The geography and geomorphic development of Gifford Point near Bellevue, Nebraska

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THE GEOGRAPHY AND GEOMORPHIC DEVELOPMENT
OF GIFFORD POINT NEAR
BELLEVUE, NEBRASKA

A Thesis
Presented to the
Department of Geography - Geology
and the
Faculty of the Graduate College
University of Nebraska

in Partial Fulfillment
of the Requirements for the Degree
Master of Arts
University of Nebraska at Omaha

by
Constance L. Watson
May 1996
THESIS ACCEPTANCE

Acceptance for the faculty of the Graduate College, University of Nebraska, in partial fulfillment of the requirements for the degree Master of Arts, University of Nebraska at Omaha.

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ABSTRACT

Anthropogenic influences frequently produce more lasting effects on the landscape than natural forces (Hook, 1994). Many areas of the world have been altered to accommodate human needs. Throughout history, rivers have been diverted or dammed in attempts to provide safe travel routes, irrigation, or energy. Gifford Point is as much a product of human forces - the need for a stable, navigable waterway - as it is of the Missouri River from which it was originally formed. This study explores the factors contributing to geomorphic changes to the point during the past 100 years with emphasis on anthropogenic changes resulting from river stabilization in the 1930s.

The main question posed for this study was: What geomorphic changes were produced by United States Army Corps of Engineers river channelization work and how did these changes compare to Gifford Point's pre-stabilization geomorphology? This study explored the factors contributing to that geomorphic change.

The problem was approached by visually interpreting historical material such as maps, satellite imagery, and aerial photographs to determine the geomorphology prior to and after river stabilization. Substrate and dendrochronological samples obtained from an area of the point which had undergone stabilization work, along with field checks and interviews were used to verify information obtained from historical material.

The shift of Gifford Point from a northeast-southwest orientation in the early 1800s to its current east-west position was illustrated by overlaying a series of historical maps (1851 - 1975). Aerial photographs (1938, 1972, and 1982) and a 1985 Landsat Thematic Mapper (TM) image provided information...
regarding landcover and geomorphic changes resulting from the United States Army Corps of Engineers (USACE) river channelization work, farming, and logging operations. Substrate samples provided a picture of the point's geologic structure and flood history. Dendrochronology played a key role in estimating when surfaces of the point stabilized above the mean-annual-flow level and, along with historical material, helped delineate the most stable area of the point.

Results indicate that anthropogenic processes have produced the most substantial changes during the past 100 years. The results also suggest that tree age corresponds well with point stabilization and can be used to estimate when surfaces first reach an elevation above-mean-annual flow. This study also provides the ground work for more selective studies of the processes affecting the point's morphology.
ACKNOWLEDGMENTS

This thesis wouldn’t be possible without the help and support of many people. I would like to acknowledge my advisors for their advice and guidance. In particular, thanks to Dr. Jeff Peake for his moral support and encouragement, especially when the going got rough. I am indebted to Jean Spraggins who had never heard of dendrochronology before we met and is now an expert tree corer. Jean steered us in the right direction whenever I got lost and kept plenty of trail mix handy. Randy Gleason and Marcy Mann provided me with much of the historical material concerning Gifford Point. Without Randy’s help, I wouldn’t have been able to collect as many tree samples as I did or get out of the mud when we got stuck. Thanks to Connie Zellmer (Mama Z) for printing that Power Point slide until we got it right. I’m particularly grateful to my family for putting up with my going back to school. Matt babysat more than he wanted, so I could go to class and conduct research. Elyse, my youngest assistant, kept me company while I studied and was always anxious to help. Finally, thank you, Mike. Without you, I could never have reached my goal.
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THE PROBLEM AND ITS SETTING

Introduction

Humans frequently act as geomorphic agents. Changes made to improve the quality of human life can dramatically alter the landscape. Mining, farming, land development, and other industries remove material from one location and add it to another. According to Hook (1994), humans move 40-45 Gt (1 Gt = 10^9 tons or 10^{12} kg) of soil and rock per year compared, for example, to 24 Gt/yr of sediment moved by rivers to interior basins and oceans. He argued that humans are the most important geomorphic agent currently shaping the Earth's surface. Gifford Point, on the Missouri River near Bellevue, Nebraska, (figure 1) is an excellent example of anthropogenic change produced by humans attempting river stabilization, farming, and logging operations. While farming has had a limited effect on leveling the central area of the point and logging has only affected landcover distribution and perhaps caused minor erosion, river stabilization has significantly increased the point's dimensions.

Gifford Point has a rich history. It is located just north of Bellevue, one of the oldest permanent settlements in Nebraska. Traces of pre-Columbian Indian habitation have been discovered along the loess bluffs just west of the point (Garabrandt, 1976) and the Omaha and Otoe tribes inhabited the local area for at least 200 years prior to European settlement. Mandan Indians lived on the bluffs in the early 1900s (Gifford, personal comm. 1993). According to Babbit (1916), a ferry landing was located on the point's southern bank during the 1820s. He also stated that during the 1840s Gifford Point was part of the Mormon migration route. The point was the focus of river trade during the early
Fig. 1. Study Area. Gifford Point is located in Sarpy County on the west bank of the Missouri River just north of Bellevue.
to late 1800s (figure 2). Local milling operations harvested timber during the mid-1800s (Garabrandt, 1978). Portions of the point have been farmed since the early 1900s. Called Wiley's Island in the 1800s, because it was periodically cut off on the west side by a channel of the Missouri (Rybar, personal comm. 1993), the point became known as Gifford Point after it was purchased by the Gifford family in 1920 (Gifford, personal comm. 1993). A swimming pool, part of a Boy Scout camp located on the western side of the point, was filled by springs flowing from the loess bluffs. Sycamore trees planted by the scouts have outlived the abandoned camp. Frequent flooding has changed point morphology and affected land use. Work by the United States Army Corps of Engineers (USACE) to stabilize the Missouri River has increased the point's size and altered its shape. Today, Gifford Point (figure 3) is a multiple use area with multiple problems. The central portion is devoted to an educational farm, while the western edge of the point is a forest preserve, Fontenelle Forest. The wooded perimeter is controlled by the Nebraska Game and Parks Commission and is used mainly for seasonal deer hunting. Deer overpopulation has seriously impacted agriculture and growth of forest vegetation. Gifford Point and Fontenelle Forest are currently being studied to determine the best solution to the deer problem. The USACE, in an attempt to re-establish a wetlands habitat on the south side of Gifford Point, is planning to dredge Hidden Lake, part of an abandoned channel located parallel to the Missouri River on the southwest end of the point. While this project will protect certain wildlife and plant species, the new waterway could increase the probability of flooding due to access to the Missouri River which currently doesn't exist and may cause additional crop and natural vegetation damage.
Fig. 2. Composite Map of Gifford Point: 1851, 1856, and 1975. Note that, due to river migration, Traders Point of 1851 no longer exists in 1856. The width of the river channel in 1851 and 1856 may be attributed to cartography, but historically the channel in the Bellevue area has been described as only a mile wide. Source: Garabrandt.
Fig. 3. Gifford Point Contour Map. From a 1975 1:24,000,000 Digital Line Graph (DLG). Dikes are indicated by short lines perpendicular to the perimeter of the point.

Source: USGS
The Problem

Both natural and anthropogenic processes have influenced the geomorphic development of Gifford Point during the past 100 years, with anthropogenic change dominating since the late 1930s. The question posed for this study was: What geomorphic changes were produced by river channelization and how did these changes compare to Gifford Point's pre-stabilization morphology? This study explored the factors contributing to that geomorphic change.

The Subproblems

1. The first subproblem. What was the historical movement of Gifford Point?
2. The second subproblem. Could landcover changes provide evidence of geomorphic change on Gifford Point?
3. The third subproblem. Could the substrate provide evidence of geomorphic change on Gifford Point?
4. The fourth subproblem. Could tree age provide an "at least as old as" age of stabilized surfaces on Gifford Point?

Hypotheses

The first hypothesis was that historic geomorphic changes to Gifford Point could be visually observed on maps, aerial photography, and satellite images. The second hypothesis was that landcover changes could provide evidence of geomorphic change on Gifford Point. The third hypothesis was that the
substrate would reflect changes to Gifford Point caused by flooding and stabilization. The fourth hypothesis was that tree age could be used to provide an "at least as old as" age of stabilized surfaces on Gifford Point.

**Delimitations**

Due to lack of pre-1850 data, this study was limited to geomorphic changes to Gifford Point occurring after 1850. Vegetation changes caused by animal disturbance were not evaluated. Substrate sampling and detailed tree sampling were conducted only in areas affected by the USACE river stabilization process.

**Assumptions**

A prime assumption was that most geomorphic changes resulted from natural river movement prior to the 1930s and resulted from river stabilization work after that. This appeared to be generally true. I assumed that results from the detailed study area could generally be applied to the remainder of the point, because the same stabilization processes were used along the entire perimeter.

**Need for the Study**

Little is known about the development of point bars affected by river stabilization processes. The study of Gifford Point provides a chronology of the geomorphic changes produced by such stabilization work. The contrast of pre-stabilization features to post-stabilization features provides insight into the importance of understanding both natural and anthropogenic processes affecting geomorphologic development of point-bar-complexes. Finally, Gifford Point has
both historical and ecological significance to the local area. Understanding the geomorphologic processes at work on Gifford Point provides a background for future development decisions such as further wetlands restoration and continued use as an educational facility.
PHYSICAL FEATURES OF GIFFORD POINT

Study Area

Gifford Point is located on the west side of the Missouri River about 15 km (10 mi) south of Omaha, Nebraska (figures 1 and 3). The 525 ha (1,297 acre) point consists of a 153 ha (378 acre) cattle-feed-grain farm (used for education) surrounded by riparian vegetation (McCaw, 1978). The point is bounded on the west by the Burlington Northern railroad located at the base of dissected loess bluffs. Slope is minimal from the railroad track to the river bank. Evidence of past positions of the Missouri River channel occur along the railroad track, to the north of the farm, and on the southern perimeter of the point.

The highest ground elevation (297 m (974 ft)) above mean sea level (msl) in the study area is located on the northwest side of the point (figure 3) and on top of several berms near the banks of the river (McCaw, 1978). At the southwest end of the point, the Hidden Lake and Great Marsh complex contains the lowest elevation (292 m (958 ft) above msl). The old river channel west of the point lies at 292.4 m (959 ft) above mean sea level. Drainage follows old channel lines.

Geology

The bedrock of the Omaha-Council Bluffs area consists of Pennsylvanian shale and limestone (Brenner, et al, 1981). In Miller's (1964) study of the geology of Omaha and Council Bluffs, he described the lithology of Gifford Point and the surrounding area. A pre-Illinoian till composed of boulders, cobbles, pebbles, and sand in a matrix of silt covers the bedrock in most places. The till is
gray except for a brownish oxidation which dominates the upper part of the profile. The Grand Island Formation, a flat-lying fluvial sand and gravel deposit of quartz, Sioux quartzite, and granitic rocks, overlays the till along the river from Bellevue north to South Omaha. Just north of Gifford Point, exposed along a deep gully in the river bluff, is the Sappa Formation, a gray to greenish-gray clay and clayey silt which includes a white to gray volcanic ash (Pearlette Ash Member). The light-brown Crete Formation composed of fine, medium, and coarse sand and lag concentrates of cobbles reworked from local deposits of Grand Island Formation is deposited on surfaces of pre-Illinoian till and the Sappa.

Along the bluffs of the Missouri River, the pre-Illinoian till and Grand Island Formation are overlain by ridges and hills of Pleistocene loesses known as the Loveland, Peorian, and Bignel. The Loveland loess consists of moderate grayish-brown clayey silt that has a moderate yellowish-brown layer in the upper 1-2 meters (3 - 6 feet). Montmorillonite, illite, kaolinite, and some vermiculite clays occur at the type section (Miller, 1964). The Loveland can be distinguished from the Peorian and Bignel loesses by its reddish color and is separated from them by the reddish-brown Sangamon paleosol. Its source was predominantly the Missouri River floodplain. Both the Peorian and Bignel loesses are buff colored and indistinguishable in the Omaha-Council Bluffs area (Miller, 1964). They consist of a yellowish-brown clayey silt (containing some sand and few pebbles) that stands in nearly vertical bluffs. The dominant clay mineral is montmorillonite. Concretions or aggregates of calcium carbonate (loess dolls) are common. The Platte River and Elkhorn River floodplains are the main sources for the Peorian and Bignel loesses.
Remnants of terrace alluvium of Pleistocene (Wisconsin) age composed of stratified dusky-yellow clayey silt are located at Bellevue and along Mosquito Creek southeast of Council Bluffs, Iowa, which flows into the Missouri River opposite Gifford Point. Two complete exposures show stratified silt over white cross-bedded sand.

Deposits of Holocene age consist of loess, terrace alluvium, floodplain alluvium, alluvial-fan deposits, and colluvium. Two flat-topped terrace deposits of recent age are comprised of older recent alluvium. The older surface, composed of stratified yellowish-brown silt, is the higher and grades into the upland Peorian and Bignel Loesses. The younger alluvium partially fills channels cut into the older alluvial deposits. Sand makes up part of the alluvium or underlies silt where available from local sources. The lithology of the older terrace changes abruptly over short distances with silt being replaced by a stratified pebble gravel of rounded limestone fragments within a distance of less than 16 meters (50 feet). Where the alluvium thickens, the lower part becomes stratified with iron carbonate-cemented sand interlensing with an olive-black to greenish-gray silt. According to Miller (1964) the silt contains fragments of wood dated 2800+/−200 yr BP.

The younger Holocene alluvium, while less continuous than the older alluvium, also extends along every valley in the area locally covering the older deposit. This alluvium is horizontally stratified except near its boundary with the older Holocene alluvium and consists of dark yellowish-brown clayey silt alternating with layers of light-gray or gray sandy silt. The two terrace alluviums are separated by a 5 m (15 ft) scarp where the valley joins the Missouri River floodplain. Near the Missouri River, a 2 m (6 ft) scarp separates the younger
terrace alluvium from the modern channel and floodplain alluvium along each stream. The younger terrace alluvium is composed of reworked humic colluvial material from soil developed on older deposits.

Along the Missouri River floodplain, a layer of humic silt (0.3 m-2 m (1-6 ft) generally overlays a coarser alluvium composed of sand and fine pebble gravel. Clayey silt forms deposits in old swales, meanders, and oxbow lakes, while fine sand covers the coarser alluvium along ridges and berms. Most of the alluvium, where more than 30 m (100 ft) thick, consists of fine to medium sand and fine pebble gravel in the upper 20 meters (60 feet). Source materials of floodplain alluvium are derived locally from tributary streams and from river deposits.

**Pleistocene and Holocene Geologic History**

Following the retreat of the pre-Illinoian ice sheet (previously known as the Kansan Glaciation (Boellstorff, 1978)) the Missouri River became entrenched, producing what is now the modern channel and depositing the reworked pre-Illinoian till. Late during this period, the Grand Island Formation was deposited. Stream flow ebbed and alluvium became finer, producing the Sappa Formation. As the Illinoian glacier advanced, local streams deposited the Crete Formation while locally reworking older formations such as the Grand Island Formation. During the following warm period, the Sangamon interglacial, north-northwesterly wind flow dominated, depositing the Loveland loess and forming the Sangamon soil. Deep weathering caused by the warm climate produced the characteristic oxidation which dominates the Loveland loess and the Sangamon soil. As the climate cooled and the wind direction became predominantly west-northwest, the Peorian and Bignel loesses were deposited. According to Miller (1964), it was at
this time (about 22,000 yr BP) that the Missouri River floodplain began to aggrade to the level of the terraces along the floodplain. Downcutting began near the end of the Wisconsin glaciation (about 11,000 yr BP) and may have continued until 3000 yr BP when Holocene alluvium deposition began. The resulting terraces are considered to be of Wisconsin age (Miller, 1964). Most downcutting stopped about 1500 yr BP when the younger Holocene alluvium began to accumulate. However according to Miller (1964), some geologists believe erosion occurred as recently as 1880. The removal of the younger Holocene alluvium during this period lowered the gully floors to their present day elevation.

Cut and fill processes caused by river migration and flooding prior to the mid-1930s produced the central core of Gifford Point. Late Holocene alluvium composed of locally reworked Pleistocene silts, sands, and gravels (described above) which have been transported down the Missouri River makes up most of the point. The alluvium, along with colluvium from the bluffs west of the point, overlays Pennsylvanian limestone and shale (Brenner, et al, 1981). The colluvium is reworked sand and silt produced by slopewash from the loess bluffs under Fontenelle Forest. Though believed to be Loveland, Peorian, and Bignel, the loesses are not mapped or dated in this region. After bank stabilization work by the USACE (e.g., dikes, revetments, and upstream dams) began in the mid-1930s, the river no longer carried the coarse bedload it did prior to the 1930s and the point dimensions increased predominantly through overbank accretions of silt and sand. Large floods in recent years, where water has extended from bluff to bluff, have deposited a fine sand grading upward to clay. After the flood of 1952, these deposits were 1-2 m (4-6 ft) thick north of Omaha (Miller, 1964) with lesser
amounts to the south. The floods of 1984 and 1993, while not as extensive as the 1952 event, produced similar sand and clay deposits.
Geomorphic Development

Natural Geomorphic Changes. To appreciate the processes involved in developing Gifford Point, one must first understand the morphology of the Missouri River and its basin (figures 4 and 5). Prior to channelization work in the 1930s and 1950s, the Missouri River frequently flooded, meandered across the Missouri River Valley, and produced numerous point-bar complexes and oxbow lakes. In the early 1800's, the Missouri River was a maze of treacherous curves, sand bars, and shallow channels. The river occupied a broad floodplain. During dry periods, the channel braided between sandbars and islands (Iowa Conservationist, 1992). By the mid-1800's, the once tree-covered slopes along the river channel had lost most of their timber. Wood was needed to fuel the steamboats that traveled the river. Material from the bare slopes was washed into the already sediment-laden water. Spring thaw often brought tremendous floods which scoured the channel and destroyed anything in the way. Frequently after the floods, a new channel would form miles away from its previous course. Floods were common and navigation unpredictable. According to Miller (1964) the river has shifted its channel locally more than a mile since the first land survey in about 1850. The greatest change near the study area was produced when the channel moved southward during the flood of 1881 causing Lake Manawa to be formed. Figure 6 depicts an early map-maker’s rendition (about 1838) of the Missouri River near Bellevue and the same area about 55 years later (1893). Even though these maps are at different scales, channel changes
Fig. 4. Missouri River Basin. Reservoirs constructed after 1950 control flow and minimize flooding. The study area is located between the letters "I" and "D" in "Middle Missouri". Source: Missouri River Basin Water Resources Plan (1977).
Fig. 5. Middle Missouri Sub-Basin. Sarpy County, Nebraska, in which the study was conducted is highlighted. Source: Missouri River Basin Water Resources Plan (1977)
Fig. 6. Gifford Point - 1838 to 1893. An early mapmaker's rendition (about 1838) compared to the 1893 map, while not to scale, illustrates channel changes over a 55 year period. Note Mosquito Creek north of the point in 1838 and south of the point in 1893. Source: Jensen (1976) and Missouri River Commission (1893)
are obvious. Mosquito Creek, entering from the Iowa side, is shown south of the point in 1838 and north of the point in 1893.

The Missouri River channel in its natural state varied in width from less than 300 m (1,000 ft) to over 2 km (1 mi) (Hamilton, 1979). The water level ranged from 1 1/2 to 3 m (5 to 10 ft) below bank full. Prior to stabilization, discharge ranged from a low of 1800 m$^3$s$^{-1}$ (6,000 ft$^3$s$^{-1}$) to a high of 60,600 m$^3$s$^{-1}$ (200,000 ft$^3$s$^{-1}$) during major floods (Hamilton, 1979). Figure 7, a graph of the annual Missouri River flow (in cubic feet per second) from 1928 to 1995, compares the unregulated flow prior to final stabilization work which occurred after the 1952 flood to the post-stabilization regulated flow.

Gifford Point initially developed as a point bar produced by the unregulated flow of the Missouri River. A point bar normally forms in a meandering river when sediment eroded from the outside of the meander is deposited downstream on the inside of the bend. This cut and fill process is interrupted by overbank deposition and erosion produced by seasonal flooding. In the case of Gifford Point prior to 1952, seasonal floods were frequently very large (150,000 cubic feet per second). Nanson (1986) stated that a pattern of catastrophic flooding following vertical accretion throughout floodplain development produced ridge leveling. He concluded that the erosional process would be repeated until the floodplain and channel banks aggraded to a point above major flood level. Sigafoos (1964) stated that sediment found on the floodplain was not part of the original point bar or overbank deposit; but, was the result of processes (erosion or deposition) much more recent then those associated with the initial floodplain formation. The end result was a surface of relatively recent origin with an average elevation which had not changed through
Fig. 7. Annual Missouri River Flow at Omaha (1928-1995). Large floods occurred approximately every other year until after the flood of 1952 when stabilization work was finally completed. After 1952, flooding decreased significantly, large floods occurring on the average of once every eight years. Source: USGS (1995).
time. In Collinson’s (1986) discussion of Lewin’s (1976) study of an artificially straightened reach of the River Ystwyth in Mid-Wales over the period 1969-1970, Collinson described development of artificially straightened river reaches. According to Collinson, mid-channel bars formed rapidly during high discharges restricting the flow between the bar and the channel banks, forming a chute. This process produced a meander bend with bank erosion occurring on one side of the channel and deposition on the other. He further noted that the primary bars became the cores of point-bar complexes and that abandoned levees and point-bar ridges became the highest elevations on a developing floodplain.

**USACE Stabilization Work.** Gifford Point developed both through this natural process and through the USACE river channelization. While numerous texts discuss point-bar development, little has been written on point-bar stabilization caused by human interference. However, Hart (1957) described the work of Major C. R. Suter of the USACE. In 1884, Major Suter began work stabilizing the banks of the Missouri. His technique, with slight modifications, was still in use through the 1950s. Since the Missouri was a meandering, silt-laden stream with highly erodable banks, this meant that the current was forced to speed up on the outside of bends causing banks to cave in. Suter protected the outside bends with revetments and pilings. The revetments shored up the banks while the pilings slowed the river's flow and trapped sediment. This design smoothed out the sharp bends and hooks in the river and left a deep, narrow channel suitable for navigation. Figure 8 illustrates this technique.
Fig. 8. Suter's Bank Stabilization Technique. This technique built up the point-bar side of the channel while maintaining the cut-bank side. After stabilization, the combination of dikes, revetments, and vegetation produced a relatively smooth channel. Source: Hamilton (1979).
Due to funding problems, however, little stabilization work was done on the Missouri River until the mid-1930's. Large floods occurred with regularity. It wasn't until the May 1935 flood of the Republican River in Kansas (which killed 105 people) and similar disasters in New York and New England during the next two years that Congress passed the first Flood Control Act (Hart, 1957). Finally, the USACE had funding to begin the channel stabilization which resulted in the transformation of Gifford Point. Figure 9 depicts the evolution of Gifford Point from an unstable sand spit in 1935 to a rounded point four years later.

More work was needed before the river would be tame enough for the point to survive in the form we see today. The USACE continued working to make the Missouri a permanent channel. In the original plan according to Terral (1947), the USACE proposed consolidating the parts of the river and deepening the channel for navigation by cutting off chutes and eliminating large sand bars and islands. The original plan disregarded political boundaries and had to be modified. This left points such as Gifford in place even though it would have been easier to carve a channel straight through. The engineers relied on the river to help them whenever possible (Terral, 1947). Dikes were placed on the point-bar side of bends to act as silt traps and keep the cutbank clear of sediment. Thus Gifford Point was enlarged by "accident", since the intent was to stabilize the Iowa-side bank, not to increase the size of the point.

In the 1940's under the auspices of the Sloan-Pick Plan, the USACE constructed six reservoirs along the Missouri River and its tributaries to control water levels during drought and flood. However, stabilization was still not complete and it took the catastrophic flood of 1952 (figure 7) to provide enough public demand for funds to finish what is known as the Missouri River Project.
Fig. 9. Maps Depicting Gifford Point During River Stabilization Work from 1935 to 1939. The dashed lines represent planned dikes and point perimeter. The solid lines indicate installed dikes and the final perimeter. The most evident change appears to occur between 1935 and 1937 as the river channel is narrowed and sediments begin to accrete along the dikes.
Source: USACE.
According to Gifford (personal comm. 1993), the flood of 1952 covered the entire point. Gifford Point acted as a safety valve for the Missouri, allowing the water to spread out. This prevented the water from backing up into Omaha. The entire project was finally completed in 1980. Figure 10, a 1982 map and aerial photograph, shows the final configuration of the point.

It turned out that leaving Gifford Point in place, along with some other large points along the Missouri River, was actually an effective means of river stabilization. The meander decreased the slope while other stabilization work shortened the Missouri River by 112 k (70 mi) from 1933 to 1981. In 1890, the river mile at Sioux City, IA was 809.2. By 1981, the river mile was 734. Since the river was straightened in many reaches, the meanders left in the system acted as controls to keep the river from eroding (Larandeau, personal comm. 1992). From 1967 to 1992, the river bed dropped nearly 2 m (6 ft) at Sioux City, Iowa, and more than 2 m (7 ft) at Gavins Point, near the Nebraska-South Dakota-Iowa border. At Omaha, the river has maintained its bed elevation. According to Larandeau (personal comm. 1992), the USACE predicts only an additional 30 cm (1 ft) drop by the year 2000. The USACE believes that in addition to Gifford Point, the nearness of the Platte River and other tributaries (Mosquito Creek for example) which add sediment to the system may also act as controls to retard downcutting.
Fig. 10. Aerial Photograph and Map of Gifford Point - 1982. Dashed lines on the photograph represent the perimeter of the point prior to stabilization. Hidden Lake provides little reflectivity (probably due to silting. The Great Marsh is more reflective and appears to contain much more water than Hidden Lake. The map shows the location of the dikes visible on the 1938 photograph (Fig. 15), but no longer visible on the 1982 photograph. Smaller dikes installed after 1952 are visible on the 1982 photograph and on the 1975 DLG (Fig. 15). Source: USACE.
Soils and Sediments

The soils on Gifford Point are classified as entisols (figure 11) and were surveyed by the U.S. Soil Conservation Service (1975). The Albaton-Haynie Association dominates the point. This association is composed of clayey, silty, and sandy alluvium described as deep, poorly-drained to moderately-well-drained, medium to fine textured. McCaw (1978) described these sediments as similar to the nearly level bottomland sediments along the Missouri River.

Albaton and Percival silty clays are scattered throughout the point in poorly-drained areas of low elevation. The Haynie silty loams and Onawa silty clays dominate the farm. The Carr sandy loams are located just east of the farm. Sarpy fine sands are developed in sandy alluvium located on the dunelike topography along the northern and eastern perimeters of the point. An in-depth description of the sediments follows.

The Haynie silty loam is a well- to moderately-well-drained sediment composed of recently stratified calcareous alluvium. It is moderately dark and occupies nearly flat rises on the floodplain. Its water-holding capacity and frost-heave potential are high. The water table is 1-2.5 m (3-8 ft) below the surface.

The nearly level, moderately dark Onawa silty clay is formed in clayey alluvium underlain by silt. This sediment is somewhat poorly drained with the water table normally 1-2.5 m (3-8 ft) below the surface. However, a seasonal high-water table contributes to the high shrink-swell rate and moderate to high frost action.

The Albaton silty clay is a moderately dark sediment scattered throughout the point in areas of low elevation. It produces marginal crops on the farm and is
Fig. 11. Soil Map of Gifford Point. Soil types follow the topography. Sandy soils are located on the berms, while the clayey soils located in swales. Source: United States Department of Agriculture Soil Conservation Service (1995).
associated with cottonwood, green ash, and other pioneer stage vegetation along the wooded areas of the point. This poorly drained clayey alluvium has low permeability, a high shrink-swell rate, and high frost-heave potential. The water table varies seasonally from 0.6-2.5 meters (2-8 feet).

Percival silty clay is formed in alluvium composed of an upper clay layer with a sand layer two feet below. This sediment is characterized by low permeability in the clay layer and high permeability in the sand layer. The Percival silty clay has a high shrink-swell rate and moderate frost-action potential. It is associated with areas which flood occasionally. Vegetation is usually cottonwood and other native bottomland vegetation, however, some areas have been converted to pasturage.

The moderately dark, excessively drained Sarpy fine sand is developed in sandy alluvium. A fine 5 cm (2 in) thick surface layer is underlain by stratified fine sand. The Sarpy fine sand is highly permeable and subject to blowing and flooding. Vegetation consists mainly of cottonwood.

The Carr sandy loam is a somewhat poorly drained bottomland sediment. It is composed of a fine, sandy loam surface and subsurface. Its water holding capacity is moderate. The dominant vegetation is cottonwood.

Vegetation

Since Gifford Point has flooded many times prior to channel stabilization, most early vegetation resulted from seeds deposited along with upstream alluvial material. The dominant bottomland vegetation consists of cottonwood (Populus deltoides), willow (Salicaceae family), soft maple (Acer saccharinum), sycamore (Platanus occidentalis), hackberry (Celtis occidentalis), red mulberry (Morus
rubra), and ash (Fraxinus americana, Fraxinus pennsylvanica var. lanceolata, and Fraxinus pennsylvanica). Elm (Ulmus americana, Ulmus rubra, and Ulmus thomasii), oak (Quercus borealis, Quercus macrocarpa), catalpa (Catalpa speciosa), and linden (Tilia americana) are now scattered throughout the point and dominate the western boundary near the bluffs. Osage orange (Maclura pomifera) and red-osier dogwood (Cornus stolonifera) have begun to invade open areas, particularly on the south east area of the point. According to biologist Randy Gleason, Educational Service Unit manager of Gifford Point, (personal comm. 1993), the dogwood has only begun to establish on the point within the past few years. Vegetation along the gently sloping outer perimeter is predominantly 30- to 40-year-old cottonwoods; which, according to McCaw (1978), is the result of river stabilization work. Sedges (Cyperaceae family) dominate low-lying perimeter areas of the point where the water table is close to the surface and flooding frequently occurs.

Gifford Point is similar to the areas studied by Vaubel and Hoffman (1975) during the summer of 1974. Vaubel and Hoffman (1975) sampled 45 sites along the Missouri River floodplain from Sioux City, IA, to Rulo, NE. Their objective was to relate vegetation succession to the age of river stabilization structures. They noted that, while willows and cottonwoods were the pioneer communities, after 18 years the cottonwoods dominated on the floodplain. During this period, slippery elm, hackberry, sycamore, and other mesophytic deciduous species began to appear. These later replaced the cottonwoods which did not reproduce well after the initial invasion (Vaubel and Hoffman, 1975). As the floodplains matured, red-osier dogwood, and gooseberry (Ribes missouriense) invaded (Vaubel and Hoffman, 1975). Figure 12 illustrates these bank stabilization and
Fig 12. Vegetation Relationships to Bank Stabilization. This figure illustrates the evolution of a stabilization area. Within six years of constructing the dikes, the land can be used for agriculture. Source: Hamilton (1979).
vegetation relationships. Soil-plant relationships were inconsistent, probably due to the immature soils occurring on the floodplain. Vaubel and Hoffman (1975) did state that soils in the mature floodplain communities tended to have higher clay content, and greater amounts of nitrogen and organic matter. They attributed this to the greater influence of biota and time on soils.

Marsh communities only occurred in backwaters of channelized areas according to (Vaubel and Hoffman, 1975). This may have been caused by the rapid development (1939 to 1974) of the substrate between adjacent stabilization structures. Vaubel and Hoffman (1975) suggested that there was not enough time for this plant community to develop. They also theorized that the swift channel adjacent to the floodplain may have prevented the marsh communities from developing, since marsh plants need undisturbed areas to grow.

Old forest vegetation (American elm, bur oak, Kentucky coffee tree - *Gymnocladus dioica*; and honey locust - *Gleditsia triacanthos*) invaded the older cottonwood communities along the floodplain. According to Vaubel and Hoffman (1975), rapid change in floodplain communities was indicated by the occurrence of the old forest vegetation after only 40 years of succession. Willows dominated nearly flat areas and had little leaf litter. Cottonwoods occurred on more irregular topography and had a distinct litter layer. This may be in part due to drainage patterns developed in the older cottonwood communities, since they were higher above the water table than the willows.

Vaubel and Hoffman (1975) could not determine how long it took substrate deposition to reach the water level, but they did note that newly exposed substrates in 1974 were almost immediately covered by willows and
some cottonwoods. Cottonwoods had completely eliminated willows from the overstory on sites adjacent to structures built in the 1930's. Vaubel and Hoffman (1975) stated that their technique was so accurate they could immediately determine the approximate age of the stabilization structure at the site by looking at the plant community next to it.

In quantitative dendrochronological studies, Sigafoos and Hendricks (1969, 1972) determined the ages of trees growing on recently deposited moraines. Their 1969 study concluded that the main source of error in age estimation was the interval between stabilization of the deposit and germination of tree seedlings. They further noted that it took 1 to 2 years for seedlings to become established on fine-grained flood-deposited material.

In their 1972 study, Sigafoos and Hendricks, working in areas of moraines, outwash, and floodplains, used ages of trees to determine the sequence of landform formation. Again, they concluded that the age of the oldest trees was a reliable record of the landform's minimum age.

Sigafoos (1964) studied the effects of floods on vegetation in areas as small as ten square kilometers. He was able to identify evidence of past flooding, erosion, and sedimentation by using dendrochronology and studying forms of flood-trained trees along the Potomac River near Washington, D.C.. Sigafoos (1964) noted that the date of sediment deposition could be determined from the study of the structure of wood in the buried part of tree trunks, and the approximate thickness of the deposit could be determined by measuring to the level of the original tree base. He also studied the channelward limit of perennial woody plants and noted that this limit represented either the level of the maximum discharge during extended periods of low flow or the edge of the
channel which was encroaching on a floodplain as the result of lateral corrasion (Sigafoos, 1964). He concluded that this area could be easily seen and mapped. Sigafoos also noted that after becoming established, trees persisted for long periods of time and acted to stabilize and reinforce the bank. This preserved the bank at closer to mean-low-water level, well below the level of two-year floods.

Climate

The study site is located in an area of mid-latitude extremes. Continental-polar airmasses dominate eastern Nebraska in the winter, producing dry and windy conditions (Weather of U.S. Cities, 1981). When snow does occur, strong winds can cause drifting, while low temperatures prevent rapid melting. Prolonged days of sub-freezing temperatures cause ice floes to form on the Missouri and Platte rivers. Rapid spring thaw produces ice jams which, prior to channelization, often resulted in flooding of both the Platte and Missouri rivers (figure 7). The Platte is still influenced by ice jams and frequently floods in the spring. However since channelization and the construction of dams upstream, floods on the Missouri are seldom produced by ice jams. Though dominated by humid, maritime-tropical airmasses, summers tend to be dry. Late spring and summer precipitation is provided by intense thunderstorms which can become violent enough to produce large hail and tornadoes. While most precipitation occurs in the spring, occasionally rain continues through the summer increasing the potential for severe flooding. Fall weather is generally dry and mild. Mean annual precipitation is near 737 millimeters (29 inches). Temperature extremes can range from a low of -35 °C (-32 °F) in January to a high of 45 °C (114 °F) in July and August.
METHODOLOGY

Use of Historical Material to Assess Landform and Landcover Changes

Maps. Base maps consisting of USGS, 1:24,000, 7.5 minute quadrangles of Omaha South, Nebraska, and Council Bluffs South, Iowa, were used to aid in the analysis of historical material. A digital line graph (DLG) subset from a 1975 quadrangle (the most recent map available) was used for geomorphologic and phytogeomorphic analysis.

To view lateral river movement over time, a series of historical maps (1851, 1856, 1879, 1885, 1913, and 1928) depicting Gifford Point was registered to the base map (1975) and digitized using ARC/INFO Geographic Information System (GIS) software. Most maps had no geographic coordinates; therefore, all were registered using township and range section corners. Prior to digitizing, the maps were scaled to 1:24,000, photographed, and transferred to mylar to prevent shrinking and stretching. Each map in the series was then compared to the others and to the 1975 base map to determine changes in point position and size.

Non-digitized USACE maps were compared to each other to analyze changes to the point's structure produced by river channelization work.

Satellite Imagery. A 1985 Landsat Thematic Mapper (TM) image was interpreted for historic geomorphic changes. Principal component images were interpreted to provide information on underlying geomorphology.

Aerial Photography. Aerial photographs from 1938, 1972, and 1982 were compared to detect geomorphic and land-cover changes. The 1938 photograph was also compared to the 1975 DLG to determine geomorphic change. The
1972 photograph could not be removed from Fontenelle Forest Nature Center. It was analyzed by tracing the landcover patterns, roads, and railroads on an acetate.

Field Checks and Interviews. Field checks and interviews with present and past residents of the point confirmed changes indicated by the USACE maps as well as changes in land use and river movement.

Substrate Sampling

Substrate samples were obtained in both ridge and swale positions of the landscape in the study area north of the educational farm and in the vicinity of Hidden Lake south of the farm. The farm was not sampled since it was not involved in the USACE river stabilization process. Data from all sampled sites were recorded in a note book (except the Hidden Lake site data which were obtained from the USACE) and plotted (including Hidden Lake data) on graph paper for comparison between sites. Figure 13 is a map of all sample sites.

Due to the high water table, conventional augers were of little use for sampling the substrate. However, two samples (sites 1 and 2) were obtained using a vibracore. Vibracore equipment (figure 14) consists of a 4.5 m (15 ft) tripod which is used to guide a 5-10 m (15-30 ft) aluminum irrigation pipe. A concrete vibrator attached to the pipe produces enough vibration to sink the pipe into the ground. Since the ground must be saturated, a hand auger is first used to reach saturated material. As the pipe is inserted, water is poured onto the ground around the pipe to ensure saturation. The vibracore is normally used to sample sandy sediments and usually takes about five to ten minutes to sink a 4.5 m (15 ft) pipe. Once the sample is extracted, the pipe is bisected lengthwise
Fig. 13. Substrate Sites. Samples were obtained from both ridge and swale positions in the landscape on the north side of Gifford Point. Sites on the south side of the point are located in and along Hidden Lake.
using a circular saw to reveal the substrate core. A thin wire is then pulled along the length of the core to clean the face of the sediments.

The two vibracore samples were obtained from an area on the north side of Gifford Point along a north-south transect and were about 50 m (165 ft) apart. The first core (site 1) was taken from a low-lying swale near the base of a berm about 100 m (330 ft) from the river bank. Due to compaction and the difficulty penetrating clay, only slightly over 1 m (3.5 ft) of sediment was extracted. Site 2 was located on a small rise about 2 m (6.5 ft) higher than the swale and about 50 m (165 ft) south of the river bank. This site was augered almost 2 m (5.2 ft) before inserting the vibracore tube. The areas sampled (sites 1 and 2) were composed of silty clay interbedded with silty sand and sand. This made it difficult for the vibracore to penetrate the substrate; taking about twenty minutes to obtain a 2.5 m (8 ft) core. The dense clay caused each core to compact by about twenty-five percent. According to Thompson, et al. (1991), compaction is common, especially in wetlands where the compaction can be up to 50 percent. They (Thompson, et al., 1991) noted that most compaction occurred in the upper portions of the core.

Three sites were sampled by using a shovel to clean exposed surfaces or dig test holes. Two sites sampled on the north side of Gifford Point were located on ridged topography. One (site 3) was located on a sandy berm south of the river and the other (site 4) on the edge of a washed out jeep trail. Due to continuous slumping, only 1 m (3 ft) profiles of these two sites were studied. The substrate were visually examined at the river's edge (site 5) about 25 m (83 ft) north of the second vibracore site.
The USACE provided information on seven samples obtained from Hidden Lake and vicinity during September, 1992.

**Dendrochronological Techniques and Species Mapping.**

Dendrochronology, the science which studies the annual growth of layers (rings) in wood (Fritts, 1976), was used to determine species age. A tree (figure 15) is composed of: the pith at the center, the phloem which contains the food-conducting tissues in the bark, the cambium which is composed of a thin layer of meristematic tissue (small thin-walled cells capable of dividing found in all growing regions of the tree), and the xylem, the water-conducting tissue which comprises the area of the tree between the pith and the bark. Tracheids (figure 16) are vertically oriented xylem cells which have relatively thick walls.

Certain tree species in temperate zones react to seasonal changes in moisture and temperature by creating annual rings. These rings (figure 16) are composed of earlywood and latewood and can be reliable indicators of the age of the tree. Earlywood is characterized by light-colored, thin-walled tracheids while latewood is characterized by dark, thick tracheids. The tree's age can be determined by counting the rings. Samples are obtained by coring the tree or cutting a cross-section. While cross-sections provide the best results, coring does not kill the tree. In this study, cross-sections were taken only from fallen trees. Live trees were cored.

The ages of trees were obtained to aid in determining the approximate year in which portions of the point rose above the mean-flow level. Most trees in the study were sampled along a north-south transect on the north side of Gifford
Fig. 15. Cross Section of a Stem. The xylem forms new rings each year, permitting the age of the tree to be determined by counting the rings. Source: Stokes and Smiley (1968).

Fig. 16. Annual Ring Structure. The contrast between the latewood cells formed in the previous growing season and the earlywood cells formed during the next growing season sets the boundary of the annual ring. Source: Stokes and Smiley (1968).
Point (figure 17 and Appendix D). This site was chosen after extensive field study, because it contained similar topography to the other stabilized areas of the point and was easily accessible. Each species was sampled at least approximately at every 3 m (10 ft) or greater change in relief. Smaller changes would not be reflected on USGS 1:24,000 topographic maps and appeared to result from tree throws or minor flood events. Samples were also selectively taken on the east and south perimeters of the point to act as checks against the main study site.

Sampling and sample preparation were accomplished in accordance with Stokes and Smiley (1968) and Schweingruber (1987). The tree species, circumference, Global Positioning System (GPS) number (when available), date, tag number, and description of the site were recorded in a notebook for each tree (Appendix C). Each tree was tagged and each cross-section or core was labeled with the tag number, date, and tree species. Cross-sections were sawed from the downed trees. In most cases due to the large diameter of the trees sampled, only one quarter of the section was cut. However, in all cases cross-sections contained the area from the pith to the bark. Cross-sections were allowed to dry, then sanded and stained in the same manner as the cores. For trees which were cored, a five millimeter diameter increment borer was used to extract cores at breast height. The cores were stored in straws containing crushed moth balls to prevent mildew during storage. The straws were sealed with masking tape and labeled with tag number, date, and species. After collection, the cores were removed from the straws and mounted on grooved wooden blocks using wood glue. Each core was mounted with the tracheids at a forty-five degree angle to ensure a clear view of the rings. String was wrapped
Fig. 17. Sampled Tree Sites Annotated with Age and Species. The oldest trees were located on the most stable area of the point Near the farm. Trees along the river's edge generally averaged 25 to 34 years old, corresponding with stabilization work.
tightly around the core and block to prevent bending while drying. After drying, the cores were sanded beginning with coarse, 80 grit sandpaper and finishing with 1500 grit sandpaper.

After preparation, the rings were counted to obtain an approximate tree age. Rings were counted from the bark to the pith, marking every ten years to aid in counting. The age was calculated by subtracting the number of rings from the year in which the sample was taken. Not all samples provided an exact age, but did provide an 'at least as old as' result. Cottonwoods and sycamores tended to have diffuse rings which were difficult to read. When diffuse rings were encountered, a ceramic coffee mug was used to obtain better polishing. Finally if needed, stain was applied to enhance the ring structure. Walnut furniture oil worked best on cottonwood and lemon oil worked best on sycamore.

When possible, GPS measurements were obtained. At each site, approximately 100 measurements (consisting of latitude, longitude, and elevation) were recorded in the GPS unit's ASCII file recorder. The stored points were downloaded to a personal computer and analyzed using postprocessing software. Not all trees could be located in this manner because of canopy thickness. Those trees that weren't located using GPS were located on an USGS 1:24,000 DLG contour coverage of the point using the GPS sites as a guide.

The positions for the GPS sampled sites were corrected using data from the Environmental Protection Agency (EPA) base station in Kansas City, MO and a commercial site near Norfolk, NE. Corrections were accurate to within one to five meters. The corrected data were transformed into an ARC/INFO software coverage, projected, and overlaid on the USGS 1:24,000 DLG contour coverage
used for the non-GPS located sites. In this way, comparisons of relief and tree age could be made using ARCVIEW mapping software.
RESULTS

The Test of the Hypotheses

Hypothesis 1. The first hypothesis was that historic geomorphic changes could be visually observed on maps, aerial photography, and satellite images. Historical maps provided the most revealing information concerning lateral migration of the point. Figure 18 illustrates the shift in Gifford Point's orientation from northeast-southwest in the early 1800s to its current east-west position and how the point's dimensions nearly doubled in size. A comparison of the pre-stabilization maps to the current position of the point revealed that stabilization did have the most substantial effect on the point's morphology when compared to pre-stabilization. Between 1851 and 1928, the point shifted positions at least four times in a lateral migration to the south (figure 18). Lake Manawa, an oxbow lake on the Iowa side of the Missouri River was formed between in 1881 as a result of that lateral migration. After stabilization efforts began in the 1930s, the point no longer migrated with floods and has maintained its east-west position up until the present. The series of USACE maps (figure 9) best defines the growth of the point from the late 1930s to 1982.

Longitudinal bars, channels, and dikes resulting from USACE channelization work were evident on the 1938 aerial photograph (figure 19). The bars appeared to be covered with low growing vegetation, possibly willows and young cottonwoods. Hidden Lake was part of the river channel in the 1938 photograph. A small channel extended from north to south on the eastern portion of the point. According to Dr. Harold Gifford (personal comm. 1993), this
Fig. 18. Historical Lateral Movement of Gifford Point. Point boundaries are depicted as the right bank of the Missouri River. Lake Manawa (upper right) was formed when the river repositioned after a flood in 1881. The extensions to the point depicted in 1885 and 1913 represent areas of sand. Source: Garabrandt, USACE, USGS, Atlas of Douglas and Sarpy County, and Plat Book of Douglas and Sarpy County.
Fig. 19. Gifford Point 1938 Aerial Photograph Compared to 1975 DLG. Features labeled on the 1935 photograph are indicated by contours on the 1975 DLG. Source: Gleason (1995) and USGS (1975).
channel was known as the Little Missouri when his family occupied the point in
the early 1900s. In the 1975 DLG, the Little Missouri appeared to have been
absorbed into the main body of the point. Though no longer easily seen on
aerial photographs, field checks revealed a ditch with the remains of rotting
pilings where the Little Missouri once flowed. The remnants of the Little Missouri
were also visible on the 1975 DLG (as a stream).

**Hypothesis 2.** The second hypothesis was that landcover changes could
provide evidence of geomorphic change on Gifford Point. Dikes and drainage
channels installed by the USACE in the mid-1930s were easily identified on the
TM image. Associated soil moisture and biomass variations revealed old
channels and deposits surrounding the point. Elevated areas, composed of
Sarpy sand, produced a higher reflectance in bands 2 and 3, while lower
topographic areas, predominantly composed of clay and retaining more
moisture, had lower reflectance values. Tonal variations revealed by principal
component three appeared to be associated with poor soil drainage and the
spatial distribution of cottonwoods.

Vegetation growth patterns on aerial photographs appeared to reflect soil
and relief differences throughout the study area. Vegetation in the vicinity of the
Little Missouri channel consisted mainly of cottonwoods. A sandy berm
extending west to east along the north side of the point was revealed on aerial
photography because larger cottonwoods were growing in its well-drained soil.
Marshy areas appeared mottled on recent photography and TM imagery,
suggesting low growing vegetation. Landcover changes between 1938 and 1972
appeared to be the result of stabilization work, while those changes between
1972 and 1982 appeared to be the result of farming practices.
The Principal Component Three image (figure 20), while of limited value, did reveal an east-west line which represented a ditch constructed by the USACE during the 1930s. This ditch was not visible on aerial photographs or current maps, but field checks verified the remnants.

**Hypothesis 3.** The third hypothesis was that the substrate would reflect changes to the point caused by flood and stabilization. Samples of the substrate (figures 13, 21, and 22) suggest this is the case. Both site 1 and site 2 were located in an area of prone to frequent flooding. Figure 23 is a photograph (taken at site 2) of the area typical to both sites. Site 1 consisted almost entirely of mottled clay over mottled silt, while site 2 was predominantly mottled silt and clay in the upper one half of the profile, becoming silty sand with silt and sand interbedded in the lower one half of the profile. The mottling, extending from about 1.5 m (5 ft) from the surface at site 1 and reaching a depth of about 4 m (11 ft) at site 2, could be the result of a fluctuating water table. At site 2, the occurrence of silt and clay over the more sandy sediment could be attributed to overbank deposition after stabilization.

Site 3 (figure 24) consisted of structureless sand for at least a meter (3 feet), while site 4 (figure 25) was comprised of 0.75 m (2 ft) of structureless sand covered by a shallow (approximately .25 m (1 ft)) sandy-loam layer. Roots permeated this profile and may have been associated with a tree throw. The location of these sites in a high position in the landscape along with their sandy composition suggest the substrata at these sites may have originated as a sand bar.

Site 5 indicated a deposition regime similar to that of the vibracore sites. Clay dominated the top of the profile and sand the bottom. The entire profile
Fig. 20. 1985 Landsat Thematic Mapper (TM) Composite Image, and PC3 Image of Gifford Point. The original image provides some obvious landscape differences, such as the fields and roads. However the PC3 image provided the most information on underlying landform and landscape differences. A) Indication of channel remnants. A1) A drainage channel extending ENE-WSW. A2) Another channel remnant extending around the east end of the point. Field checks indicate both channels are now overgrown depressions clogged with flood debris. B) The edge of the original point perimeter when stabilization work began in the 1930s. C) Agricultural fields. D) Buildings. E) Railroad track. Source: University of Nebraska, Department of Geography.
Fig. 21. Gifford Point Substrata Sample Sites 1-5. Mottling suggests a fluctuating water table at sites 1, 2, and 5. Sites 1 and 2 were located in a swale, while sites 3 and 4 were located on a sandy berm. Site 5 reflects the substrate of the river bank north of sites 1 and 2. The sandy sediments in the lower 1.5m of site 2 may be the result of lateral river migration, while the clay in the upper portions of the profile suggests overbank or flood deposition.
Fig. 22. Gifford Point Substrata Sample Sites 6-12. These samples taken by the USACE in the vicinity of Hidden Lake are similar in structure to sites 1, 2, and 5 with clay dominating the upper profile and sand the lower. The two exceptions, sites 6 and 10, suggest anaerobic conditions at about 2m below the surface. Note that while this feature is mapped as a lake, it was cut off from the main river channel and contained very little water during the research period due to siltng.
Figure 23. Substrata Site 2.

Located on a slight rise just north of site 1, the area is vegetated with 30-40 year old cottonwood and mulberry. During the summer, mesophytic grasses grow to a height of over 1.5 meters (5 feet). Note the buried tree bases - indicators of a flood regime.
Figure 24. Substrata Sample Site 3.

A profile of structureless sand helps locate the remnants of a longitudinal bar now incorporated into the point as a berm.

Figure 25. Substrata Sample Site 4.

This sandy profile along the edge of a jeep trail has been covered with a shallow sandy-loam layer, possibly the result of vegetation and a tree throw.
(figure 26) consisted of a series of benches extending from the river surface to a height of approximately 2 meters (6 feet). Mottling was most common in the middle of the profile (figure 27) and evidence of past flooding could be seen throughout the profile. Figure 28 shows a clay layer covered by sand and then another layer of clay. The lower clay layer appeared to have been scoured (see contact) and then covered by sand. Roots extended throughout the upper 0.5 m (18 in) of the profile. Slumping was common all along the river bank and flood-trained trees imbedded in the bank were oriented north-south suggesting flow from the point to the river as flood waters receded.

Most samples taken by the USACE in the vicinity of Hidden Lake on the south side of Gifford Point (figures 13 and 22) revealed a similar structure to sites 1, 2, and 5 studied on the north side of the point. Clay dominated the upper 1-2 m (3-6 ft) of the profiles studied. The water table tended to be at about 1 m (3.3 ft) below the surface except at site 10 where the water table was at the surface. Since site 10 was not in the lake, the high water table could be caused by recent precipitation or the site may be located in a swale. Two sites (6 and 10) registered black clay at about 3.8 m (5 ft). The black coloration may have been caused by anaerobic processes in which there was not enough oxygen available for decomposition. Two other sites (7 and 10) graded to sandy silt (site 7) and sand (site 11) at about 3.8 meters (5 feet). The differences between the two sites with black clay and the two with sandy sediment could be attributed to the ridge and swale topography typical of point-bar topology.

Hypothesis 4. The fourth hypothesis was that tree age could be used to determine the most stable part of the point during the past 100 years. The age of trees located on Gifford Point (figure 17) appeared to reflect the change in
Figure 26. Profile of the North Bank of Gifford Point (Substrata Site 5).

Flood trained logs projecting form the bank at several levels present evidence of seasonal flooding. View is to the west.
Figure 27. Substrate Site 5 (upper profile).

Increased mottling toward the bottom of the photograph indicates a fluctuating water table.
Figure 28. Substrata Site 5 (middle profile).

A clay deposit just below the center of the photograph appears to have been scoured by flooding. The sand deposited on top fines upward into clay, suggesting overbank deposition and a loss of competence as the flood waters receded.
morphology since river channelization began in the 1930s. The oldest trees were located on the most stable part of the point near the educational farm.

This area contained the widest species variety, with old forest vegetation such as walnut beginning to appear in the late 1950's. Further evidence of this stability was provided when the dendrochronological map was overlaid on the historical maps (figure 29). It indicated the oldest trees (a sampled cottonwood of approximately 117 years among them) were located in this area. One tree destroyed by a wind storm during the research period was estimated by the farm manager to be 125 years old. It had been the largest tree on the point and the fourth largest cottonwood in Nebraska (Mann, personal comm. 1993). While size is not necessarily a good indicator of tree age, since trees of the same age can be of radically different sizes due to differences in site and situation, the location of this tree in the potentially most stable area of the point suggests that it could have been as old as estimated.

In the study area north of the farm, trees became progressively younger toward the river (figure 17). The oldest tree sampled near the river was a 34-year-old mulberry. This area (see figure 19) was a vegetated sandbar in the 1930's prior to stabilization. The sand bar may have been above the mean-flow level by 1938, but was most likely scoured by the 1952 flood. There was little change in tree age throughout the area in which dikes were installed in the 1930's, suggesting an unstable environment until enough sediment accreted to permit trees to maintain a foothold during flooding.
Fig. 29. Comparison of Tree Data to Historical Maps. Point boundaries are depicted as the right bank of the Missouri River. In a comparison of the dendrochronological data to the historical maps (1851-1976), the most stable surface depicted by the map series correlated with oldest trees sampled (65, 117, and 125 year old cottonwoods). This triangular area (outlined) of the point may have been the original point-bar core. Source: Garbrandt, USACE, USGS, Atlas of Douglas and Sarpy County, and Plat Book of Douglas and Sarpy County.
SUMMARY and CONCLUSIONS

Summary

Gifford Point, a 19th and 20th century point-bar complex located on the right bank of the Missouri River near Bellevue, Nebraska, was modified by the USACE in an effort to channelize the Missouri River between Sioux City, Iowa, and Rulo, Nebraska. This research investigated the geomorphic development of Gifford Point during the past 100 years and the effect on its development caused by anthropogenic intervention.

The study attempted to answer four questions. What was the historical movement of Gifford Point? Could landcover changes provide evidence of geomorphic change on Gifford Point? Could the substrate provide evidence of geomorphic change on Gifford Point? Could tree age provide an "at least as old as" age of stabilized surfaces on Gifford Point?

The Missouri River prior to stabilization has been described as frequently flooding with numerous sand bars and changing channel margins (Rufus, 1947). River channelization along the Missouri helped stabilize and increase the dimensions Gifford Point. Geomorphic change from the 1830s to present was evident in maps, aerial photography, and satellite imagery. Maps showed changes in point dimensions, while imagery also indicated a relationship between topography and vegetation. To interpret geomorphic change to the point, the problem was approached in several ways. The first was to determine the geomorphic history prior to river stabilization and compare that to the modern point dimensions. To determine historical movement, six previous positions of Gifford Point (1851, 1856, 1979, 1885, 1913, and 1928) were digitized and compared to a digitized 1975 United States Geological Survey (USGS) 1:24,000
scale, 71/2 minute quadrangle map. This map series, along with historical references made by visitors to the region during the 1800s and early 1900s, provided a picture of the constantly changing river channel prior to stabilization. It depicted Gifford Point's shift from a northeast-southwest orientation in the early 1800s to its current east-west position and illustrated how the point nearly doubled in size from its pre-stabilization dimensions.

Landcover changes across the point suggested a relationship between past positions of the point-bar complex and current vegetation. To assess development during and after stabilization, aerial photographs (1938, 1972, and 1982) were analyzed. The photograph comparisons revealed geomorphic and land-cover changes resulting from the USACE work to install dikes and revetments along the perimeter of the point as well as changes produced by farming and logging operations. The vegetation pattern provided clues to the underlying geomorphology. For example, marshy areas were once part of the old river channel. Berms, where less mesophytic vegetation was located, related to areas depicted as sand bars prior to stabilization. A 1985 Landsat Thematic Mapper (TM) image was compared to the aerial photographs to detect geomorphic changes.

The results suggested that while land-cover changes after 1972 can be attributed mainly to changing farming practices, landcover changes between 1938 and 1972 correlated with geomorphological changes to the point produced by USACE river stabilization work. Field size has varied since farming began in the late 1800s (Gifford, personal comm. 1993)) and center pivot irrigation was introduced during August of 1981 (Mann, personal comm. 1993). Flooding, an
increasing deer population, and silting of Hidden Lake and the Great Marsh also appeared to have affected vegetation patterns.

Field checks and interviews were conducted to verify information on the maps and aerial photographs. Substrate samples provided a picture of the point's geologic structure. Mottled clay interbedded with sand dominated the swales, while ridges were composed mainly of sand. In high-water-table areas such as Hidden Lake, clay dominated. Dendrochronology played a key role in estimating when surfaces of the point stabilized above the mean-annual-flow level. Global Positioning System (GPS) equipment was used as an aid in spatially locating sampled trees when possible. The ages of trees sampled along a transect from the center of the point to the river were plotted on a DLG, 1:24,000 scale, USGS contour map of Gifford Point. The tree ages reflected the effects of point-bar stabilization. The oldest tree sampled was 117 years old and was located on one of the most stable areas of the point near an agricultural area. Near the river, the oldest trees sampled averaged 40 years in age and corresponded with growth after the flood of 1952, the last major flood before channelization was complete.

Conclusions and Recommendations

The results of this study indicate that anthropogenic processes have produced the most substantial effects on Gifford Point during the past 100 years. The results also suggest that tree age corresponds well with point stabilization and can be used to estimate when surfaces first reached an elevation above-mean-annual flow. While this has been a fairly general study, it correlates with
previous work (Garabrandt, 1976) done in Fontenelle Forest and the loess bluffs located to the west of Gifford Point.

This research provides the ground work for more selective studies of the processes affecting the point's morphology. It also provides data which can be used in studies of floodplain communities, and as background material to aid decision makers conducting wetlands restoration along the Missouri River. Finally, this thesis provides a detailed analysis of an area of historical significance to the Bellevue area, adding another chapter to the development of Nebraska's oldest settlement.
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USACE Map of Gifford Point (1928). Provided in Xerox copy by Gary Garabrandt, Chief Forester, Fontenelle Forest Nature Center.

USACE (1935). Missouri River, Omaha Bend to Bellevue Reach (Map).

USACE (1936). Missouri River, Omaha Bend to Bellevue Reach (Map).

USACE (1937). Missouri River, Omaha Bend to Bellevue Reach (Map).

USACE (1939). Missouri River, Omaha Bend to Bellevue Reach (Map).


USGS Graph Depicting Missouri River Flow at Omaha, NE from 1928 to 1995 (1995). Obtained from USACE Hydrology Office at Omaha, NE.


APPENDIX A

Definitions of Terms

Abbreviations
Definitions of Terms

ARC/INFO. An interactive off-the-shelf software used to convert geographic location information into digital map displays.

ARCVIEW. An of-the-shelf software used to more easily view and manipulate ARC/INFO coverages.

Acre. An acre is the equivalent of 4,840 square yards. 640 acres are equal to one square mile.

Dendrochronology. The science which studies the annual growth of layers (rings) in wood (Fritts, 1976).

Historic - For this study, historic encompasses the time from 1850 to present.

Entisol. A young soil with little or no horizonation. These sediments are usually found in areas of little stability.

Geomorphology. The science of landforms, including their history and processes of origin (Strahler and Strahler, 1987).

Gigaton. A gigaton is the equivalent of $10^9$ tons or $10^{12}$ kilograms.

Hectare. A hectare is the equivalent of 10,000 square meters or 2.471 acres.

Kilogram. A kilogram is the equivalent of 1000 grams. One thousand kilograms equal a metric ton.
Abbreviations

°C. Degrees Celsius.
°F. Degrees Fahrenheit.
DLG. Digital Line Graph.
EPA. Environmental Protection Agency.
GIS. Geographic Information System.
GPS. Global Positioning System.
gt. Gigaton.
ft. Foot.
ha. Hectare.
kg. Kilogram.
km. Kilometer.
m. Meter.
mi. Mile.
msl. Mean sea level.
TM. Thematic Mapper.
UTM. Universal Transverse Mercator.
USACE. United States Army Corps of Engineers
yr. Year
yr BP. Years before present.
APPENDIX B

Tree Sample Data
## Tree Sample Data

<table>
<thead>
<tr>
<th>#</th>
<th>NAME</th>
<th>CIRCUM</th>
<th>SAMPLE</th>
<th>AGE</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>(in cm)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P012116A</td>
<td><strong>Cottonwood</strong></td>
<td>249cm</td>
<td>none</td>
<td></td>
<td>01/21/94 GP Office&lt;br&gt;01/21/94 SE end of main point at SE end of long hay meadow, SE of fallen tree and just N of road. W of # 503. LAT/LON 01/22/94</td>
</tr>
<tr>
<td>P012117A</td>
<td><strong>American Elm</strong></td>
<td>124cm core #9</td>
<td>28</td>
<td></td>
<td>11/16/93 Photo #12 West of #18 just below 1m drop from main point. This was the first Randy knew of Elms on this portion of the point. He also mentioned Dogwood is growing on the point. LAT/LON 01/21/94</td>
</tr>
<tr>
<td>P012116B</td>
<td><strong>Sycamore</strong></td>
<td>140cm</td>
<td>none</td>
<td></td>
<td>10/19/93 Low terrace ~400m N of office. West of White Tail trail.</td>
</tr>
<tr>
<td>P012220A</td>
<td><strong>Maple</strong></td>
<td>180cm</td>
<td>none</td>
<td></td>
<td>10/19/93 ~950m N of office. (Left white rope marker) Sandy soil. Stump sprouted.</td>
</tr>
<tr>
<td>P012117B</td>
<td><strong>Cottonwood</strong></td>
<td>307cm</td>
<td>none</td>
<td></td>
<td>10/19/93 On edge of berm just S of marsh. ~1010m N of office.</td>
</tr>
<tr>
<td>08</td>
<td><strong>Cottonwood</strong></td>
<td>249cm</td>
<td>none</td>
<td></td>
<td>09/28/93 Due south of Sycamore on berm. (some flare at base, but still evidence of burial.</td>
</tr>
<tr>
<td>11</td>
<td><strong>Sycamore</strong></td>
<td>140cm</td>
<td>none</td>
<td></td>
<td>10/19/93 ~950m N of office. (Left white rope marker) Sandy soil. Stump sprouted.</td>
</tr>
<tr>
<td>12</td>
<td><strong>Maple</strong></td>
<td>180cm</td>
<td>none</td>
<td></td>
<td>10/19/93 ~950m N of office. (Left white rope marker) Sandy soil. Stump sprouted.</td>
</tr>
<tr>
<td>13</td>
<td><strong>Cottonwood</strong></td>
<td>307cm</td>
<td>none</td>
<td></td>
<td>10/19/93 On edge of berm just S of marsh. ~1010m N of office.</td>
</tr>
<tr>
<td>14</td>
<td><strong>Cottonwood</strong></td>
<td>180cm</td>
<td>none</td>
<td></td>
<td>10/19/93 In marsh at base of berm. ~10m N of #13.</td>
</tr>
<tr>
<td>500</td>
<td><strong>Cottonwood</strong></td>
<td>333cm</td>
<td>none</td>
<td></td>
<td>01/22/94 Largest tree on point. Was fourth largest tree in NE until July storm. Marcy estimates age 125yr. LAT/LON 01/21/94</td>
</tr>
<tr>
<td>501</td>
<td><strong>Cottonwood</strong></td>
<td>333cm</td>
<td>none</td>
<td></td>
<td>01/21/94 South side of point. Near N-S road west of long hay meadow. Corer broke in tree. May have hit frozen area. Temp on Tue was -7F. By Fri, was 30F. LAT/LON 01/21/94</td>
</tr>
<tr>
<td>502</td>
<td><strong>American Elm</strong></td>
<td>124cm</td>
<td>core #9</td>
<td>28</td>
<td>11/16/93 Photo #12 West of #18 just below 1m drop from main point. This was the first Randy knew of Elms on this portion of the point. He also mentioned Dogwood is growing on the point. LAT/LON 01/21/94</td>
</tr>
</tbody>
</table>
Cottonwood 376cm section #8 64 11/16/93 Photos #6-#9. NW side of jeep trail on East end of point just below main point. Photo #4 shows road facing East. LAT/LON 01/21/94

Cottonwood 175cm core #5 37 11/08/93 Photos #1 and #3. North side of point near first vibracore. LAT/LON 01/21/94

Sycamore 188cm core #6 23 11/08/93 Photos #2 and #3. Just east of first vibracore. LAT/LON 01/21/94, but GPS battery low. Questionable reading.

Cottonwood 5' 1" core #7 20* 11/08/93 Photos #20 and #21. North side of point next to second vibracore. ~100m N of first vibracore. (~1 1/2" stuck in borer). LAT/LON 01/21/94

Cottonwood 9' 5" * section #2 117 08/10/93 Photo #13 south of Wandering Club across road. Fallen tree - measured circumference 17' 8" from base. LAT/LON 01/22/94

Catalpa 196cm core #1 30 08/10/93 Photo #8 north of Wandering Club near outhouse. LAT/LON 01/22/94

Cottonwood 579cm none 08/10/93 Photo #6 ~300m N of office. LAT/LON 01/22/94

Sycamore 419cm none 08/10/93 Photo #7 east of Wandering Club. LAT/LON 01/22/94

Mulberry 183cm none 08/10/93 Photo #9 north of Wandering Club east of outhouse. LAT/LON 01/22/94

Cottonwood 386cm none 08/10/93 Photo #10 just south of old river channel (Photos # 10 & #11) on Wandering Club trail northeast of club. LAT/LON 01/22/94

Black Walnut 239cm core #4 38 10/19/93 West side of road, NNE of office (chain around tree). LAT/LON 01/22/94

Sycamore 391cm none 10/19/93 West side of road ~300m NNE of office. N of walnut just before road curves east. LAT/LON 01/22/94
<table>
<thead>
<tr>
<th>Core</th>
<th>Species</th>
<th>Diameter</th>
<th>Core Type</th>
<th>Location Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>515</td>
<td>Sycamore</td>
<td>67 cm</td>
<td>core</td>
<td>05/05/94 On berm north side of point, ~35m west of 600.</td>
</tr>
<tr>
<td>P050517C</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>516</td>
<td>Maple</td>
<td>183 cm</td>
<td>core</td>
<td>05/05/94 At base of berm near 600 on north side of point.</td>
</tr>
<tr>
<td>P050518A</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>517</td>
<td>Mulberry</td>
<td>28 cm</td>
<td>core</td>
<td>05/05/94 On north side of point, north of second vibracore near river.</td>
</tr>
<tr>
<td>P050518B</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>518</td>
<td>Sycamore</td>
<td>104 cm</td>
<td>core #3</td>
<td>09/28/93 On north side of point near river. Remains of pilings just east on river. Across river from red trailer/green house. Evidence of flood burial/no flare.</td>
</tr>
<tr>
<td>P050519A</td>
<td></td>
<td>at 76 cm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>519</td>
<td>Mulberry</td>
<td>172 cm</td>
<td>none</td>
<td>05/16/94 Between 513 and 514 on west side of road northeast of office.</td>
</tr>
<tr>
<td>P051616E</td>
<td></td>
<td></td>
<td></td>
<td><strong>DIFF COR</strong></td>
</tr>
<tr>
<td>520</td>
<td>Maple</td>
<td>none</td>
<td></td>
<td>06/13/94 Next to office. Tried to core with 3ft corer. Center of tree was rotten and corer got stuck. Had to remove with a front-end loader.</td>
</tr>
<tr>
<td>521</td>
<td>Maple</td>
<td>core</td>
<td>31</td>
<td>05/18/94 South side of horse field. Just north of marsh and due south of office.</td>
</tr>
<tr>
<td>522</td>
<td>Hackberry</td>
<td>core</td>
<td>30</td>
<td>05/18/94 Due W of #521. South side of horse field. Just N of marsh and due south of office.</td>
</tr>
<tr>
<td>526</td>
<td>Willow</td>
<td>244 cm</td>
<td>core</td>
<td>06/15/94 East side of point, near dike across from power plant.</td>
</tr>
<tr>
<td>527</td>
<td>Cottonwood</td>
<td>222 cm</td>
<td>core</td>
<td>06/15/94 West of 526, still in swale. Core very wet. Difficult to remove entire core from tree. (Won't break at end of borer).</td>
</tr>
<tr>
<td>528</td>
<td>Cottonwood</td>
<td>193 cm</td>
<td>core</td>
<td>06/15/94 North of 527 on swale. Very wet core. See note in 527.</td>
</tr>
<tr>
<td>529</td>
<td>Cottonwood</td>
<td>223 cm</td>
<td>none</td>
<td>06/15/94 Northwest of 528 on west side of road. Too wet to obtain core. See note in 527.</td>
</tr>
<tr>
<td>530</td>
<td>Hackberry</td>
<td>268</td>
<td>none</td>
<td>02/02/95 On S side of road to Educational Area. Just W of corn field trash can (Photo #1).</td>
</tr>
<tr>
<td>P020220A</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>531</td>
<td>Maple</td>
<td>121 cm</td>
<td>core</td>
<td>02/02/95 N side of road just past trail to Education Area (Photo #2-3).</td>
</tr>
<tr>
<td>P020221A</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>532</td>
<td>Cottonwood</td>
<td>236 cm</td>
<td>none</td>
<td>02/02/95 N side of road just past trail to Education Area Same area as #531. Took photo #3 of dike and alluvium.</td>
</tr>
<tr>
<td>P020221B</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ID</td>
<td>Species</td>
<td>Diameter</td>
<td>Condition</td>
<td>Date</td>
</tr>
<tr>
<td>------</td>
<td>------------</td>
<td>----------</td>
<td>-----------</td>
<td>--------</td>
</tr>
<tr>
<td>533</td>
<td>Cottonwood</td>
<td>380 cm</td>
<td>none</td>
<td>02/02/95</td>
</tr>
<tr>
<td>534</td>
<td>Maple</td>
<td>174 cm</td>
<td>none</td>
<td>02/02/95</td>
</tr>
<tr>
<td>535</td>
<td>Sycamore</td>
<td>256 cm</td>
<td>none</td>
<td>02/02/95</td>
</tr>
<tr>
<td>536</td>
<td>Cottonwood</td>
<td>481 cm</td>
<td>none</td>
<td>04/05/95</td>
</tr>
<tr>
<td>537</td>
<td>Cottonwood</td>
<td>254 cm</td>
<td>section</td>
<td>06/95</td>
</tr>
<tr>
<td>538</td>
<td>Cottonwood</td>
<td>231 cm</td>
<td>section</td>
<td>06/95</td>
</tr>
<tr>
<td>539</td>
<td>Cottonwood</td>
<td>211 cm</td>
<td>none</td>
<td>06/95</td>
</tr>
<tr>
<td>540</td>
<td>Maple</td>
<td>262 cm</td>
<td>core</td>
<td>05/12/95</td>
</tr>
<tr>
<td>541</td>
<td>Cottonwood</td>
<td>383 cm</td>
<td>none</td>
<td>04/06/95</td>
</tr>
<tr>
<td>542</td>
<td>Cottonwood</td>
<td>191 cm</td>
<td>core</td>
<td>05/12/95</td>
</tr>
<tr>
<td>543</td>
<td>Maple</td>
<td>163 cm</td>
<td>none</td>
<td>04/06/95</td>
</tr>
<tr>
<td>544</td>
<td>Cottonwood</td>
<td>163 cm</td>
<td>section</td>
<td>06/95</td>
</tr>
<tr>
<td>545</td>
<td>Mulberry</td>
<td>79 cm</td>
<td>section</td>
<td>06/95</td>
</tr>
<tr>
<td>546</td>
<td>Cottonwood</td>
<td>183 cm</td>
<td>core</td>
<td>05/12/95</td>
</tr>
<tr>
<td>547</td>
<td>Cottonwood</td>
<td>324 cm</td>
<td>none</td>
<td>04/06/95</td>
</tr>
<tr>
<td>No.</td>
<td>Species</td>
<td>Diameter</td>
<td>Notes</td>
<td></td>
</tr>
<tr>
<td>------</td>
<td>-------------</td>
<td>----------</td>
<td>-------------------------------------</td>
<td></td>
</tr>
<tr>
<td>548</td>
<td>Elm</td>
<td>134cm</td>
<td>04/06/95 Near bottom of slope, S edge of marsh, directly N of #547.</td>
<td></td>
</tr>
<tr>
<td>549</td>
<td>Cottonwood</td>
<td>199cm</td>
<td>04/06/95 In marsh, N of #548.</td>
<td></td>
</tr>
<tr>
<td>550</td>
<td>Cottonwood</td>
<td>200cm</td>
<td>04/06/95 In marsh, N of #549.</td>
<td></td>
</tr>
<tr>
<td>551</td>
<td>Willow</td>
<td>128cm</td>
<td>04/06/95 N of #550 about 50m S of river.</td>
<td></td>
</tr>
<tr>
<td>552</td>
<td>Mulberry</td>
<td>100cm</td>
<td>04/06/95 Due W of #532. N of perimeter road, E of trail to vibracone site.</td>
<td></td>
</tr>
<tr>
<td>553</td>
<td>Mulberry</td>
<td>105cm</td>
<td>04/06/95 Due w of #552. N of perimeter road, E of trail to vibracone site.</td>
<td></td>
</tr>
<tr>
<td>554</td>
<td>Cottonwood</td>
<td>170cm</td>
<td>04/06/95 South of road, due W of #553. E of trail to vibracone site.</td>
<td></td>
</tr>
<tr>
<td>555</td>
<td>Cottonwood</td>
<td>183cm</td>
<td>04/06/95 N of volksmarch area ~5m SW of #554.</td>
<td></td>
</tr>
<tr>
<td>556</td>
<td>Cottonwood</td>
<td>177cm</td>
<td>04/06/95 N of volksmarch area ~15m WNW of #555.</td>
<td></td>
</tr>
<tr>
<td>557</td>
<td>Maple</td>
<td>195cm</td>
<td>04/06/95 N of volksmarch area, just E of #554.</td>
<td></td>
</tr>
<tr>
<td>558</td>
<td>Cottonwood</td>
<td>190cm</td>
<td>04/06/95 N of volksmarch area NW #556.</td>
<td></td>
</tr>
<tr>
<td>559</td>
<td>Mulberry</td>
<td>136cm</td>
<td>04/06/95 N of volksmarch area W of #558.</td>
<td></td>
</tr>
<tr>
<td>560</td>
<td>Cottonwood</td>
<td>303cm</td>
<td>04/06/95 N of volksmarch area W of #559.</td>
<td></td>
</tr>
<tr>
<td>561</td>
<td>Mulberry</td>
<td>150cm</td>
<td>04/06/95 N of volksmarch area ~20m E of #560.</td>
<td></td>
</tr>
<tr>
<td>562</td>
<td>Hackberry</td>
<td>107cm</td>
<td>04/06/95 N of volksmarch area. E of #561.</td>
<td></td>
</tr>
<tr>
<td>563</td>
<td>Ash</td>
<td>138cm</td>
<td>06/95 At base of berm almost in marsh N of volksmarch area. ~15m N of #548.</td>
<td></td>
</tr>
<tr>
<td>Code</td>
<td>Species</td>
<td>Location</td>
<td>Year/Timestamp</td>
<td>Notes</td>
</tr>
<tr>
<td>-------</td>
<td>-------------</td>
<td>------------------</td>
<td>----------------------</td>
<td>----------------------------------------------------------------------</td>
</tr>
<tr>
<td>565</td>
<td>Mulberry</td>
<td>section 23</td>
<td>06/95 E of #564 on berm just S of trail.</td>
<td></td>
</tr>
<tr>
<td>600</td>
<td>Cottonwood</td>
<td>236cm core 45</td>
<td>05/05/94 On berm on north side of point next to trail.</td>
<td></td>
</tr>
<tr>
<td>601</td>
<td>Mulberry</td>
<td>section 57</td>
<td>08/10/93 Fallen west side of road to retreat house. Across road from #507.</td>
<td></td>
</tr>
</tbody>
</table>