wet and are often frozen over. The soil in the sloughs is rather heavy with clay and is mottled at a depth of 6 to 8 in. The herbaceous vegetation develops after the sloughs dry out; thus they become vegetated at a later date than the better drained places between them. A sodden layer of litter frequently covers large areas with little or no vegetation even as late as June. However, with the reduction in soil moisture during the summer months, the parts of these areas which receive adequate sunlight become covered with plant life, even though shaded portions remain sparsely vegetated.

The composition of the herbaceous layer on the terrace was very different from any of the other areas. Very few herbs were present in July. In early summer *Podophyllum peltatum* was common but by late June it had largely died back to the ground. There were only 19 species of herbs along the transect on the terrace as compared to 43 on the inner flood plain.

Between the terrace and the upland there was a low area which bore some similarity to the sloughs except that it was higher and above the flood level. The vegetation was very similar to that of the low sloughs but had a greater cover of herbs. *Glyceria septentrionalis* was dominant locally and there was an abundance of mosses.

In the present study data for early summer herbaceous species (Table 1) and tree seedlings (Table 2) were obtained from quadrats during the period May 28 to June 10, 1954. Two months later, August 27 to September 4, the late summer herbaceous growth and the changes that had occurred during the intervening months were recorded.

There were 63 species of herbs recorded on quadrats at the three locations during the entire summer. More kinds of herbs were present on the outer flood plain and on the inner flood plain than on the terrace. The amount of herbaceous cover was greater in early summer than in late summer at each of the 3 locations. *Mertensia virginica*, which was dying back at the time the early summer data were obtained, had the highest cover value, 7% on the outer flood plain. *Impatiens capensis* had the highest cover value, 33% on the inner flood plain and *Podophyllum peltatum* the highest, 53%, on the terrace. By late summer the species composition had changed resulting in a striking difference in the percentage of cover of the various species. On the outer flood plain Mertensia was no longer in the active state of growth and *Aster divaricatus* had the highest cover value, 9%. *Leersia oryzoides* and *Boehmeria cylindrica* contributed the most cover on the inner flood plain with 13% and 9% cover respectively. No single herb species had a cover value greater than 1% on the terrace; however, sugar maple seedlings grew in profusion and covered most of the ground.

Differences in the number and kinds of tree seedlings were found in each of the 3 communities (Table 2). On the outer flood plain in early summer there were only 24 seedlings per 40 sq m; whereas, on the terrace there were 423 seedlings for the same area. Correspondingly, only 2 species of seedlings were present on the outer flood plain quadrats and 9 were found on the terrace quadrats. Sugar maple seedlings were most abundant in these 2 communities. They occurred with 79% frequency on the terrace but only 20% on the outer flood plain. On the inner flood plain seedlings of boxelder were the most numerous.

Data obtained in late summer from the same communities indicated an increase in the number and species of seedlings (Table 2). Three more species appeared on the outer flood plain, and the total number of tree species as seedlings increased from 24 to 31. On the terrace the same number of species were present as in the early summer, but there was an increase in the total seedling count. Red maple and tuliptree seedlings were abundant on the inner flood plain where they had been absent in early summer.

### RIVER BANKS

There are two kinds of river banks at Burnt Mills: (1) those where transported materials are being deposited and (2) those where the eroding action of the river has undercut the banks. Where deposition occurred, the soil is gravelly with an intermixture of sand and little silt. These areas are immediately and often deeply inundated during floods but during dry periods are exposed and have a rich cover of herbaceous plants. Tree species on the areas of deposition are sycamore, river birch, boxelder, American elm, and slippery elm. Shrubs are not very common on the

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TABLE 1. Percent cover (C) and % frequency (F) of herbaceous species on quadrats at three locations—outer flood plain (OFP), inner flood plain (IFP), and terrace (Ter.)—in the Burnt Mills area and in Mertensia Woods during early and late summer. D—Density, F—Frequency, X—cover values less than 1%.

| | Burnt Mills | | | | | | | | | | | | Mertensia | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Early Summer | | | | | | Late Summer | | | | | | E. Sum. | | L. Sum. | |
| | OFP | | IFP | | Ter. | | OFP | | IFP | | Ter. | | Woods | | Woods | |
| | % C | % F | % C | % F | % C | % F | % C | % F | % C | % F | % C | % F | % C | % F | % C | % F |
| *Acalypha virginica* | | | | | | | | | X | 8 | | | | | | |
| *Agrostis tenuis* | | | | | | | | | | | X | 3 | | | | |
| *Alliaria officinalis* | 3 | 60 | | | | | 3 | 48 | | | | | | | | |
| *Allium tricoccum* | | | | | X | 3 | X | 3 | | | | | 1 | 60 | 1 | 48 |
| *A. vineale* | X | 28 | X | 15 | | | | | | | | | X | 10 | | |
| *Amphicarpa bracteata* | | | X | 8 | | | | | X | 13 | | | | | | |
| *Arisaema triphyllum* | 1 | 5 | 2 | 50 | X | 10 | X | 5 | | | | | X | 5 | | |
| *Asarum canadense* | | | | | | | X | 3 | | | | | | | | |
| *Aster divaricatus* | 6 | 63 | 2 | 23 | X | 3 | 9 | 73 | 1 | 23 | X | 3 | | | | |
| *A. simplex* | | | | | | | | | X | 5 | | | | | | |
| *Boehmeria cylindrica* | | | 1 | 8 | | | | | 9 | 25 | | | | | | |
| *Carex amphibola* | X | 20 | 1 | 25 | X | 3 | X | 10 | 1 | 8 | X | 5 | | | X | 3 |
| *C. grayii* | X | 3 | X | 8 | | | X | 10 | 1 | 25 | X | 3 | | | X | 8 |
| *C. lupulina* | | | 2 | 13 | | | | | | | | | | | | |
| *C. rosea* | X | 5 | X | 8 | X | 13 | | | 1 | 28 | X | 5 | X | 3 | X | 8 |
| *Caulophyllum thalictroides* | | | | | | | | | | | | | 10 | 25 | 2 | 10 |
| *Cinna arundinacea* | | | | | | | X | 23 | X | 8 | | | | | X | 10 |
| *Circaea quadrisulcata* | X | 5 | 4 | 25 | 6 | 48 | 1 | 13 | 1 | 25 | X | 43 | | | | |
| *Commelina communis* | | | | | | | | | X | 3 | | | | | | |
| *Cryptotaenia canadensis* | X | 8 | X | 3 | | | X | 3 | X | 3 | | | X | 13 | X | 3 |
| *Dentaria laciniata* | X | 10 | X | 3 | X | 3 | | | | | | | X | 5 | | |
| *Echinocystis lobata* | | | | | | | | | | | | | | | X | 3 |
| *Floerkea proserpinacoides* | X | 3 | | | | | | | | | | | | | | |
| *Galium* sp. | X | 3 | X | 3 | X | 3 | | | X | 3 | X | 3 | X | 15 | | |
| *Geranium maculatum* | 1 | 33 | | | X | 13 | X | 20 | | | | | | | | |
| *Geum canadense* | X | 8 | 1 | 28 | | | X | 25 | X | 25 | | | X | 3 | X | 15 |
| *Glyceria septentrionalis* | | | | | | | | | X | 5 | | | | | | |
| *G. striata* | | | 1 | 3 | | | X | 3 | X | 5 | | | | | | |
| *Hydrophyllum virginianum* | 2 | 43 | X | 3 | | | X | 13 | | | | | 11 | 72 | 5 | 80 |
| *Hystrix patula* | | | | | X | 3 | | | | | | | | | | |
| *Impatiens capensis* | 3 | 43 | 33 | 83 | 2 | 40 | | | | | | | 1 | 26 | | |
| *Laportea canadensis* | X | 8 | X | 3 | | | X | 8 | X | 3 | | | 42 | 88 | 27 | 78 |
| *Leersia oryzoides* | | | | | | | X | 3 | 13 | 63 | | | X | 6 | X | 3 |
| *Lycopus virginicus* | | | X | 15 | | | | | 1 | 10 | | | | | | |
| *Lysimachia nummularia* | | | 2 | 23 | | | | | | | | | | | | |
| *Mertensia virginica* | 7 | 83 | | | | | | | | | | | | | | |
| *Myosotis scorpioides* | | | | | | | X | 3 | | | | | | | | |
| *Osmorhiza claytoni* | X | 3 | X | 3 | X | 3 | | | | | | | | | | |
| *Oxalis* sp. | X | 3 | X | 3 | X | 3 | X | 3 | X | 3 | | | | | | |
| *Panicum clandestinum* | X | 3 | | | | | X | 3 | | | | | | | | |
| *Pilea pumila* | | | | | | | X | 3 | 1 | 28 | | | | | | |
| *Poa pratensis* | X | 5 | X | 13 | X | 28 | | | X | 3 | X | 28 | X | 13 | X | 3 |
| *Podophyllum peltatum* | 4 | 23 | 8 | 35 | 53 | 100 | | | | | | | 1 | 8 | | |
| *Polygonatum biflorum* | X | 10 | | | | | | | X | 3 | | | X | 13 | | |
| *P. canaliculatum* | | | | | | | | | | | | | X | 3 | | |
| *Polygonum arifolium* | | | | | | | | | X | 3 | | | | | | |
| *P. hydropiper* | | | X | 3 | | | | | X | 20 | | | | | | |
| *P. pensylvanicum* | | | X | 10 | | | | | X | 25 | | | | | | |
| *P. sagittatum* | | | X | 3 | | | | | X | 3 | | | | | | |
| *Potentilla canadensis* | X | 3 | X | 3 | | | X | 3 | X | 8 | | | | | | |
| *Ranunculus abortivus* | X | 3 | X | 5 | | | | | | | | | | | | |
| *Rudbeckia laciniata* | | | | | | | X | 3 | | | | | | | | |
| *Sanguinaria canadensis* | | | | | X | 20 | | | | | | | X | 3 | | |
| *Sanicula gregaria* | X | 10 | | | | | | | | | | | 1 | 25 | X | 13 |
| *Scutellaria lateriflora* | | | | | | | | | X | 8 | | | | | | |
| *Sicyos angulatus* | | | | | | | X | 3 | | | | | | | | |
| *Smilacina racemosa* | | | X | 3 | X | 3 | | | | | X | 3 | | | | |
| *Solidago caesia* (?) | | | X | 10 | X | 3 | | | | | | | | | | |
| *S. flexicaulis* | X | 5 | | | | | 1 | 15 | | | | | 5 | 52 | 5 | 45 |
| *S. rugosa* | | | | | | | X | 3 | | | X | 5 | | | | |
| *Thalictrum* sp. | | | | | | | X | 3 | | | | | | | | |
| *Tovara virginiana* | 1 | 15 | | | | | 1 | 28 | X | 10 | | | 1 | 15 | 2 | 18 |
| *Viola* spp. | 4 | 53 | 1 | 13 | 1 | 48 | 2 | 48 | X | 3 | | | 3 | 40 | 3 | 30 |
| *Botrychium* sp. | | | | | | | | | | | X | 3 | | | | |

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TABLE 1. (Continued)

| | Burnt Mills | | | | | | | | | | | | Mertensia | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Early Summer | | | | | | Late Summer | | | | | | E. Sum. | | L. Sum. | |
| | OFP | | IFP | | Ter. | | OFP | | IFP | | Ter. | | Woods | | Woods | |
| | % C | % F | % C | % F | % C | % F | % C | % F | % C | % F | % C | % F | % C | % F | % C | % F |
| Mosses | 1 | 25 | 1 | 30 | X | 3 | X | 30 | X | 28 | X | 3 | 2 | 35 | 1 | 25 |
| Logs | 5 | 35 | 4 | 25 | 1 | 13 | 3 | 15 | 2 | 18 | 2 | 23 | 2 | 8 | 1 | 25 |
| Litter cover | 77 | 100 | 98 | 100 | 95 | 100 | 59 | 100 | 77 | 100 | 86 | 100 | 57 | 100 | 19 | 98 |
| Litter depth (cm) | 1.8 | | 1.8 | | 2.2 | | 1.1 | | 1.2 | | 1.4 | | 0.9 | | 0.5 | |
| SPACE | 58 | 100 | 45 | 98 | 29 | 100 | 82 | 100 | 68 | 95 | 97 | 100 | 26 | 75 | 53 | 100 |

TABLE 2. Number of tree seedlings on 40 quadrats (0.5 x 2 m) on 3 locations—outer flood plain (OFP), inner flood plain (IFP), and terrace (Ter.)—in the Burnt Mills area and in Mertensia Woods during early and late summer. D—Density, F—Frequency.

| | Burnt Mills | | | | | | | | | | | | Mertensia | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Early Summer | | | | | | Late Summer | | | | | | E. Sum. | | L. Sum. | |
| | OFP | | IFP | | Ter. | | OFP | | IFP | | Ter. | | Woods | | Woods | |
| | % D | % F | % D | % F | % D | % F | % D | % F | % D | % F | % D | % F | % D | % F | % D | % F |
| *Acer saccharum* | 19 | 20 | 3 | 8 | 358 | 77 | 18 | 15 | 2 | 5 | 410 | 70 | 13 | 15 | 6 | 10 |
| *A. negundo* | 5 | 8 | 8 | 8 | 13 | 25 | 5 | 10 | 12 | 15 | 8 | 18 | | | | |
| *Carya cordiformis* | | | 3 | 8 | 7 | 18 | 2 | 5 | 4 | 10 | 8 | 18 | | | | |
| *Cornus florida* | | | 1 | 3 | 7 | 5 | | | | | 1 | 3 | | | | |
| *Fraxinus americana* | | | 2 | 5 | | | 5 | 8 | 1 | 3 | 2 | 5 | | | | |
| *Quercus palustris* | | | 2 | 5 | | | | | 1 | 3 | | | | | | |
| *Ulmus americana* | | | | | 33 | 33 | 1 | 3 | | | 32 | 33 | | | 1 | 3 |
| *Prunus serotina* | | | | | 2 | 3 | | | | | | | | | | |
| *Quercus velutina* | | | | | 1 | 3 | | | | | 3 | 8 | | | | |
| *Q. rubra* | | | | | 1 | 3 | | | | | 2 | 10 | | | | |
| *Carpinus caroliniana* | | | | | 1 | 3 | | | | | | | | | | |
| *Crataegus* sp. | | | | | | | | | 2 | 5 | | | | | | |
| *Acer rubrum* | | | | | | | | | 19 | 10 | | | | | | |
| *Liriodendron tulipifera* | | | | | | | | | 13 | 8 | | | | | | |
| *Tilia americana* (sprouts) | | | | | | | | | | | 2 | 3 | | | | |
| Number of species | 2 | | 6 | | 9 | | 5 | | 8 | | 9 | | 1 | | 2 | |
| Total seedlings | 24 | | 19 | | 423 | | 31 | | 64 | | 466 | | 13 | | 7 | |

newly deposited areas. Spice bush is one of the first to appear, but only after trees have grown enough to produce some shade.

There was no clear evidence of vegetational zonation on these usually small areas of deposition, but a change was evident in the vegetation from the river inward. On the edge of the river the trees were younger than those farther in. River birch and sycamore commonly formed clusters of young sprouts near the water. Shrubs and seedlings were usually absent, but during the summer months there was a profusion of herbs. Growing in the shallow water at the edge of the banks were *Elodea canadensis, Ludwigia palustris, Lindernia dubia,* and occasionally some Potamogeton. On the very edge of the water, masses of *Polygonum hydropiper* were very common. Many species of *Polygonum* were found on these areas of deposition including: *P. pensylvanicum, P. coccineum, P. sagittatum, P. scandens, P. lapathifolium, P. arifolium* as well as *Tovara virginiana.* In addition, 32 other herbs were found on one area of deposition which was about 100 sq m in size. Of these *Pilea pumila, Poa pratensis, Verbena urticifolia, Oxalis europaea, Panicum clandestinum, Carex stricta,* and *Impatiens capensis* were abundant.

## ISLAND

One of the largest islands in the Burnt Mills area (island B, Fig. 8), 380 m long, was studied by means of transect and reconnaissance. Data along a single transect which extended the full length of the island were obtained during the period July 7th to July 20th, 1954. This island had been greatly disturbed in the central part where, at the time of sampling, soil was being trucked out. In summer, when river flow was low, there was little or no water flowing over the 10 to 20 m wide river bed of red shale which lies along the western side of the island. The main course of the river lies on the eastern side of the island and flows over a bed of coarse gravel. Topo-

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graphically the island was highest near the center (about 4-5 ft above the river) and more or less low and wet near the margins. The upper end of the island from the beginning of the transect to 110 m was low, uneven and subjected to most frequent flooding (Fig. 11). The middle portion of the transect extended from 110 m to 240 m and traversed the high central section of the island which was level and infrequently flooded. The last section of the transect from 240 m to 380 m traversed the lower part of the island whose surface was uneven. This section was lower than the middle but not as low as the upper end. The lower tip of the island, the last 4 m, was a sandy point exposed only during low water. Dense vegetation, especially the herb layer, covered the island.

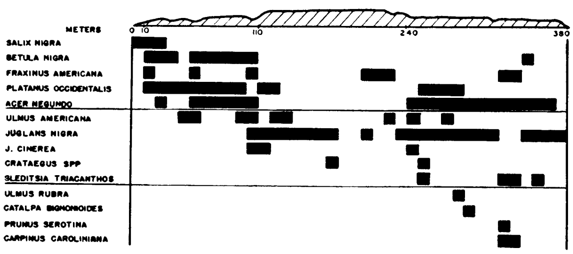


FIG. 11. Distribution of tree species along a single transect line extending the full length of an island, island B, in the Burnt Mills area (Fig. 8). The transect starts at the upstream end of the island at 0 meters. Data based on the presence of species within 10 m segments of transect. Vertical profile exaggerated.

From the upper to the lower end of the transect there was a transition in the saplings and trees (Fig. 11). The surface for the first 110 m gradually increased from water level to a height of about 1 m above the river. In this section there were many sloughs and a large accumulation of logs and flood debris. Black willow *(Salix nigra)* saplings were numerous as a result of sprout growth and were the first woody plants along the transect and only along the first 30 m. River birch first appeared along the second 10 m segment of the line and was the first tree species with stem diameters greater than 1 in. d.b.h. This species was represented on the transect for a distance of 110 m. Stem diameters increased along the transect from 2.2 in. at about 20 m to 11.8 in. at about 70 m, after which most stems were greater than 6 in. Associated with the river birch were several other species, predominantly sycamore, forming masses of sprout growth with stems mostly over 1 in. d.b.h. This species occurred as far as 130 m from the upper end and in places completely shaded the ground. A tree with a d.b.h. of 21.5 in. was encountered about 120 m from the upper end, while the first one at about 30 m was only 1.8 in. d.b.h. Boxelder, mostly as saplings or sprouts, was also represented at the upper end; its greatest contribution to cover being between 50 and 110 m from the end of the island. Other trees present on the first 110 m were ash, American elm, silver maple *(Acer saccharinum)*, black walnut *(Juglans nigra)*, and butternut *(J. cinerea)*. The latter two species were only on higher ground and were the most important trees on the higher central area. Silver maple was not as common as were elm and ash, which were general throughout the island.

Although the sprout growth of willow, river birch, sycamore, and boxelder gave a shrubby appearance to the upper end of the island, few shrubs or lianas were present. Only speckled alder *(Alnus rugosa)*, silky dogwood *(Cornus amomum)*, and poison ivy *(Rhus radicans)* were found along that part of the transect.

Herbs were very abundant on the island, and 84 species were identified along the entire 380 m of the transect (Fig. 7). Unoccupied space rarely amounted to 70% along the line except where there was an accumulation of flood deposited debris or where there were sloughs too wet to support vegetation. During periods of low river flow, herbs were present on the exposed gravelly river bed on the upper end of the island. Herb cover there was not complete but was represented by a large number of rather widely spaced individuals. The species that were on the open, gravelly bed at the upper end of the island made up most of the herbaceous vegetation for the first 110 m of transect. After that distance the topography rose rather abruptly from a slough to the high central portion.

The tree cover of the central area was rather open. One 30 m section of the transect had no tree cover at all. Black walnut and butternut were common, although many other species were present, including elm, ash, shagbark hickory *(Carya ovata)*, and hawthorn *(Crataegus)*. Although shrubs and lianas were more common on this middle portion of the island, they were not frequent and consisted mostly of blackberry *(Rubus)* and grape *(Vitis)*. The herbs *Alliaria officinalis* and *Impatiens capensis* were extensive on the slope from the low area. On the higher central ground goldenrods of several species were frequently dominant with an underlying cover of grasses and sedges, particularly *Agrostis tenuis* and *Carex rosea*. Locally along the line *Panicum clandestinum, Teucrium canadense, Lysimachia nummularia, Helianthus decapetalus, Silphium perfoliatum, Geum canadense, Glechoma hederacea,* and *Laportea canadensis* were abundant.

The lower end of the island had more kinds of trees than the upper end; boxelder was one of the most abundant. River birch and sycamore were represented on the lower end but only near sloughs. Hawthorn, slippery elm, catalpa *(Catalpa bignonioides)*, black cherry *(Prunus serotina)*, and ironwood were also present. On the lower end shrubs and lianas were more abundant. Spicebush and blackberry were most frequent and were dense locally. Found occasionally were grape, honeysuckle *(Lonicera japonica)*, and elderberry *(Sambucus canadensis)*. On the lower end of the island where tree, sapling, and shrub cover was greatest, there was least

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herbaceous cover. The extreme lower end of the island dropped off suddenly where at low water a low, sandy point extended 4 m to the river. Here *Teucrium canadense* and *Verbena urticifolia* gave way to *Leersia oryzoides* dominance at the edge of the water.

Although trees were rather small on the island, mostly 6 to 8 in. d.b.h., one sycamore on the lower end measured 55.0 in. d.b.h. The largest American elm was 25.6 in. d.b.h.; white ash, 29.1 in. d.b.h. Seedlings were rare, and only 3 species were encountered at sampling places along the transect, boxelder, silver maple, and pin oak, with totals of 3, 12, and 1 respectively.

Upstream from island B there was another rather large island, island A, which was about 250 m long and 50 m wide (Fig. 8). Diameter measurements of several of the largest of the most common trees near the center of the island showed the following: pin oak, 27.2, 28.2; shagbark hickory, 19.7, 18.5, 15.4; white ash, 17.5, 17.0; hackberry, 23.5, 10.9; boxelder, 13.8; American elm, 12.2; slippery elm, 5.0 in. These were the most important species, which formed an almost completely closed canopy. They varied greatly in size. Few saplings were evident except for those of boxelder which grew in abundance, especially along the edges of the island and along sloughs. The shrub layer consisted largely of spicebush, which covered about 50% or more of the island. Some bladdernut *(Staphylea trifolia)* and barberry *(Berberis thunbergii)* were also present in minor amounts. On the periphery of the island, especially on the upper end, poison ivy was profuse. Species found in sloughs and other habitats in the Burnt Mills area are listed in Figure 7.

## MERTENSIA WOODS

On the rather extensive flood plain below the confluence of the North and South Branches of the Raritan River, there is a small but relatively undisturbed wooded area which physiographically is similar to the outer flood plain at the Burnt Mills study area (Fig. 12). It is partially cut off from the main part of the flood plain by a deep slough and has been referred to by local botanists as Mertensia "island" because of the profusion of *Mertensia virginica*. It is referred to as Mertensia Woods in this paper. This area was the subject of detailed study using quadrat and transect methods similar to those of the Burnt Mills studies.

A detailed study of the woody species of this area was made by Buell & Wistendahl (1955). Eleven tree species were found along cover transects and of these slippery elm and hackberry were the dominants. About 10% unoccupied space occurred in the tree canopy. Diameters at breast height of some of the largest trees were: slippery elm 34.2, 17.5, 15.6; hackberry 40.8, 28.0, 27.0; black walnut 34.9, 20.0, 17.0; and ash 22.7, 20.0, 16.5 in. Few large sugar maple, pin oak, and shagbark hickory trees occurred on this area. Although trees were of various sizes.

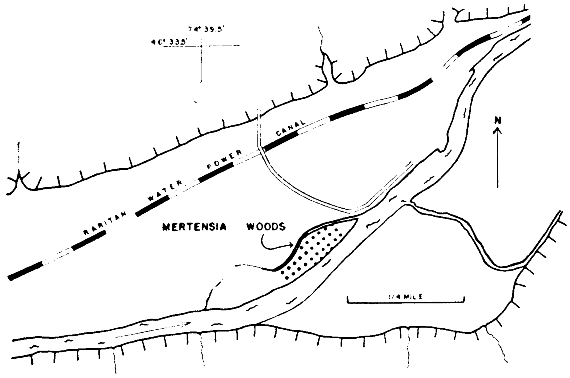


FIG. 12. Map of flood plain near Raritan, N. J., showing location of Mertensia Woods in which detail studies (dotted area) were made. This is location "B" on Fig. 1.

saplings were not abundant. At the sapling-shrub level bladdernut and spicebush were the dominant shrubs and in places formed an almost completely closed layer.

The species forming the herb cover in early summer, June 15, 1954, and in late summer, September 8, 1954, are presented in Table 1. The June date was too late to record any of the typical spring flowering plants, such as *Mertensia virginica, Claytonia virginica,* and Viola, which were present in early May. Differences in the herbaceous cover between seasons were not as striking at Mertensia Woods as at Burnt Mills—22 species of herbs in early summer and only 17 in late summer. Six species had cover values greater than 1% in early summer—*Laportea canadensis* 42%, *Hydrophyllum virginianum* 11%, *Caulophyllum thalictroides* 10%, *Solidago flexicaulis* 5%, and Viola 3%. The cover values for the first 3 species decreased by late summer to 27, 5, and 2% respectively. The last two species had no change in cover. *Tovara virginiana,* which had only 1% cover in early summer, was the only species to show an increase in value by late summer. None of these 6 species was missing at the late summer date. The amount of unoccupied space in the herb layer for late summer amounted to 53%, which was about twice the value of early summer.

There was no noticeable tree reproduction in the well developed part of the woods, although quadrat studies in early summer showed 13 boxelder seedlings on 40 sq m (15% frequency). In late summer only 6 boxelder seedlings and one American elm seedling were recorded on the quadrats. This general paucity of seedlings also characterized the outer flood plain at Burnt Mills.

Litter covered 57% of the ground in early summer. By late summer the value had decreased to 19%. Somewhat comparable figures were obtained on the outer flood plain at Burnt Mills (Table 1). This decrease occurred in spite of the fact that no flooding of the area took place between sampling dates.

A transect from the edge of the river across the woods showed a striking transition in the topography

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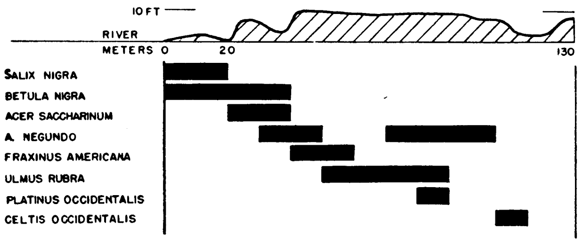


FIG. 13. Distribution of species along a single transect extending from the river across the natural levee or outer flood plain which is occupied by Mertensia Woods. Data based on presence of specimens within 10 m segments of the transect. Vertical profile exaggerated about 3 times. Horizontal distance is given in meters, vertical in feet.

and the associated vegetation (Fig. 13). Starting at the river, the first trees were black willow, which formed a dense cover on a small sandy deposit. The next trees were river birch. On a larger and higher sand bar farther in from the river silver maple assumed dominance and overtopped the smaller river birch. Continuing in from the river, boxelder and ash became important, and willow, river birch, and silver maple successively lost dominance.

Along the transect, shrubs were sparse for the first 30 m from the river. After that, spicebush formed a dense cover. Occasionally bladdernut was found in abundance. Small amounts of poison ivy and Virginia creeper (*Parthenocissus quinquefolia*) were present.

Herbs were variously distributed along the transect. At the edge of the river there were 19 species with Polygonum contributing the most cover. Herbs were under the dense cover of willows, but were more important in and around the sloughs between the low sand bars. The first slough encountered was predominantly covered with *Phalaris arundinacea*. *Ludwigia palustris* occupied much of the wetter spots. In the second slough *Carex grayii*, Viola, *Impatiens capensis*, and *Geum canadense* were common. From the second slough back across the woods *Laportea canadensis* was dominant (50% cover). Viola, *Alliaria officinalis*, and *Impatiens capensis* were less abundant, along with several other species. The deep slough behind the woods had almost 100% herb cover of which *Phalaris arundinacea*, *Polygonum arifolium*, *Peltandra virginica*, *Impatiens capensis*, *I. pallida*, *Hystrix patula*, *Myosotis scorpioides*, *Sparganium americanum*, Cuscuta, *Laportea canadensis*, and *Geum canadense* were most conspicuous. Additional species for all these areas are listed in Figure 7.

## DISCUSSION OF BURNT MILLS AND MERTENSIA WOODS AREAS

Detailed studies of the vegetation in the Burnt Mills and Mertensia Woods areas show that slight differences in topography and flooding effects have a marked influence on vegetation, and that flood plain dynamics can be interpreted from the topography and vegetation. River banks, islands, sloughs, and vegetation are all useful in interpreting the changes that are taking place in the course of the river.

Old meander patterns are especially discernible on air photos of the Burnt Mills area, and it is likely that flood plain formation and destruction throughout the river system has occurred many times in the past. The present vegetation where it is best developed reflects not only the potentialities of the mature forest but also shows the general pattern of construction and destruction of the river flood plain.

The topography and the vegetation of island A at Burnt Mills show that there is a tendency for this island to build out toward the main channel of the river and that the slough on the east side of the island is filling up (Fig. 8.) Downstream, island B, on the other hand, is building at its upper end and toward the main channel where small subsidiary islands have developed. The upstream migration of island B will probably not be great, as the usual tendency is for islands and meander patterns to move downstream (Cowles 1901, Turner 1931, Matthes 1941). Braun (1916) found islands near the margin of the Little Miami River in Ohio which seemed to be growing toward the main channel rather than downstream. Both islands, A and B, at Burnt Mills showed somewhat similar development, although the small adjacent islands showed the characteristic downstream growth Island B will continue to grow toward the main channel as long as the river meanders farther to the east at that point. The eastward meander is also made evident by active undercutting of the outer flood plain across from island B. Further evidence of eastward meander is found on the inner flood plain (Fig. 8, D). Here single erosion sloughs are often divided into two by mature trees which have prevented erosion below them (Fig. 10). The severity of erosion on the inner flood plain as compared with the outer flood plain indicates that at times of major floods much of the force of the river is diverted by the meander into this inner flood plain.

The well developed forests of the Burnt Mills and Mertensia Woods flood plains are indicative of the mesophytic forests that probably once occupied much of the natural levees along the Raritan River and which could possibly once again exist if allowed to develop fully (Buell & Wistendahl 1955). The development of mesophytic forests on flood plains has been described by Cowles (1901), Nichols (1916), Braun (1916), and others for other flood plains in the deciduous forest regions. The successional trend is toward mesophytic conditions, which may later be destroyed by the meandering river. Mertensia Woods, like that on the outer flood plain at Burnt Mills, is composed of mature trees of a mixture of species. Deposition is active in Mertensia Woods and the forest will tend to occupy a wider area as the sand bars adjacent to it become more mesic. On the other hand, the outer flood plain at Burnt Mills is being eroded away and some of the magnificent trees now occupying that area stand close to the undercut

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river bank. That the two areas are not identical in their tree composition is not surprising, considering the differences in location, use, and stream action.

### RARITAN LANDING

The section of the flood plain extending about 1 mi. upstream from Landing Lane (Fig. 14), subjected in the past to various land uses, now supports a variety of plant communities. With its natural

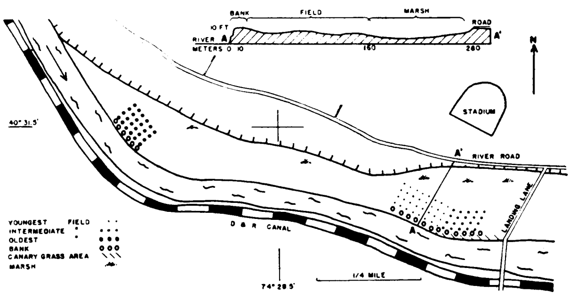


FIG. 14. Map of Raritan Landing area showing location of study areas. Vertical scale of profile A—A′ exaggerated 6 times.

levee next to the river and marshland behind, the flood plain presents striking soil variations (Fig. 2). Of all the flood plain sites, the margin of the levee nearest the river has been least disturbed and has a large number of trees of different sizes and species. The poorly drained marshlands behind the levee are dominated by grasses, sedges, and other plants characteristic of wet places. The better drained soil of the levee itself was for the most part cleared of its original plant cover but is now in various stages of revegetation. To discover the characteristics of the vegetation of these closely associated habitats, detailed studies were made of several rather distinct plant communities.

The lowlands along the Raritan River have a long history of utilization. Prior to the coming of the white man the Raritang Indians cultivated the fertile bottom lands (Walsh 1928). The earliest land grant for the north bank of the river (Raritan Landing) lying opposite New Brunswick dates back to 1685 (Vermeule 1936). According to Vermeule, dams and mills functioned in the Landing Lane area from 1750 to 1833 when the Delaware-Raritan Canal was constructed along the south bank. Wharves and warehouses prospered at Landing Lane until floods and changing economy destroyed them. By 1875 all the warehouses were destroyed and ". . . the green grass grew and cattle grazed over the site of Raritan Landing." (Vermeule 1936).

#### REVEGETATION OF FIELDS

Aerial photographs taken in 1940 of the Landing Lane section of Raritan Landing show several distinct fields varying in size and bordered by hedgerows. Some fields on the slopes adjacent to the flood plain were under cultivation. Those of the flood plain, however, had ceased to be used agriculturally. These fields, abandoned at different dates, are readily discernible as one traverses the mile-long section.

Three fields which were abandoned at different dates but which were on similar soil were studied in detail (Fig. 14). The largest of the three fields was about 3 A and had been used most recently for agriculture. This field will be referred to as the youngest field. The exact date of abandonment is unknown; however, an ash sapling 6 ft tall had 7 growth rings at its base. Although a few red cedars (*Juniperus virginiana*) were as tall as 12 ft, the average was about 8 ft; one 8 ft tree had a ring count of 8. Thus it is obvious that the field was treeless at least 8 years ago, although some seedlings and saplings were undoubtedly present. This youngest field was bordered by river bank vegetation on one side and marsh on the opposite. The other two sides of it had hedgerows of trees.

A second field (the intermediate field) had ash trees with ring counts at breast height up to 16. Allowing 5 yrs for a tree to grow to 4.5 ft, one would presume that it has probably been at least 21 yrs since this field was treeless.

A third field had ash trees with ring counts up to 31 at breast height. Using the same basis as above, this field was treeless about 36 yrs ago and will be referred to as the oldest field.

The soils of these 3 adjacent fields are similar, since they occupy the same relative position on the top of the natural levee. The great variation in soils occurs as one goes from the river toward the upland. The characteristics of this levee soil were obtained in a soil transect study that transversed the youngest field (Fig. 2).

A comparison of the data for the herbaceous vegetation found on quadrats on the 3 fields presents some striking differences. A total of 70 species of herbs contributed to cover on all 3 fields, with only 5 species common to all fields (Table 3). Unoccupied space for the youngest field was only 7%, whereas it was 47% and 81% for the intermediate and the oldest field respectively.

On the youngest field *Agrostis tenuis* contributed 55% cover. This species occurred with almost 100% frequency and dominated the field with respect to cover (Table 3). *Solidago graminifolia, Panicum clandestinum, Andropogon scoparius,* and *Solidago canadensis* contributed conspicuously to cover through the matrix of Agrostis. On the intermediate field Agrostis contributed 48% cover and on the oldest field less than 1% cover.

On the oldest field the only species contributing more than 3% cover was *Carex rosea,* 11%. There were 29 other herbaceous species. Most of them do not appear in the data for the other two fields. Heliophytes were poorly represented, whereas shade tolerant species, such as *Alliaria officinalis, Geranium maculatum,* and Viola were more abundant. The total cover contributed by herbs amounted to 19%, which was 74% less than the youngest field and 34% less than the intermediate. As the flood plain becomes a young woodland, there is a change in the

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TABLE 3. Percent cover (C) and % frequency (F) of herbs on 3 fields at Raritan Landing. Based on 80 quadrats (0.5 x 2 m) for the youngest field and 40 quadrats (0.5 x 2 m) for the intermediate and the oldest field. X—less than 1% cover.

| Species | YOUNGEST | | INTERMEDIATE | | OLDEST | |
|---|---|---|---|---|---|---|
| | % C | % F | % C | % F | % C | % F |
| *Agrostis tenuis* | 55 | 94 | 48 | 88 | X | 3 |
| *Solidago graminifolia* | 15 | 86 | X | 3 | | |
| *Panicum clandestinum* | 10 | 58 | X | 6 | X | 10 |
| *Solidago canadensis* | 7 | 39 | X | 3 | | |
| *Andropogon scoparius* | 4 | 34 | X | 3 | | |
| *Potentilla canadensis* | 3 | 43 | 3 | 53 | 1 | 43 |
| *Achillea millefolium* | 2 | 85 | 2 | 20 | | |
| *Pycnanthemum virginianum* | X | 54 | X | 3 | | |
| *Solidago gigantea* | X | 20 | X | 10 | | |
| *S. nemoralis* | X | 16 | 2 | 48 | | |
| *Oxalis europaea* | X | 29 | X | 50 | X | 10 |
| *Apocynum cannabinum* | X | 13 | X | 8 | | |
| *Aster lateriflorus* | X | 13 | X | 3 | 1 | 13 |
| *A. ericoides* | X | 11 | X | 10 | | |
| *Solidago juncea* | X | 10 | 2 | 28 | | |
| *Aster novae angliae* | X | 9 | X | 40 | | |
| *Triodia flava* | X | 7 | 3 | 30 | | |
| *Allium vineale* | X | 6 | | | | |
| *Physalis heterophylla* | X | 4 | | | | |
| *Bidens coronata* | X | 4 | X | 5 | | |
| *Panicum virgatum* | X | 3 | | | | |
| *Solanum carolinense* | X | 3 | | | | |
| *Linaria vulgaris* | X | 3 | | | | |
| *Daucus carota* | X | 3 | | | | |
| *Scutellaria integrifolia* | X | 1 | X | 3 | | |
| *Erectites hieracifolia* | X | 1 | | | | |
| *Acalypha virginica* | X | 1 | X | 3 | | |
| *Trifolim agrarium* | X | 1 | | | | |
| *Ambrosia artemisiifolia* | X | 1 | X | 18 | | |
| *Cirsium discolor* | X | 1 | X | 5 | | |
| *Pycnanthemum muticum* | X | 1 | | | | |
| *Thalictrum polygamum* | X | 1 | | | | |
| *Epilobium angustrifolium* | X | 1 | | | | |
| *Geum canadense* | | | X | 3 | | |
| *Oenothera* sp. | | | X | 10 | | |
| *Anthoxanthum odoratum* | | | X | 13 | | |
| *Helianthus decapetalus* | | | X | 3 | X | 5 |
| *Fragaria virginiana* | | | X | 3 | X | 23 |
| *Polygonum scandens* | | | X | 3 | | |
| *Prunella vulgaris* | | | X | 6 | | |
| *Desmodium paniculatum* | | | X | 33 | | |
| *Lysimachia nummularia* | | | X | 5 | | |
| *Lactuca canadensis* | | | X | 5 | | |
| *Agrimonia parviflora* | | | X | 3 | X | 3 |
| *Asparagus officinalis* | | | X | 3 | | |
| *Plantago lanceolata* | | | X | 15 | | |
| *Carex rosea* | | | X | 3 | 11 | 75 |
| *Aster divaricatus* | | | | | X | 25 |
| *Galium triflorum* | | | | | X | 30 |
| *Carex amphibola* | | | | | X | 30 |
| *Hypericum punctatum* | | | | | X | 6 |
| *Polygonum pensylvanicum* | | | | | X | 3 |
| *Alliaria officinalis* | | | | | X | 35 |
| *Lycopus virginicus* | | | | | X | 3 |
| *Muhlenbergia tenuiflora* | | | | | X | 15 |
| *Geranium maculatum* | | | | | X | 13 |
| *Cinna arundinacea* | | | | | 1 | 10 |
| *Tovara virginiana* | | | | | X | 5 |
| *Cryptotaenia canadensis* | | | | | X | 5 |
| *Viola* | | | | | 1 | 5 |
| *Rudbeckia laciniata* | | | | | X | 3 |
| *Eupatorium fistulosum* (?) | | | | | X | 3 |
| *Amphicarpa bracteata* | | | | | X | 5 |
| *Sanicula gregaria* | | | | | X | 3 |
| *Mentha arvensis* | | | | | X | 3 |
| *Polygonatum biflorum* | | | | | X | 3 |

TABLE 3. (Continued)

| Species | YOUNGEST | | INTERMEDIATE | | OLDEST | |
|---|---|---|---|---|---|---|
| | % C | % F | % C | % F | % C | % F |
| *Smilax rotundifolia* | | | | | X | 13 |
| *Botrychium* | | | | | X | 30 |
| Mosses | | | | | 1 | 48 |
| Space | 7 | 61 | 47 | 93 | 81 | 96 |
| Number of species. 70 | 33 | | 35 | | 31 | |

species represented and a reduction in the amount of ground covered by herbs.

Quantitative data for the woody species growing on these 3 fields were obtained from the transect lines giving cover (Fig. 15) and from quadrats giving density, frequency, and basal area. The species list derived from all sampling included 37 woody species, of which 24 were trees. Sycamore, black walnut, and tree-of-heaven were present on the periphery of some fields but do not appear in the data. Shrubs (*Viburnum acerifolium, Rosa multiflora, Pyrus angustifolia,* and spice bush) were also present but are not represented in the data. Several tree species—ash, red cedar, black cherry, apple (*Pyrus malus*), elm, hawthorn, and silver maple—were common to all 3 fields, as were the shrubs—poison ivy, silky dogwood, Japanese honeysuckle, grape, blackberry, and black haw (*Viburnum prunifolium*).

The total of all openings in the tree canopy is referred to as space in Figure 15. On the youngest field, space unoccupied by trees amounted to 99% of the total transect length. Only 3 species contributed to tree cover on this transect—wild black cherry with 80% of the total tree cover, red cedar 17%, and ash 3%. Several other species, such as American elm, red maple, silver maple, pin oak, and hawthorn, were present on the field but did not occur on the transect lines. There were 5 species of trees in the 1.0 to 3.9 in. size class, which was the largest size class represented. American elm and pin oak, absent from transects, were present on quadrats as young trees along with wild black cherry, red cedar, and ash. The density of saplings was greater for ash and elm than for any of the other species. Seedlings were not frequent. Although seedlings of the above 5 species were seen on the field, only elm and wild black cherry seedlings were found on quadrats. The youngest field thus had few tree species greater than 1 in. d.b.h., and these contributed very little cover. Saplings were the most abundant size class of tree species on quadrats, and reproduction although not profuse was evident.

The intermediate field had 60% of the transect lines unoccupied by tree cover. Seven species of

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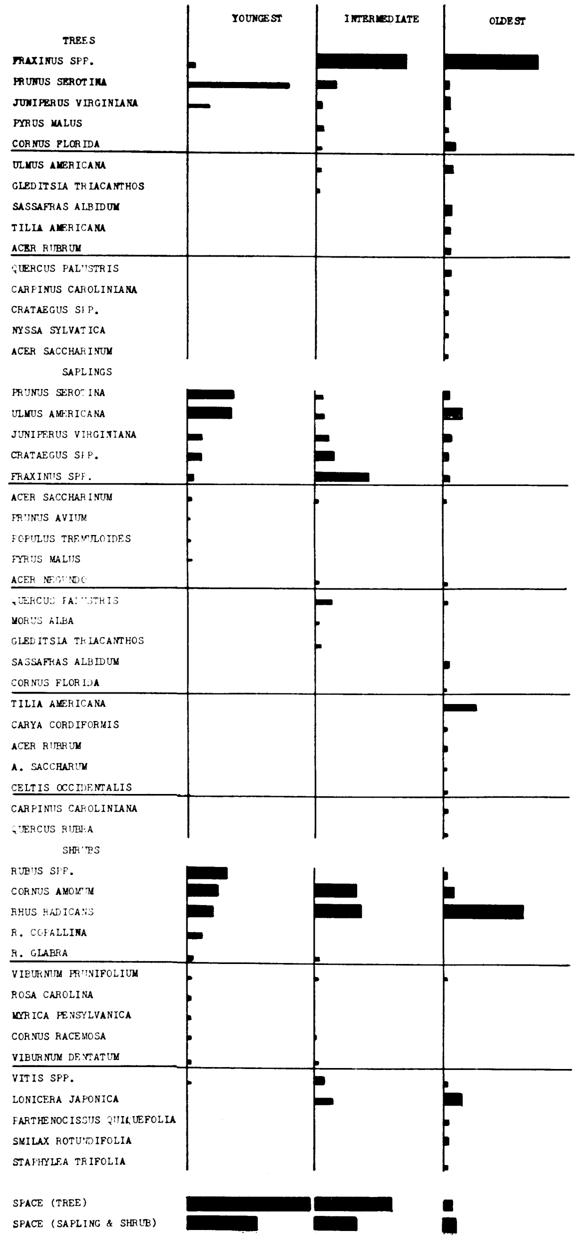


FIG. 15. Percent relative cover and frequency of trees, saplings, and shrubs found along transect lines on three fields at Raritan Landing. Data based on 400 m of transect for the youngest field, 200 m for the intermediate field, and 200 m for the oldest field. Values for less than 3% cover and 20% frequency are represented by a bar the size of that for *Gleditsia triacanthos* tree cover on the intermediate field. Length of bar indicates % cover; width indicates % frequency. For example, on the oldest field Fraxinus had 77% cover with 100% frequency.

trees had representatives over 1 in. d.b.h. and as such were considered contributing to the tree cover. Ash occurred with 100% frequency and contributed 69% cover, whereas the comparable cover values were 17% for black cherry and 5% for red cedar. Ash had the greatest total density on the quadrats and was well represented in all size classes up to 5 in. d.b.h., the greatest diameter recorded. No other species attained this diameter size on quadrats. Seedlings, saplings, or young trees of 12 species were present—a greater number of species than was on the youngest field. Saplings and young trees were both frequent and abundant.

Space in the tree layer of the oldest field was only 8%. The species contributing the greatest cover was ash, 77% (Fig. 15). There were 15 species of trees on quadrats on this oldest field. This size class representation for ash was complete from seedings to trees greater than 10 in. d.b.h. Pin oak, the only other tree found in the largest size class, was missing in the smaller size classes. Some individuals of wild black cherry, red cedar, sassafras, and basswood were present in the 4.0 to 9.9 in. d.b.h. size class. No seedlings of red cedar were found. The density and frequency of tree species were high compared to that of the younger fields. Total density of ash amounted to 286 individuals of all size classes for an area of 800 sq m. More tree species were represented on this oldest field than on either of the others with ash the most important.

The dominance of ash in the revegetation of the fields at Raritan Landing led to a study of its rate of growth as indicated by growth ring counts, heights, and d.b.h. (Figure 16). Thirty straight-trunked trees

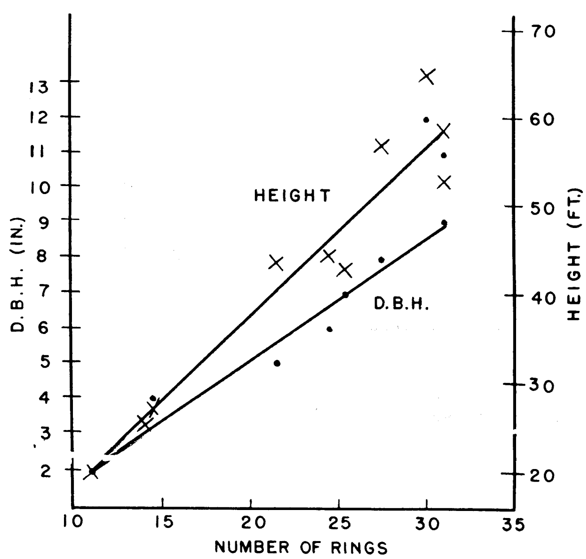


FIG. 16. The average number of growth rings and average height for each inch of diameter at breast height from 30 ash trees at Raritan Landing.

ranging from 2 to 12.6 in. d.b.h. were sampled at random from study areas. The heights and number of rings at breast height of these trees were averaged for each inch of diameter. Although this resulted in only a few points upon which to base a curve, it is sufficient to show the general rate of growth for ash on the Raritan Landing flood plain. The curves are missing for trees with fewer than 10 rings and

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more than 31 rings at breast height, however, some trees are capable of attaining heights of almost 60 ft. and diameters of 9 in. or more by the time 30 rings at breast height have been formed. By adding about 5 yrs for a seedling to attain breast height the ages of those trees could be estimated as 35 yrs. It is possible, then, for ash trees on Raritan Landing to average approximately 2 ft of vertical growth and 0.3 in. diametral growth per year during their first 35 yrs.

Space in the shrub-sapling layer refers to the absence of both shrubs and saplings on the transect lines. However, cover values for shrubs and saplings have been computed separately. On the youngest field 55% of the total transect line was unoccupied by shrubs or saplings (Fig. 15). Of the total cover contributed by saplings only, American elm and wild black cherry contributed 35% and 34% cover respectively. The cover for red cedar was 10% and ash only one-half that value. Hawthorn and red cedar had equal values, 11%. Three shrubs, blackberry, silky dogwood, and poison ivy, had cover values greater than 20% each. A total of 9 trees occurring as saplings and 11 shrub species were encountered along the transect.

On the intermediate field, space in the shrub-sapling layer was 33%. The cover for ash was 42%, a value far in excess of that for the same species on the youngest field. American elm and wild black cherry contributed less than 10% cover each. The cover values for poison ivy and silky dogwood were 38% and 33% respectively. These values are greater than the values on the youngest field for the same species. Blackberry did not occur on the transect lines, although it was found elsewhere on the field. A total of 10 sapling species and 8 shrub species occurred along the transect.

The oldest field had only 13% space in the shrub-sapling layer. The relative importance with respect to cover for any single species is not as striking as it was on the younger fields. In other words there was less discrepancy between species in the contribution they made. Ash saplings had a cover value of only 7%. Basswood, not found on the younger fields, had 30% cover but was less frequent than American elm, ash, wild black cherry, red cedar, or hawthorn. The cover value for American elm was 18%, a greater value than it had on the intermediate field. Poison ivy was by far the most important species in this layer contributing 65% cover on the oldest field. Silky dogwood and Japanese honeysuckle had an actual cover of 12% and 17% respectively. A total of 18 species occurring as saplings and 9 shrub species contributed to cover. This large increase in number of sapling species as compared to the younger fields, associated with a reduction in single species dominance, is indicative of the trend of flood plain revegetation.

When the 3 fields on Raritan Landing are compared, there appears a striking succession of changes from one field to the next. Unfortunately there were no additional fields in comparable stages of succession to substantiate these vegetational changes. However, it may be presumed that these 3 fields show, in a general way at least, the trend of secondary succession on the natural levee of the flood plain. Comparison of this study with secondary successional studies on flood plains in other regions is not strictly possible as comparable data are lacking. In general, upland successional studies on abandoned fields have been more thoroughly done than flood plain studies. The heterogeneous nature of flood plain soils, moisture conditions, and the availability of suitable areas for study may well account for the lack of more complete information on bottomland succession. Oosting (1942) has dealt with the problem in North Carolina, and other workers have added their knowledge in other parts of the country (Featherly 1941, Turner 1931, Barclay 1924, Hotchkiss and Steward 1947).

The rate of secondary succession on the flood plain of the Raritan River is comparatively rapid. The rate of reinvasion is dependent upon many factors, among which the most important are the proximity of suitable species as a source of seed and a favorable environment for ecesis. Once plants are established the soil nutrients, the moisture relations, and the eventual effects of competition between species will greatly influence the progress of succession. The strip of woody species along the bank of the river, the hedgerows of trees and small but well developed "pin oak groves" in the vicinity of the Raritan Landing fields contain a large variety of species. The fields, wooded areas, and marshlands are frequented by a large number of birds throughout the year. The birds along with rodents and other animals common to flood plain areas greatly aid in the dissemination of seeds of certain species and wind, of course, is an effective agent of dispersion for the rest. Furthermore great numbers of seeds must certainly be deposited with the alluvium at times of floods. The soil of the Raritan River flood plain is quite fertile (Patrick *et al.* 1923), as such flood plains generally are. This soil, especially on the natural levee where the fields are located, is rather well drained (Fig. 4). The water table is usually less than 6 ft below the surface and hence water supply is never critical even during long periods of drought, at least for deep-rooted species. Thus it is reasonable to assume that succession would be rapid on such fields where seed source, facility of dissemination, and favorable growing conditions prevail. The rapidity of the succession, especially in the early stages on the fields at Raritan Landing, is reflected in the invasion by trees. Less conspicuously there are some indications that the herbaceous stages are of shorter duration than comparable stages on adjacent upland fields.

The flood plain fields were pastured for considerable time previous to the cessation of agricultural uses. The early herbaceous stages can be expected to have been influenced by this usage. The abundance of common pasture grasses reflect this. The starting point of natural revegetation thus began on fields

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which had some plant cover, mainly grasses. The trend in the herbaceous layer as indicated by the fields studied shows a decrease in herb cover with an increase in time. This change is associated with a change in species composition and dominance.

A rather large cover value for goldenrods on the youngest field corresponds to a similar early upland stage in New Jersey as described by Bard (1952). However, on the uplands Andropogon follows the goldenrods, displacing them and often dominating large parts of fields for periods as long as 40 yrs after abandonment (Bard 1952). No such Andropogon stage occurs at Raritan Landing. Andropogon actually contributed very little to cover on any field. Instead, *Agrostis tenuis,* a pasture grass probably persisting from the time when the flood plain was used for pasture, was the most important species on the 2 youngest fields, but it did not appear to displace the goldenrods. Rather, they became established in the grass, possibly even during the time pasturing was going on. If anything, certain of them, at least *Solidago juncea* and *S. nemoralis,* increased in spite of the grass. It is probably the shading by trees and shrubs that caused a decrease in both the goldenrods and the grass.

Some 36 yrs after trees (greater than 1 in. d.b.h.) appeared, as indicated by the oldest field, an almost entirely new combination of herbaceous species occurs under the closing canopy of trees and shrubs (Table 3). These herbs are generally shade tolerant. The presence of a large ground cover of poison ivy and Japanese honeysuckle in the oldest field also greatly restricts summer herbs. Nevertheless, a rather large variety of species were present although their actual cover was small.

One of the most noticeable aspects of early stages of succession in this area is the presence of shrubs and vines, sometimes as scattered individuals, sometimes in clones *(Cornus racemosa, Myrica pensylvanica).* Shrubs and vines were rather well represented on the youngest field at Raritan Landing. Poison ivy had the greatest cover. Although shrubs, in general show an increase in cover values as the series of fields is studied in sequence, the progressive increase in dominance of poison ivy is most pronounced. This was also recorded by Bard (1952) in her upland study, in which she found this species was most important in the 60-year-old fields. A less obvious but interesting comparison may be noted with respect to silky dogwood. Nowhere did this species account for more than 1% cover in the upland succession (Bard 1952), while on the intermediate flood plain field, it was almost equal in cover value to poison ivy. Silky dogwood is characteristically a species of lowlands or moist sites, while poison ivy is ubiquitous in central New Jersey.

The first trees to invade the fields were red cedar, wild black cherry, and ash. The first of these was especially obvious on the youngest field. Saplings of American elm were frequent and contributed much to cover in the same field. This indicates that elm increases a little later in the succession than cherry, red cedar, or ash. With time ash cover increases tremendously; after 21 yrs ash completely surpasses all other species with respect to cover and density. This trend continues so that by the end of 36 yrs the fields may be dominated by a young ash forest. The rapid development of an ash forest within 36 yrs is strikingly different from the usual development of surrounding upland fields as described by Bard (1952).

As the ash forest develops, the species that preceded it are generally eliminated and a variety of new species appear in its understory. Wild black cherry and red cedar are overtopped by ash; they are suppressed, are in poor condition, and are not reproducing. Elm, on the other hand, is well represented by saplings. Basswood, pin oak, hackberry, and boxelder along with several other species are also present as saplings, and their presence suggests the future mixed composition of the forest. The percent of cover due to ash in the sapling layer of the oldest field is less than that for the younger fields. Thus ash, although reproducing some, will become less important in proportion as the other tree species increase.

Ash has been shown by others to be an important tree on flood plains and bottomlands. Oosting (1942) found it the second most frequent transgressive tree in a 36-year-old stage of a birch succession. In the same study, succession through sycamore revealed that ash had the highest reproduction, with elm second in a 35-year-old stand. Although bottomland succession varied in its early stages depending on a variety of circumstances, Oosting states, "All evidence indicates eventual maple-elm-ash dominance" prior to ultimate development.

On western flood plains the excessive silting of the Deep Fork River in Oklahoma killed off an oak-hickory flood plain forest and within 10 to 12 years a young forest of ash, cottonwood, and willow occupied the space between dead trees of the old forest (Featherly 1941). In the same state Penfound (1948) describes a green ash-American elm dominated area of the South Canadian River. Barclay (1924) working on primary succession, as indicated by denuded plots on the Mississippi flood plain in Minnesota, considered American elm and green ash as a subclimax stage of the mature flood plain forest.

The rapidity with which woody species invade flood plain areas has been noted by Turner (1931) in succession on artificial levees of the Illinois River Valley. American elm and silver maple attain sufficient dominance in 40 yrs so that he tentatively predicted an elm-maple climax attainable in 50 yrs. Ash was present along with pin oak, hackberry, and other species.

Secondary succession at Raritan Landing is thus somewhat similar to succession of other flood plains. In the first place, the development is comparatively rapid. Secondly, ash if not the most important species, generally plays a conspicuous role. The first

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forests are generally composed of one or a few species, while later stages become quite mixed in composition with a change in dominance.

### REED CANARY GRASS AREA

In places along the river's edge, especially below the confluence of the North and South Branches, occur low, flat areas dominated by *Phalaris arundinacea* (reed canary grass). These low-level flood areas vary from a few meters to 20 m in width. They are bordered by the river on one side and by the levee bank on the other. The areas are only about 1 m above the normal river level and are thus subjected to more frequent and forceful flooding than the levee proper. This flooding results in an accumulation of sand in the sod of grass. Where water movement is especially rapid, sloughs may be cut in the grass area. A slough of this kind is usually present at the base of the levee bank where shading by overhanging trees has reduced the vitality of the grass. Series of these sloughs give an undulating topography to the surface of the low level flood plain. Such an area near Landing Lane was studied in detail (Fig 14).

The transect which was extended for 200 m along this section of the flood plain was intersected by only 3 species of trees which together covered about one-third of the area. Boxelder contributed 23% cover, black willow 6%, and silver maple only 2%. Stems of silver maple were in reality upright branches of fallen trees whose roots remain embedded in the levee bank. These fallen trunks were completely hidden by the reed canary grass so that the upright stems looked and functioned like trees. Elsewhere on high hummock-like areas occasional sycamore, river birch, and ash trees were present. They were not abundant on the area studied in detail. In general, trees on the area bore indications of flood or storm damage with many sprouts arising from a single base.

Only one shrub was encountered, elderberry, and this contributed less than 1% cover along the 200 m. In the herb layer reed canary grass showed practically complete dominance. There was no unoccupied space in this layer and *Impatiens capensis* was the only other species to contribute more than 1% cover. Twelve other species listed in the section on flora (Fig. 7), each contributing much less than 1%, made up the total list of species on the transect.

Along the water's edge where water movement had been decreased by obstructions, a zone of emergent plants occurred. These were usually masses of Polygonum, *Pontederia cordata*, or *Zizania aquatica*.

Reed canary grass covers almost the entire low-level flood plain area (Fig. 17). Nichols (1916) also found this grass common in marshy areas along the Connecticut River. It grows to a height of 6 ft or more and flowers in June. By August the grass has produced a profusion of seeds, and many of the tall culms have fallen or been knocked down by storms and floods so that the grass is then only about knee deep. During the late summer months new shoots are produced at the nodes which break through the sheaths of the old leaves. These shoots root and

FIG. 17. Photograph of a reed canary grass area bordering the levee bank at Raritan Landing showing the winter aspect of the dominance of the grass. Trees are mostly sycamore, silver maple, river birch, and boxelder.

a new entangled mass of plants becomes established. The result is a dense, soft, springy, mattress-like mass of old stems with a green, meadow-like, new growth. This manner of growth virtually excludes all other species except in and around sloughs. The plants occupying these wet, grass-free sloughs are: *Pilea pumila*, *Boehmeria cylindrica*, *Polygonum coccineum*, *Solanum dulcamara*, *Geum canadense*, *Alliaria officinalis*, *Peltandra virginica*, *Acalypha virginica*, *Lysimachia nummularia*, and *Saururus cernuus*.

### RIVER BANK

Near the river at Raritan Landing the trees of the levee had not been removed, at least for a long time. A wooded strip which varies in width but is usually not more than 30 m wide, borders much of the river. At places the strip is on the immediate bank of the river, or a low-level reed canary grass area may lie between it and the river. In any case there is a steep rise of at least 1 or 2 m forming a distinct bank. Two sections were studied in detail (Fig. 14).

As might be expected this river border strip of woodland was quite diversified. The two sections studied in detail bear this out (Fig. 18). On both areas there was a total of 19 tree species, which were those commonly found on other places along the river. One section of bank studied was dominated by silver maple, whereas the other section was dominated by ash and sycamore. Poison ivy, Japanese honeysuckles, bladdernut, and occasionally grape contributed heavily to cover and greatly increased the competition for light. The most important herbs were *Phalaris arundinacea*, *Alliaria officinalis*, *Hystrix patula*, *Impatiens capensis*, and *Torara virginiana*. Others are listed in Figure 7.

The trees contributing the largest total basal area along the bank (Sect. 1, Fig. 18) in order of decreasing importance were: silver maple, sycamore, river birch, basswood, American elm, and white ash. At the other place studied they were: ash, hackberry, basswood, honey locust *(Gleditsia triacanthos)*, American elm, and swamp white oak *(Quercus bicolor)*.

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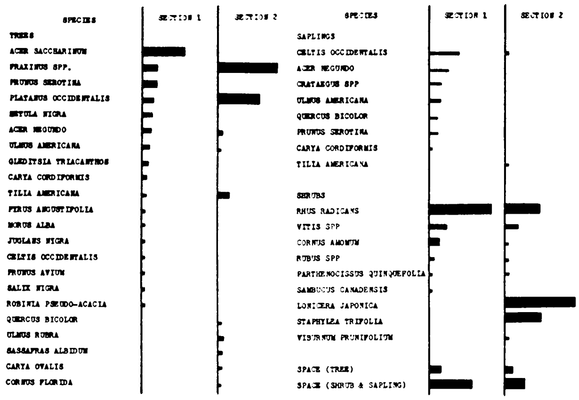


FIG. 18. Percent cover and frequency of trees, saplings, and shrubs occupying two sections of the bank of the levee at Raritan Landing. Section one lies opposite the youngest and intermediate aged fields (Fig. 14); section two lies opposite the oldest field. Data based on 15 transect segments of 20 m each at section one and 5 transects of 20 m at section two. Length of bar indicates % cover, width % frequency. Values for less than 3% cover and 20% frequency are indicated by a bar the size of that for *Pyrus angustifolia* at section one.

Silver maple and bitternut hickory were the only species found as seedlings. Saplings and sprout growth were abundant. Almost all the silver maples were multitrunked and had numerous sprouts.

The river bank vegetation at Raritan Landing is composed of species which are found generally throughout the flood plain of the river. Black willow, river birch, silver maple, sycamore, and boxelder are the species most characteristic of the river bank. These sprout readily and survive flood damage. They are probably favored by the relative high light intensities characteristic of the river bank habitat.

### MARSH

At places along the river there are poorly drained areas which vary in size behind the natural levee. At Raritan Landing a rather extensive marsh has developed on such an area (Fig. 14). The plants occupying these areas are those characteristic of marshes in general and present striking seasonal aspects.

Many species of marsh plants grow in large masses and show some degree of zonation. *Leersia oryzoides* occasionally forms a rather definite border between the better drained soil of fields adjacent to the waterlogged soils of the marsh. Through the main portion of the marsh *Sparganium americanum, Typha latifolia, Carex stricta,* and *Acorus calamus* also form distinct bands. Although grasses and sedges prevail throughout the area, masses of Polygonum occupy wet situations, and *Lemna minor* seasonally covers the surface of the standing water.

The dominant shrub is silky dogwood, although crab apple and marshmallow *(Hibiscus palustris)* are conspicuous when in flower. Poison ivy and blackberry are abundant locally throughout the marsh. Trees are usually small and occur as scattered individuals of ash, elm, pin oak, swamp white oak, and honey locust. Where wooded areas are adjacent to the marsh, there is a migration of trees onto the fringes of the march (Fig. 19).

FIG. 19. Transition from pin oak woods to marsh showing young trees and shrubs invading the marsh at Raritan Landing.

In winter the color aspect of the marsh is a dull gray-brown except for the red stems of the silky dogwood. With the coming of spring and early summer the rich herbaceous growth gives a lush green color to the marsh. During the summer and the onset of fall Solidago, *Bidens coronata, Eupatorium purpureum, Vernonia noveboracensis, Aster novae-angliae,* and other plants (Fig. 7) give a very colorful aspect to the marsh.

## GENERAL ASPECTS OF THE RARITAN RIVER BASIN

The extent of the Raritan River flood plain between Burnt Mills and New Brunswick has been mapped from air photos (Fig. 3). Evidently only a small portion of the flood plain is heavily covered by trees; many areas are pastures or newly brush-covered. Several industrial sites are found along the river, indicating the economy of much of the lower Raritan River Valley. The valley has grown enormously in population, the number of people employed in industry having increased from 6,700 in 1901 to over 40,000 in 1952 (Hurd 1954). Thus the emphasis on land use has been shifting away from agriculture especially in the lower part of the valley. There land formerly used agriculturally has either been put to non-agricultural use or allowed to remain idle. Some of the idle fields have become revegetated, but only in remote parts of the valley is it possible to find stands of large trees.

The numerous habitats present on the Raritan River flood plain support a large number of plant species and if allowed to revert to its natural condition the flood plain will support luxuriant vegetation diverse in composition. There would be the same general character to the vegetation throughout the entire system, although the composition of the predominantly eroding upper part of the river would

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differ in detail from the predominantly depositing areas of the downstream end of the river. In general, recognizing the differences in vegetation along the length of the river, there are four physiographic features with major plant communities on the Raritan River flood plain. (1) The newly depositing sand bars and river banks have an extensive herb cover and established bars have profuse growth mainly of willow, river birch, and sycamore. These bars may develop into islands rich in vegetation. (2) The natural levees or outer flood plains support magnificent forests consisting of a mixture of largely mesophytic species. Once established these forests may ultimately be destroyed by the slow process of stream meandering. (3) The inner flood plain also supports a large mixture of plants, but these areas are wet and support primarily boxelder, pin oak, red maple, river birch, swamp white oak, and black gum. Marshes may exist in places on these areas, but with continued accumulation of alluvium the trees will become established. (4) The terrace which in places borders the flood plain has the potentiality of a mesic forest that could be expected to have a high percent of such species as sugar maple, basswood, beech, and some flowering dogwood.

The present vegetation of the flood plain of the Raritan River is only suggestive of the potential development of its flood plain forests. If revegetation of former agricultural land continues to be permitted, a splendid mixed forest will ultimately grow there with the forest floor covered with showy flowering herbs changing with the seasons. The diversity of habitats within small areas makes a flood plain ideally suited for natural area reservations in such highly populated areas as the lower Raritan Valley. The increasing recognition of the value of natural areas as part of park systems makes it possible that certain parts of the flood plain system may ultimately be allowed to grow back to their original magnificence.

## SUMMARY

1. The flood plain of the Raritan River is derived from diverse geologic materials, since the river flows over three of New Jersey's four geologic provinces.

2. Flood waters deposit the finer particles of alluvium at a greater distance from the river than the coarser particles. This results in the development of a flood plain which has a greater percentage of sand on the river bank than it has farther from the river. The dynamics of such deposits were apparent in a soil profile on the natural levee or outer flood plain at Raritan Landing.

3. Floods on the Raritan River are unpredictable and range from none to about 16 days of flooding a year. The more recent trend as interpreted from existing records seems to be toward higher annual average temperatures, lower precipitation, and fewer floods. Monthly records show that March has the most floods, although the greatest average monthly precipitation is in summer when temperatures are high, plant cover dense, and floods scarce.

4. The flood plain forest at Burnt Mills is composed of a large number of species. Within this forest several plant communities are evident: the outer flood plain with mesophytic species, the diverse inner flood plain forest, and the sugar maple dominated terrace. River banks and islands show successional trends on newly deposited alluvium which reflect the dynamics of stream action.

5. The mesophytic forest of the outer flood plain at Burnt Mills and the vegetation of Mertensia Woods are on similar sites and are comparable in many respects.

6. Secondary succession at Raritan Landing is rapid and the rapidly growing ash trees play an important role in early forest formation. Pasture grasses rather than Andropogon are important in early stages of the revegetation of formerly pastured fields.

7. The tree species occupying banks of the levee are characteristically willow, river birch, sycamore, and boxelder, although species of the mature forest of the levee are present. The river bank may be bordered by a reed canary grass fringe. Behind the levee marshland may exist.

8. The present vegetation of the Raritan River flood plain shows that the utilization of the flood plain for agricultural purposes is decreasing. Thus more land is reverting to its natural condition, or is being occupied by industrial sites or recreational areas.

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