The Doan Brook Handbook

Laura C. Gooch

THE NATURE CENTER AT SHAKER LAKES

CLEVELAND, OHIO

First Edition

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To Mary Elizabeth Croxton, Jean Eakin, Betty Miller, and all the women of the garden clubs.

Without you there would be little left to say about Doan Brook.

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The brook as it passes through a layer of Euclid Bluestone in the Doan Brook gorge. Photograph by L.C. Gooch.

A Brook in the City

The farmhouse lingers, though averse to square
With the new city street it has to wear
A number in. But what about the brook
That held the house as in an elbow-crook?
I ask as one who knew the brook, its strength
And impulse, having dipped a finger length
And made it leap my knuckle, having tossed
A flower to try its currents where they crossed.
The meadow grass could be cemented down
From growing under pavements of a town;
The apple trees be sent to hearth-stone flame.
Is water wood to serve a brook the same?
How else dispose of an immortal force
No longer needed? Staunch it at its source
With cinder loads dumped down? The brook was thrown
Deep in a sewer dungeon under stone
In fetid darkness still to live and run –
And all for nothing it had ever done
Except forget to go in fear perhaps.
No one would know except for ancient maps
That such a brook ran water. But I wonder
If from its being kept forever under
The thoughts may not have risen that so keep
This new-built city from both work and sleep.

— Robert Frost

1 Introduction to Doan Brook

Doan Brook…A small, seemingly insignificant, creek in the midst of a city. Hardly worthy of mention, much less of a book all its own. And yet, Doan Brook has claimed the attention of the people around it for over two hundred years. It has been a focus of the community ever since 1799, when Nathaniel Doan settled his family by the stream and built a tavern at a ford. The village around Doan's tavern on the brook rivaled the city of Cleveland for more than one hundred years. A few miles upstream from the tavern, the North Union Shakers made their living from the brook and saw the reflection of God in its natural beauty. Later, as Cleveland grew, philanthropists recognized the Doan Brook valley as the perfect place for a line of parks to provide respite for harried city folk. They gave the Doan Brook parks as a gift to the people of greater Cleveland. Later still, the brook's neighbors rallied to defeat a planned Interstate freeway that threatened to replace the peace of those parks with the roar of traffic.

Today, Doan Brook remains an oasis in the heart of the city. Parks line its banks from Lake Erie to Shaker Heights. Migrating birds pause along the stream, and deer browse in the underbrush. Hikers explore its valley while strollers enjoy the lakeshores. But the brook is no longer as it was when Nathaniel Doan came here, or even as it was when the philanthropists first gave us the parks that line its banks. The growth of the city has chipped away at the parks and sullied the stream. There are few fish left, and the lakes sometimes stink in summer. It is rarely wise to wade or swim in the brook's polluted water. We were given the stream as a gift, but it is threatened by our very presence around it. We must deflect the threat if we are to pass on the gift.

This handbook is the story of Doan Brook and its watershed. That story is one not only of human settlement, but also of the stream's relationship with the landscape and city around it and of the creatures that make their lives along it. The story of the brook's past and present ends with a question: What can we do now to preserve and restore what we have been given? The *Handbook* begins to answer that question by outlining some actions that we can take and suggesting ways that we can make restoration of the brook a reality.

Not everyone who picks up *The Doan Brook Handbook* will read it cover to cover. Some may be more interested in the watershed's history, others in its biology or geology, others in the possibilities for the stream's restoration. Appendices give detailed information about the brook for those who wish to dig deeper. Our hope is that the *Handbook* will help many people enjoy and appreciate what the brook has to offer and, even more, that it will serve as a common foundation for all those seeking to preserve and restore Doan Brook.

Horseshoe Lake dam from downstream – 1900. Photograph by L. Baus. From the collection of the Nature Center at Shaker Lakes.

This land was heavily timbered. — and a prodigal use was made of its contents. Little did we dream then of Cleveland's rapid growth, would in a few years demand all our saw timber, and a great deal more than we could produce. A deep regret was felt at the time of being obliged to burn up so much valuable saw timber to clear the land. But this was the best could be done at that time — we needed the land more than we did the timber.

— Shaker Elder James Prescott

The History of North Union: Containing the Origin, Rise, and Progress of the Community, from 1822 to 1879

2 The Hand of Man: The Human History of Doan Brook

Around 1800, several cities began to emerge slowly from the unbroken wilderness on the south shore of Lake Erie. Moses Cleaveland established one of these early settlements near the mouth of the Cuyahoga River in 1796. Mosquitoes that inhabited the river's swampy mouth tormented the first pioneers who came to this settlement, which was to become the city of Cleveland. Miserable, ill, and plagued with malaria, some of the settlers soon sought a healthier environment.

Within three years of Moses Cleaveland's arrival, some of these refugees from the ague founded a settlement near a small brook about four miles to the east of the Cuyahoga River. This village and the adjacent stream took on the name of the first settlers, the Doan family. Doan's Corners and Doan Brook were born. For the next 100 years, Doan's Corners — and the other communities that were soon to appear along the brook — prospered and maintained identities distinct from the larger city to the west. The brook was a critical resource for the early settlers, who relied on it for water and power and harvested the natural resources it supported.

Eventually, the thriving city of Cleveland expanded and merged with the communities in the Doan Brook watershed. The stream suffered as the city grew, but the brook continued to serve as the focus of an impressive park system, and its valley drew many of Cleveland's cultural institutions. This is the story of our predecessors in the Doan Brook watershed and of how they molded the watershed and the brook into the shape we see today.

2.1 Who Was Here First? Pre-European History

The first European settlers who came to the Cleveland area entered an uninhabited landscape with few traces of earlier occupation. They followed Native American trails through the area and encountered some Native Americans of the Ottawa tribe, but found no settlements of any kind in the immediate vicinity of Cleveland. The closest Native American settlements lay west of the Cuyahoga River and to the south along the Middle Cuyahoga.

Although few obvious traces remained to be found by the first Europeans, there is evidence that Native Americans had once lived in northeast Ohio, possibly beginning as long ago as 12,500 B.C.E.[1] Some of these people, whose origin is unknown, may well have made the Doan Brook valley their home. Sand ridges along the Lake Erie shore, the shores of small ponds and bogs, and the headwaters of small streams such as Doan Brook would have been attractive locations for the spring agricultural camps of the hunter-gatherers who occupied northern Ohio between about 100 and 700 C.E.[2] More permanent communities, which began to appear in the area around 1000 C.E., tended to be strategically located on steep-sided promontories overlooking the Cuyahoga Valley. The modest Doan Brook valley was probably ill-suited for the settlements of this period. Mysteriously, occupation of the permanent Native American sites near Cleveland seems to have stopped around 1640 C.E., without evidence of deliberate destruction or any European contact. After these settlements were abandoned, the area

1 Before the Common Era. Equivalent to B.C. when used with dates.

2 Common Era. Equivalent to A.D. when used with dates.

Definitions and Orientation

The fold-out figure in Chapter 3 shows an overall map of the Doan Brook and its watershed that supplements the maps in this chapter. The *watershed* is the area of land that drains into the stream. See Chapter 3 for a more detailed definition. The *upper Doan Brook* is the part of the brook that lies on the higher land upstream from the steep hill that cuts across the brook near the intersection of North Park Boulevard with Martin Luther King, Jr., Boulevard. The *upper watershed*, which lies mostly in Cleveland Heights and Shaker Heights, is the part of the watershed on the high ground east of this hill. The *lower Doan Brook* runs north from University Circle through Rockefeller Park and into Lake Erie in Gordon Park. The *lower watershed* surrounds the brook in these areas. The *Doan Brook gorge* is a deep channel (as much as fifty feet deep) that the stream cuts into the rock as it makes its way between the upper and lower watersheds. The gorge lies between the Lower Shaker Lake and University Circle.

remained essentially uninhabited until a few members of the Ottawa tribe migrated from the west in about 1740.

The Native Americans who passed through the Doan Brook watershed left little physical evidence of their presence. Among the few definite signs remaining when Europeans arrived were the Indian path that crossed Doan Brook at what later became Euclid Avenue and an earthen vessel filled with arrowheads that was found in the mid-1800s near what is now the intersection of Ansel and East 101st Streets. These tokens seem sadly insignificant to be the only reminders of the many peoples who may have lived here at different times over a period of more than 14,000 years. Other evidence of their lives may have been destroyed by early European settlers and later construction, or it may still lie within the watershed waiting to be found.

2.2 European Explorers: Moses Cleaveland and the Surveyors

The surveyors of Moses Cleaveland's 1796 Connecticut Land Company surveying party were the first known Europeans to explore the Doan Brook watershed. Although exploration of an untamed wilderness seems romantic, Cleaveland's party came to northeastern Ohio for purely commercial reasons. The Connecticut Land Company was in possession of property it wished to sell, and that property had to be divided into townships and lots before sales could begin. The task of the surveyors was to partition the land for sale.

The territory belonging to the Connecticut Land Company consisted of a sixty-mile wide strip of land extending along the Lake Erie shore from the eastern boundaries of what are now Sandusky and Seneca Counties to the Pennsylvania border. In 1786, Connecticut reserved this land for development by the state, and in 1795 the state sold the area, which came to be known as the Connecticut Western Reserve, to the Connecticut Land Company.

Although the Iroquois had previously ceded the portion of the Connecticut Western Reserve east of the Cuyahoga River to the King of England, a party of Iroquois claiming title to the land intercepted Moses Cleaveland's surveying party as they neared the Western Reserve. In negotiations near present-day Buffalo, New York, Cleaveland repurchased the tract for $1,250 (New York trade currency), two beef cattle, and one hundred gallons of whiskey.

Cleaveland's surveyors began their work in the Western Reserve in 1796 and returned in 1797 (without Moses Cleaveland) to complete the survey. They worked in the Doan Brook watershed in both years, with most of its survey apparently completed in 1797. The surveyors' interest in the watershed was purely professional — it was merely one small part of the immense and difficult landscape they were hired to traverse. As they trudged back and forth across the area, laying down the grid of townships and lots for their masters in Connecticut, they dutifully recorded the condition of the country they encountered.[3]

> *Friday 9 June 1797 — Cleaveland: Major Shepard & Esq. Warren returned from their tour. They report that…they travelled on the South & the East part of No 7 — 11th Range [the northern part of the upper Doan Brook watershed]. Also over the North part of S[ai]d town. They Report that their whole rout on this town was over Choice Land gentle Rises & descents plenty of small Creeks or runs of water not sufficiently large for mill — timber*

3 Some punctuation and capitalization have been added for clarity.

Chestnut some Hard Maple. Plenty White wood. Elm. Ash, butternut, some beech. Maple. Elm, Hickory, Oak Red & White, Bass, Cucumber, Cherry & vast quantity of Grape Vines & a fine growth of herbage — Creek have all stoney bottom & excellent water…

— Surveyor Seth Pease, 1797

Although much of the land the surveyors encountered appeared to them to be suitable farm land, they had no doubt that it needed to be tamed before it would be comfortably habitable. For themselves, they found conditions difficult and deadly in the dense forest that was pock-marked with swamps and inhabited by bears, rattlesnakes, wolves, and malaria-bearing mosquitoes. The surveyors' journals intermingle accounts of mundane details with those of hardship and death:[3]

Monday 12th June [1797]…Atwater came up with the horses… He just before had killed 8 Rattle Snakes — 6 of which he brought with him to cook… Thursday morning 22nd of June… we were much troubled with Pond & Swamps on our line. We run but about 1-1/2 Miles — & Incamped by a bad Swamp[4] — Musketoes & Gnats very troublesome… Friday 7th July — Mr. Redfield took the compass — I was so ill as not to be able to assist. I took some Reubarb[5] but it did not operate… Saturday 15th July — Our men are employed in washing & mending their clothes. This day our old frend Pontiock came to our Camp with 2 other Indians — & a Squaw & 3 pappooses … Sunday 16th July…This morning our horse called Copperbottom died of the blind Staggers… Wednesday the 19th, 1797… Saml Spafford found a swarm of Bees in a tree. The men soon cut down the tree & took the honey — which was sufficient to give us a meal. Monday 24th July… Miner Bicknals [Minor Bicknall]… [was] taken of a violent fever. They were conveying him on an horse litter to the Cuyahoga River…I immediate made preparation to have them met by a boat at that Place…Tuesday 25th — The boat… arrived at the appointed Place about 3 OC PM — Atwater had reached the River with Bignal [Bicknall] about 2 hours before their [the boat's] arrival. He died about 10 minutes after they got him to the River. They buried as decently as their situation would permit… Sunday 6th August 1797…Peleg Washburn (an apprentice boy to Mr. Doane) died at 1 hour & 30' PM of the Dysintery. We buried him at evening…

— Surveyor Seth Pease, 1797

In October 1797, the second surveying party, still including many ill, sailed east along Lake Erie to return to the civilized country on the Atlantic coast. In spite of the report of an inhospitable land that some of the surveyors must have given when they returned home, there were many in the east who waited eagerly for an opportunity to make some portion of this new country their own. Only three years after the initial survey, the Connecticut Land Company sold a parcel in the Doan Brook watershed to Nathaniel and Sarah Doan, who settled there with their nephew and six children.

2.3 First European Settlers: Nathaniel Doan and the Lower Watershed

Nathaniel Doan (or Doane) was a blacksmith for the 1797 Connecticut Land Company surveying party. In spite of all of the surveyors' hardships, he must have liked what he saw of the Connecticut Western Reserve, because he returned to the area with his family in 1798. They settled first on Superior Street near the Cuyahoga River on property granted to Doan by the Connecticut Land Company on the condition that he operate a blacksmith shop there. However, the mosquitoes and resulting malaria quickly drove the family away from its land grant on the river. After less than a year, they resettled on one-hundred purchased acres on the north side of what is now Euclid Avenue between East 105th and 107th Streets (see Figure 2-1). This spot (now occupied by the Ronald McDonald House) became known as "Doan's Corners" and soon became a gathering place for other local settlers. It was also the ford where travelers along the main east-west artery between Buffalo and Cleveland crossed Doan Brook.

Although the community at Doan's Corners grew steadily, the surrounding wilderness isolated it from the still-small settlement at Cleveland. At first, the Doans' only neighbors were a few families on Woodland Hills Avenue (now Woodhill Avenue) to the south and a single settler near what is now Euclid and East 55th Street. Wolves are reported to have attacked travelers between Doan's Corners and Cleveland as late as 1820.

There was soon a sizable village at Doan's Corners, as well as a number of farms in the lower watershed in what are now the Cleveland neighborhoods of Glenville and Hough.[6] Nathaniel Doan and his neighbors were quick to open businesses to support the growing community. Shortly after he settled at the Corners, Doan built a hotel and tavern to serve travelers along the Buffalo-Cleveland road. He and other settlers quickly built a store, a blacksmith shop, a church and school, and a saleratus (baking soda) factory near the ford.

4 Caroline Piercy indicates in *The Valley of God's Pleasure* that this camp was near the current location of the Lower Shaker Lake. Careful examination of the surveyors' notes indicates that this is not the case.

5 Rhubarb (spelled reubarb by Pease) has a laxative effect. It and other similar herbal laxatives and emetics were used by the surveyors to combat fever and chills and a variety of other ills. It is not clear what Pease's illness was, but he complained of headache, back ache, and fever and may have been suffering from malaria.

6 The lower watershed north of Superior Road lies in Glenville. South of Superior, the western edge of the lower watershed lies in Hough, with the remainder in University Circle.

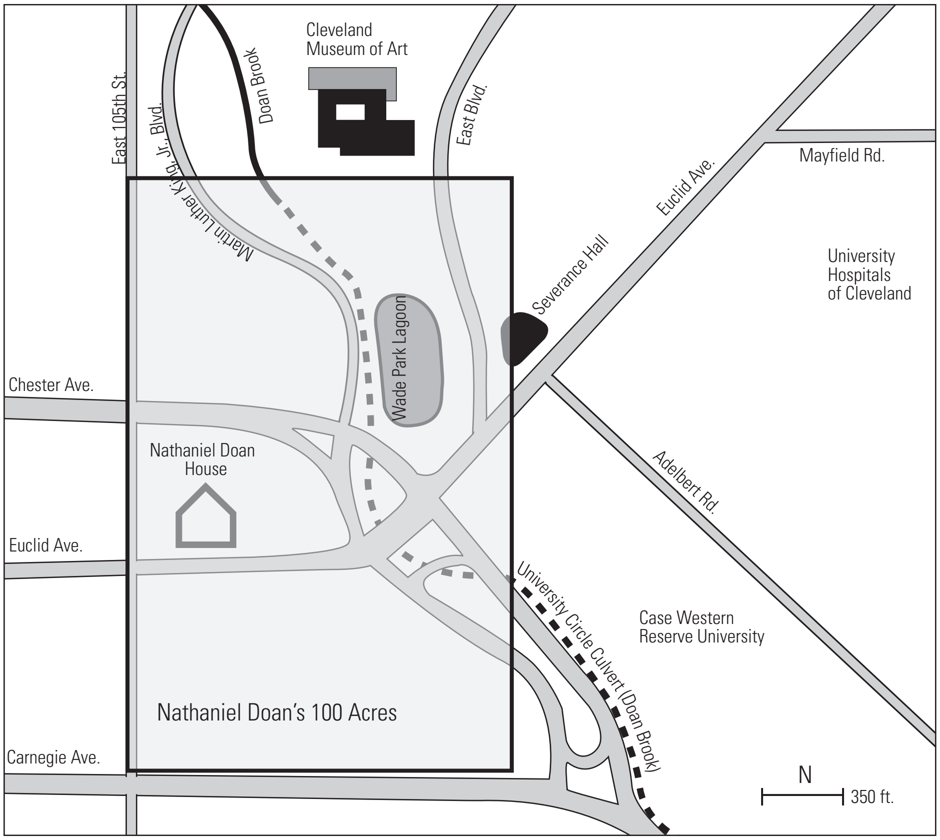


Figure 2-1 Nathaniel Doan's Original Land

The growth of industry was not far behind. Since processed grain and sawn lumber were fundamental to the society, a grist mill and a sawmill were among the first industries. The grist mill was located near the current Wade Park Lagoon and was operated by Samuel Cozad. The Crawford dam and sawmill were located near Superior Avenue. A tannery, a clock factory, a plant for the manufacture of oil from coal, a malleable iron foundry, a mowing machine company, and a sorghum mill were also established in the lower watershed at various times before the mid-nineteenth century.

An attempt was made at some point to drill for oil in Wade Park, resulting in nothing but an oily smell and some natural gas at a depth of 1,300 feet. Sandstone was quarried from the Doan Brook gorge near the top of Cedar Glen.[7] In 1834 or 1835 the first railroad in Cleveland was built to carry stone from the quarry to Public Square. Gravity pulled the loaded cars down the hill from the quarry. Elsewhere, the cars were pulled along the tracks by horses. The line, which crossed the brook on an embankment at Euclid Avenue, met with limited success and was abandoned after a few years.

A number of springs fed Doan Brook near Doan's Corners. One, in what is now the Cleveland Botanical Garden's Japanese Garden, was long used as a source of drinking water (see Section 3.3). Another, which came from the escarpment just north of Cedar Glen, had a high sulfur content and was believed to have therapeutic properties. Dr. Nathan Ambler and Daniel Caswell built the Blue Rock Spring House on this site (now the location of Case Western Reserve University's Emerson Gym) in the 1880s. The spring house, which had baths carved into the rock of the escarpment, was used first as a resort and then as a sanitarium offering patrons the "water cure."

Even as the community and industry around Doan's Corners grew, the lower watershed continued to be dominated by farms. The area north of Doan's Corners was settled first by farmers from New England, then by immigrants from Scotland, Ireland, and England. Around 1870, the Village of Glenville came into its own as the hub of the thriving farming community. Centered at East 105th Street and St. Clair Avenue, the village was surrounded by truck farms (owned primarily by German-Americans) that supplied produce to Cleveland. At the same time, the village became the home of the later-famous Glenville Racetrack, located along St. Clair between East 88th and East 101st Streets. During the 1890s, the picturesque landscape of the lower Doan Brook valley, the racetrack, and the nearby Lake Erie shore made Glenville a fashionable summer residence for wealthy Clevelanders.

Throughout the nineteenth century, Doan's Corners and Glenville retained their own village characters and the lower watershed

7 Cedar Glen is the steep valley along Cedar Road between the intersection of Cedar with Euclid Heights Boulevard and the point where Cedar passes under the rapid transit and railroad tracks. A tributary to Doan Brook that once flowed through this valley is now hidden in a sewer beneath the road.

remained largely rural. The villages served as important meeting and trading points for people living in the surrounding areas, including the Shakers and others who lived in the upper Doan Brook watershed. By 1900, however, the city of Cleveland had begun to absorb the villages, gradually eclipsing their original identities. Doan's Corners evolved into the University Circle cultural center, while Glenville became an affluent Cleveland garden suburb.

2.4 The Valley of God's Pleasure: The Shakers and the Upper Watershed

While Nathaniel Doan and his neighbors were settling in the lower watershed, a rather different community was making its home along the upper reaches of Doan Brook. Beginning in 1822, the Shakers, a utopian Christian sect, lived and farmed along the brook between today's Warrensville Center Road and Martin Luther King, Jr., Boulevard. They were the primary occupants of the upper watershed for almost seventy years.

Although the Shakers were eventually the upper watershed's principal land-holders, they were not its first settlers. In 1810, Daniel and Margaret Warren settled near its southern boundary, close to the current intersection of Lee and Kinsman Roads. In 1811, the Warrens were joined by eight members of Margaret's family, the Prentisses, and in 1812 twenty members of the Jacob Russell family settled about a mile farther north, near the current intersection of Lee Road and South Park Boulevard, just south of Doan Brook. The township was named Warrensville Township in 1816 in honor of the first settlers.

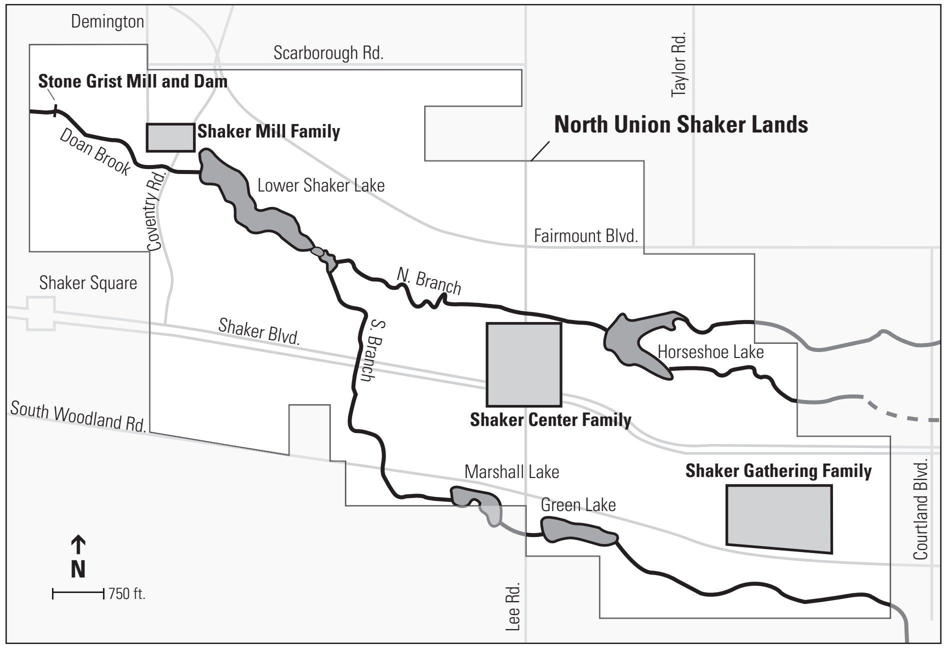


Figure 2-2 North Union Shaker Lands and Communities
Based on Mead 1961 from the collection of the Shaker Historical Society, Nord Library, Shaker Heights, Ohio.

The hardships of the early settlers are best seen through the eyes of Melinda Russell, granddaughter of Jacob Russell, who was about eight years old when she arrived in Warrensville Township in 1813:

> *Our journey was attended with great suffering, my youngest sister was sick all the way, dying three days after our arrival… Father was taken sick with ague the next day after we arrived, so our house was built slowly, and with the greatest difficulty mother hewed with an adze the stub ends of the floor boards, and put them down with the little help father could give her. We moved in the last of November, without a door or window, using blankets for night protection. At that time two of the children were sick with ague. Father worked when the chills and fever left him for the day, putting poles together in the form of bedsteads, and a table, upon which to put the little we could get to eat, and benches to sit upon; there was no cabinet shop at that time where such articles could be purchased.*
>
> *…The only flour we could get…was so disgusting to the taste, that no one could eat it unless compelled by extreme hunger. I was then eight years old and not sick, so I had to satisfy my hunger with it, and give the others more of a chance at the scanty corn meal rations…I once or twice obtained surreptitiously a little cold mush, father said that although he could never countenance stealing, he did not blame me for that. I often wondered why he cried when he sat down at the table, and looked at the food; the johnny-cake*

Who Were the North Union Shakers?

The Shaker order is a Christian sect, formally called The Millenium Church of United Believers, founded in England by Mother Ann Lee during the latter part of the eighteenth century. The fundamental principles of the order are commitment to God, separation from the secular world, celibacy and sexual equality, confession of sin, and communal living. Those who joined the North Union Shakers committed themselves to daily religious observance, a communal life with those of the same sex, strict separation from those of the opposite sex, and hard work under the direction of community leaders.

At North Union, Shaker men and women met each other only in groups, could not touch each other under any circumstances, and could not correspond with each other. The children of families who joined the Shakers were treated well, but they were separated from their parents and taken to live in the community's "children's houses." The Shakers also took in and cared for many orphans.

All Shaker activities were directed by elders and eldresses. The leading elders of the North Union Shakers were appointed by church authorities in other Shaker communities, and they frequently came to North Union specifically to assume leadership positions.

The Shakers' beliefs were carried out in the plan and construction of their communities.

The commitment to communal living is reflected in the presence of a relatively small number of large dwellings in a typical Shaker village. As one observer remembered the North Union Center Family settlement in about 1870, there were four dwelling houses in the village. One housed the elders and eldresses (in separated quarters), another the adult "family" members, another the boys, and still another the girls. A large meeting house where religious services were held was the focus of the community.

The Shaker commitment to industrious labor is indicated by the large number of "shop" buildings in each village. The North Union Center Family village included a woolen mill and broom factory, a blacksmith shop, a tannery, a carpenter shop, a bee house, a cheese house, a smoke house, numerous barns to support the community's agriculture, and a plant nursery. The Shakers were known for their honesty, and their work was known for its quality and well thought-out, sometimes innovative design. They believed that all work was performed for the glory of God and therefore strove for perfection in every task.

Today, Sabbathday Lake, Maine, is the only remaining Shaker community. Fewer than a dozen Shakers make their home there.

and mush appeared so luscious to my hungry eyes…Toward the end of February…father and one of his brothers started out for Aurora …[where] they paid ten shillings a bushell for corn and two dollars and a quarter for wheat, bought an iron kettle for making sugar…A glorious surprise awaited them in the woods in the form of a bee-tree, from which they obtained nearly one hundred pounds of honey.

— Melinda Russell, 1880

Nine years after Melinda came to Warrensville Township, Jacob Russell's extended family formed the nucleus of the North Union Shaker community. In 1820, Ralph Russell, one of Jacob's sons, had become involved with the Shakers at Union Village, Ohio. He visited Union Village in 1821, intending to move there with his family to join the community. To his surprise, a different vision awaited him when he returned home to Warrensville:

…[the vision] consisted in a strong, clear ray of light, that proceeded from Union Village, in a perfectly straight, horizontal line until it reached a spot near his dwelling [in Warrensville], about where the center house[8] now stands, and there it arose in a strong, erect column, and became a beautiful tree.

— J. P. MacLean, 1900

Ralph followed his vision. He stayed in Warrensville Township, and in 1822, with the approval and assistance of Union Village, he established the North Union Shaker community on the Russell property adjacent to Doan Brook.

Over the next sixty-seven years, the Shakers developed their land in the upper watershed. They cleared most of the unbroken forest within

8 The center house was the dwelling house at the heart of the North Union Shaker community.

their 1,366 acres and replaced it with orchards, mills, three communities, and small manufacturing operations. They centered their villages around Doan Brook, giving their home in the stream valley the religious name of "the Valley of God's Pleasure." Two of the North Union "family" settlements were located on the brook itself and based their industry on power supplied by the stream (see Figure 2-2). First built was the Center Family village (see Figure 2-3), located between the brook and Shaker Boulevard along what is now Lee Road. A few years later, the Mill Family village was begun on the brook about a mile downstream (west), near the point where the brook now crosses Coventry Road (see Figure 2-4). The third community, the Gathering Family (also called the East Family), was located a bit farther from the brook, northwest of the intersection of Claremont and South Woodland Roads (see Figure 2-5). The Shakers built with an eye to quality, simplicity, and permanence, constructing some very impressive buildings in North Union (see Figures 2-6 and 2-7).

Shaker industry in North Union had begun in earnest by 1824, by which time a sawmill was in operation near the location of what is now the Lower Shaker Lake dam.[9] Prior to the construction of the sawmill, the community had no means of sawing logs into boards, and all family members were living in small log cabins near the intersection of South Park Boulevard and Lee Road. Since communal living was part of the Shaker ideal, and board lumber was required to build communal houses, an operating mill was a necessity.

In 1829, the original sawmill was joined by a grist mill about a quarter-mile downstream. A small dam near the location of the current Lower Shaker Lake dam was built to power this mill and the sawmill. This dam was enlarged a number of times over the years to power a succession of mills. The most notable rebuilding took place in 1831, when the dam was rebuilt using large quantities of stone and earth from the south bank upstream from the dam, and in 1837, when the dam was again completely rebuilt. After the 1837 work, the reservoir is reported to have covered an area of about twenty acres.[10] In 1843, the Lower Shaker Lake grist mill was replaced by an impressive stone grist mill farther downstream (Figure 2-7).

At the beginning of the 1850s, there was great demand for Shaker-manufactured brooms and woolen goods. The Elders at North Union decided to build a powered woolen mill and broom shop to meet the demand. Once again, their power source was Doan Brook, and in 1852 they built a dam on the brook to form Horseshoe Lake. This dam, which was enlarged in 1854, was an impressive stone structure with a finished stone spillway and ashlar-stone upstream face. Although it has been modified and repaired many times, traces of the original dam can still be seen. Water from the dam was carried to the woolen mill via a series of wooden troughs along the south side of the brook valley. At the woolen mill (see Figure 2-6), located just east of Lee Road and north of South Park Boulevard, the water turned an overshot wheel, which in turn powered machines for carding, spinning, and weaving wool and lathes for turning broom handles.

The 1850s marked the peak in the prosperity of the North Union Shakers. The community grew to a maximum of about 300 members and had land holdings of 1,366 acres and 60 buildings. After the Civil War, however, North Union began to decline, as did Shaker communities all over the country. In 1889, when there were only twenty-seven members remaining, the North Union community dissolved, and the remaining family members dispersed to other Shaker villages. In 1892, the Shaker lands were sold to a development syndicate.

Sadly, almost all traces of the Shakers were obliterated by the later development of their land. The Shaker buildings were neglected during the sect's decline and after the last members moved away. The structures that remained when the land was sold were razed. The Shaker cemetery was moved from its original location (south of South Park Boulevard about 300 yards west of the intersection of South Park and Lee Road) to the Warrensville West Cemetery at 3467 Lee Road. The Shaker Lakes and their dams are the only intact features of the Shakers' life along Doan Brook, although even the dams have been modified over the years. Appendix C describes some other remaining traces of the Shakers.

2.5 The City Moves East: Development of the Watershed

Although urbanization of the Doan Brook watershed began when Nathaniel Doan settled there in 1799, development did not begin in earnest until around 1900, when Cleveland's eastern border reached almost as far as Doan's Corners. After this time, both the lower and upper watersheds rapidly became the urban and suburban neighborhoods we know today. The story of the city's arrival is outlined here. The impact that development had on the brook is explored in more depth in Chapter 5.

9 It is not clear whether this sawmill was powered by the normal flow in the brook or, more likely, by the first dam on Doan Brook.

10 Some accounts give an area of thirty acres for the lake completed in 1837. Given that the current combined area of the Lower Shaker Lake and the adjoining marsh is 19.2 acres, and that there are no other references to a much larger lake, these accounts appear to be erroneous.

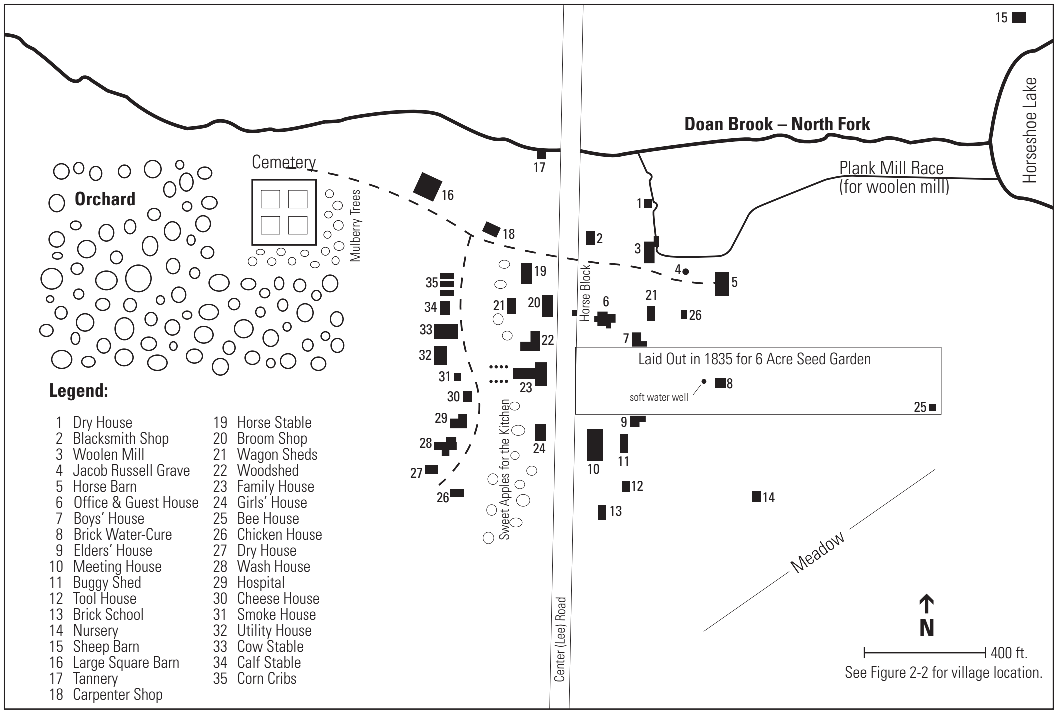


Figure 2-3 Shaker Center Family Village – ca. 1870

Based on Mead 1961 from the collection of the Shaker Historical Society, Nord Library, Shaker Heights, Ohio.

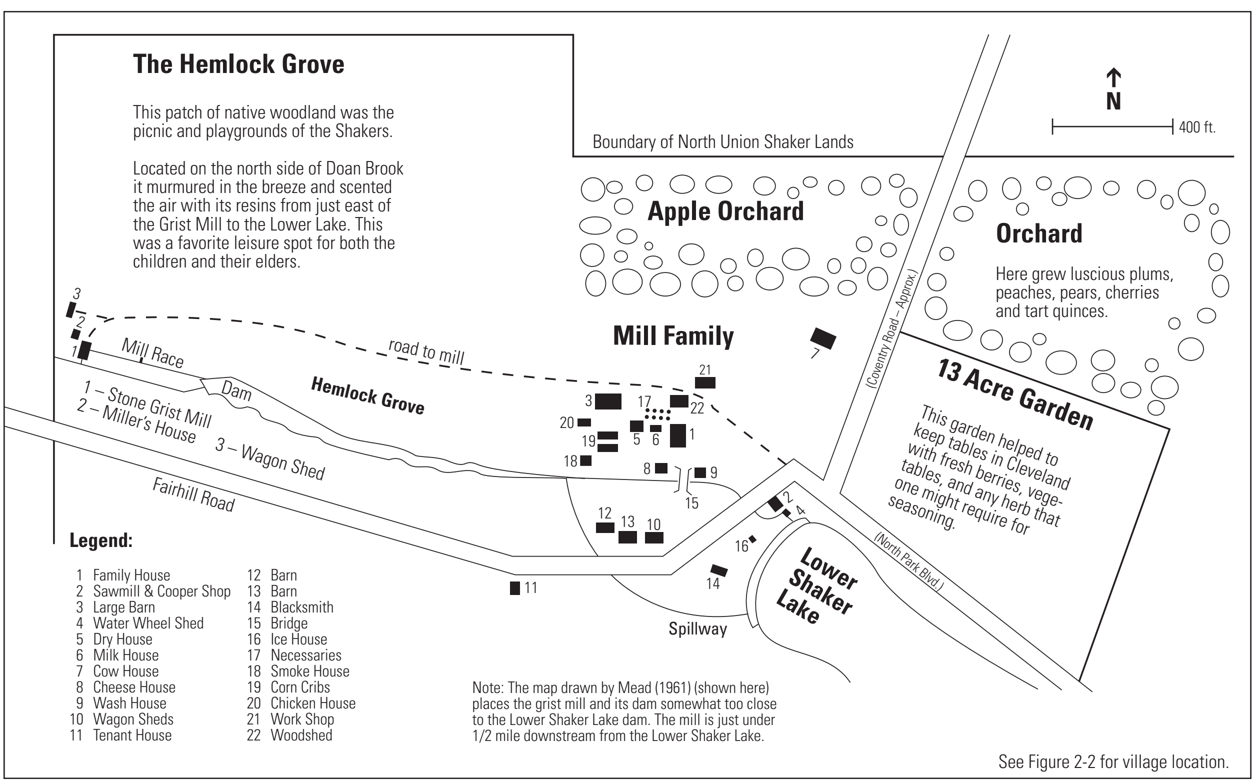


Figure 2-4 Shaker Mill Family Village – ca. 1870

Based on Mead 1961 from the collection of the Shaker Historical Society, Nord Library, Shaker Heights, Ohio.

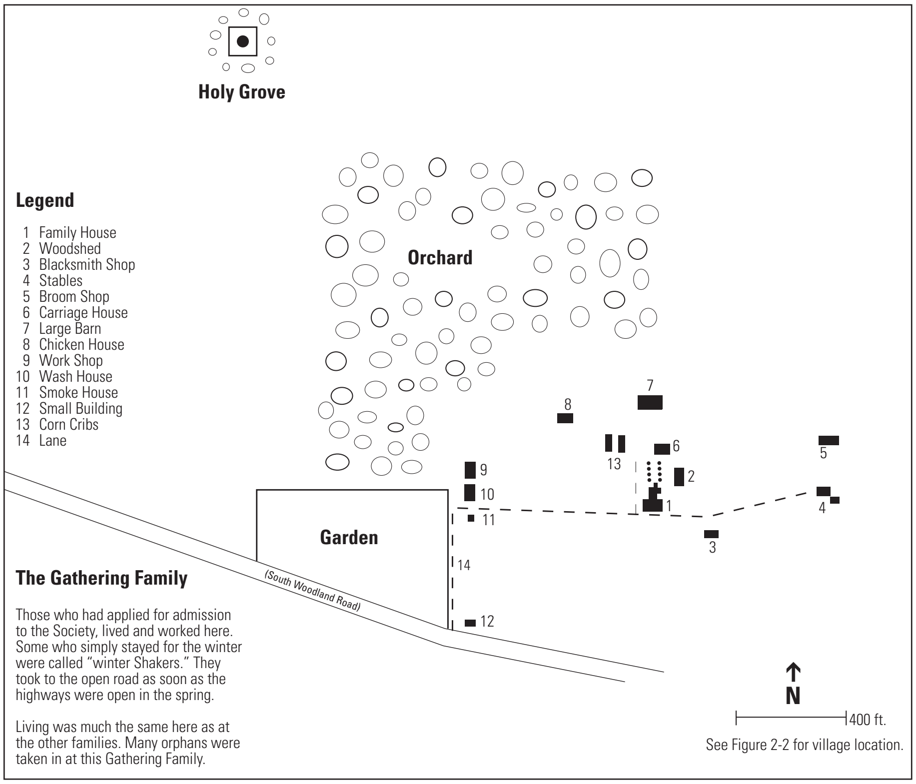


Figure 2-5 Shaker Gathering Family Village – ca. 1870

Based on Mead 1961 from the collection of the Shaker Historical Society, Nord Library, Shaker Heights, Ohio.

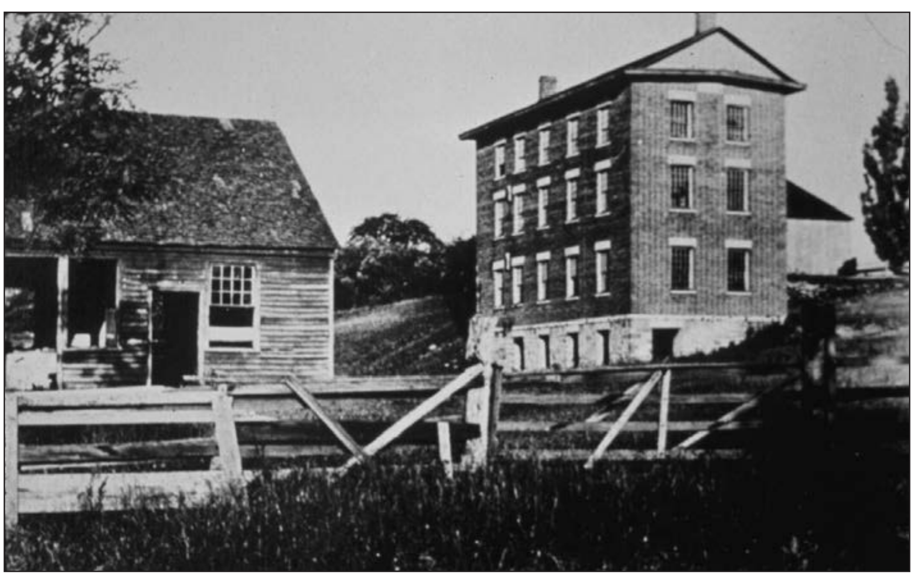


Figure 2-6 Shaker Woolen Mill

Built in 1854 in the northwest quadrant of what is now the intersection of Lee Road and South Park Boulevard.

Photographer unknown. From the collection of the Nature Center at Shaker Lakes.

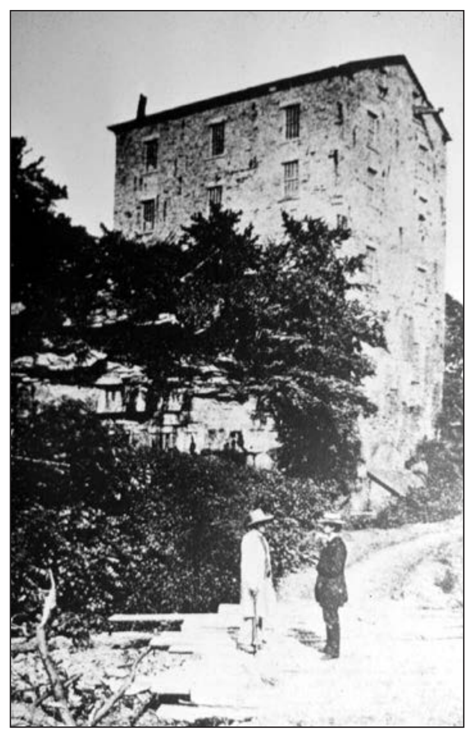


Figure 2-7 Shaker Stone Grist Mill

Built in 1843 on the edge of the Doan Brook gorge opposite the current intersection of North Park Boulevard and Roxboro Road.

Photographer unknown. From the collection of the Nature Center at Shaker Lakes.

The Rise and Fall of the Great Stone Grist Mill

The North Union Shakers' mills and dams were the foundation of their industry and were their most impressive building achievements. The stone grist mill that was built in 1843 was by far North Union's greatest building (see Figure 2-7). Located on the north edge of the Doan Brook gorge about one-half mile downstream from the Lower Shaker Lake dam, the grist mill was described by Shaker Elder James Prescott as follows:

> *In 1843 a new stone grist mill was built standing on the north side of the creek, a little west of the hemlock grove. On the south end it was four stories high. Its massive walls of the basement story were built of sand stone, four feet thick, quarried on the spot, or near by — the gearing was mostly of cast iron — the penstock was hewn out of solid sand stone, fifty feet deep, the front was laid with heavy blocks of stone, mitred in, laid in hydraulic cement — three run of stone — cast iron shafts, fifty feet long, running from the stones above down to the cast iron, arm [?] wheels below — two new bolts and screen smut [?] mill, and a place for grinding coarse feed etc.*
>
> *When it was built it was pronounced by good judges to be one of the best flouring mills in the State of Ohio. It stands as a durable monument of solid masonry and workmanship, and like the old mill has an extensive patronage from the surrounding country, and is one of the principal resources of the community.*

— James Prescott, 1880

Power for the mill was not supplied directly from the Lower Shaker Lake. Instead, a third dam was built across a narrow point in the Doan Brook gorge, about 0.45 miles downstream from the lake. This dam, constructed of forty-foot-long 2-foot by 2-foot timbers morticed into the sandstone on either side of the gorge, was about 30 feet high. A flume cut into the stone at the top of the north side of the gorge carried water from the reservoir behind the dam to the grist mill, about 400 feet farther downstream. This arrangement took advantage of a natural abrupt fall of the stream bed between the dam and the mill, so that the mill was powered by water falling from the top of the gorge to the floor of the gorge a full 50 feet below.

The grist mill served the Shakers well for many years, but the slow decline of the Shaker community and the gradual transition of milling to steam power eventually overtook the mill and made its continued operation uneconomical. By 1876 the mill had been converted to steam power, but this conversion failed to keep it running for long. In 1886, the mill and the land on which it stood were leased to Charles Reader to be used as a sandstone quarry. The machinery was removed from the mill building and taken to the sawmill at the Lower Shaker Lake, where it was used for a few more years.

Reader, who needed to demolish the grist mill in order to quarry the stone beneath it, decided to make the mill's destruction spectacular. He planned to dynamite the building as part of a public Fourth of July celebration held on July 5, 1886. Over 4,000 people attended the festival, which included the firing of cannons, re-enactment of the Battle of Bull Run, tightrope walking over the gorge, and entertainment supplied by several brass bands. Dinner, lemonade, and gambling at cards were provided by various enterprising organizations and individuals. The celebration culminated with the dynamiting of the mill, which tumbled into the Doan Brook gorge with the American flag tacked to a staff on the roof. A very few remains of the great grist mill can be seen as you walk along the north edge of the Doan Brook gorge today (see the Historic Watershed Tour in Appendix C).

2.5.1 The Lower Watershed

The first hint of the modern lower watershed came when the Case School of Applied Science and Western Reserve University moved to Doan's Corners in the 1880s. The universities and the expanding city to the west brought the beginnings of an urban neighborhood. Between 1900 and 1918, the surrounding farms gave way to opulent residential neighborhoods in Glenville and in University Circle, and by the 1920s a number of hotels, shops, and businesses were located at Doan's Corners. Several vaudeville theaters added their attraction to the area and were later joined by movie houses. The Cleveland Museum of Art and the Western Reserve Historical Society came to the lower watershed during the early part of the century, soon to be followed by an impressive array of other cultural institutions (see Appendix D).

Through the early part of the twentieth century, the various attractions of Doan's Corners brought a weekend crowd of shoppers and museum and theater-goers to what had become Cleveland's "second downtown." The parks along the lower Doan Brook (see Section 2.6) drew city dwellers seeking a break from the noise, dust, and smoke of increasingly industrial Cleveland. At the same time, the urban center at Doan's Corners drew citizens from rural areas to the east who were in search of city amenities. The importance of the Doan's Corners/University Circle area as a weekend haven for east-siders seeking shopping and entertainment continued through the 1950s.

While Doan's Corners became an urban center, the Glenville[11] residential neighborhoods to the north remained more suburban, with intermixed single-family homes and commercial centers. The population of the area changed, becoming largely Jewish by the 1930s and then largely African-American by the 1950s. In 1968, a shootout between a black militant group and Cleveland police triggered several days of social unrest in Glenville, including looting and destruction of a number of businesses. Repair of the damage has been slow, and some parts of the neighborhood have suffered from declining population and neglect by absentee landlords. Other parts of Glenville have continued to be stable neighborhoods of owner-occupied single-family homes, with the more opulent sections of the old garden district along the Doan Brook valley retaining some of their original glory. Home values rose sharply in the late 1990s as interest in high quality housing stock relatively close to downtown Cleveland revived.

The urban decline that struck much of the east side of Cleveland beginning in the 1970s was more dramatic in the residential areas around University Circle than it was in Glenville. The decay began to reverse in the late 1980s, when major expansions of the Cleveland Clinic and University Hospitals transformed much of the area. The hospitals, Case Western Reserve University, and the museums located in and around Wade Park now dominate the University Circle section of the Doan Brook watershed.

2.5.2 The Upper Watershed

A few years after Nathaniel Doan and his neighbors began to create a village in the lower watershed, the Warrens and the Russells began to turn the forests of the upper watershed into farmland. When the Shakers established their villages there, they worked tirelessly to clear and tame their land and to use the resources it offered to make their living. Although the watershed left by the Shakers bore little resemblance to the original wilderness, it remained a rural farming community during their tenure.

Real urbanization of the upper watershed did not begin until about 1895, when Patrick Calhoun and John Hartness Brown began to develop the "garden suburb" of Euclid Heights north of Cedar Road and west of Coventry Road. By the early 1900s, development of the western edge of the upper watershed was well under way, as Daniel Caswell and William Ambler began to build Ambler Heights (now known as Chestnut Hills) between Martin Luther King, Jr., Boulevard, North Park Boulevard, Cedar Road, and South Overlook. The Van Sweringen brothers began their early real estate ventures along Fairmount Boulevard at about the same time.

The Shakers' land (see Figure 2-2) remained largely undeveloped during the first urbanization of the upper watershed. The Shakers sold their 1,366 acres to a group of Cleveland businessmen in 1892. This group soon resold the land to the Shaker Heights Land Company, a syndicate headed by H.W. Gratwick and J.J. Albright of Buffalo, New York. Gratwick and Albright began the work of laying out lots and streets in preparation for lot sales, but the economic conditions of the late 1890s did not favor their venture, and the work stalled. In 1905 and 1906, the Cleveland brothers O.P. and M.J. Van Sweringen bought the land from Gratwick and Albright and began to lay the groundwork for Shaker Heights. The Van Sweringens developed Shaker Heights as one of the first planned communities in the United States. Their intention was to provide a suburb with superior services and an aesthetic environment to attract the moderately to extremely

11 A small part of the lower watershed between University Circle and Glenville is located along the eastern edge of Cleveland's Hough neighborhood. This area shares some characteristics of University Circle and some of Glenville.

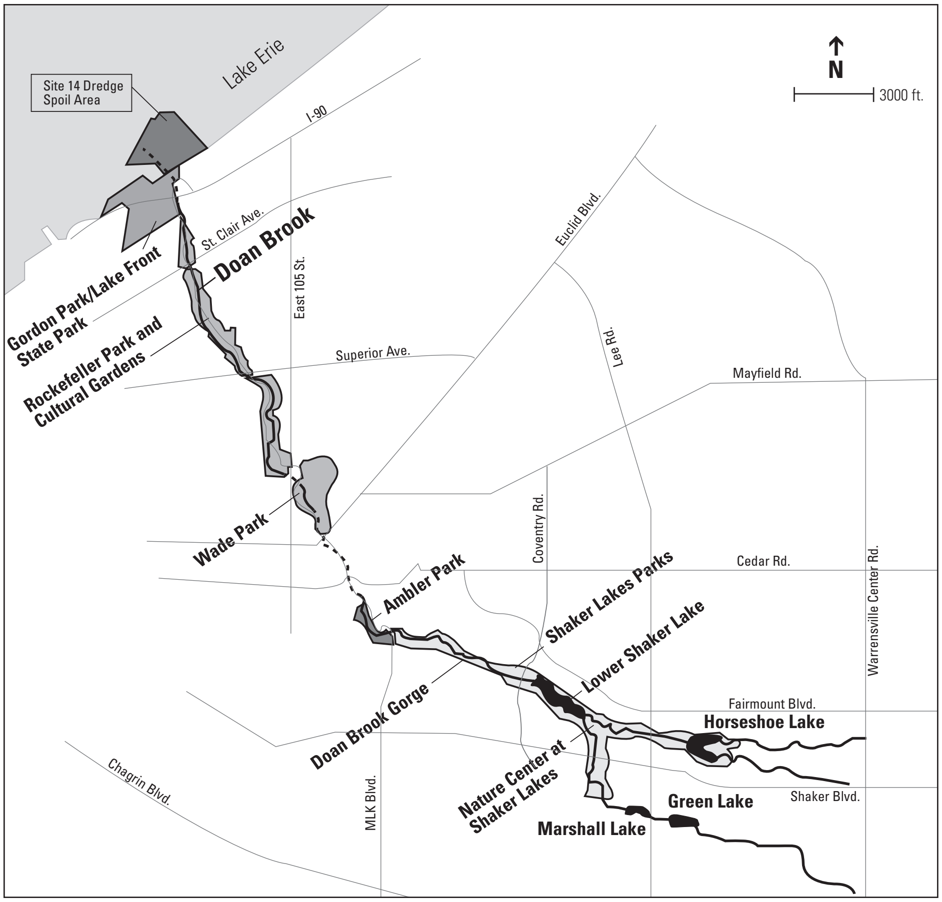


Figure 2-8 Doan Brook Park Lands

wealthy of Cleveland. Building was steady but gradual at first: the village had a population of 200 in 1911 and 1,600 in 1920. The expansion of Cleveland and the Van Sweringens' construction of the Shaker Rapid Transit system, which began operating in 1920, accelerated growth so that the population of Shaker Heights was 18,000 by 1930.

Cleveland Heights shared the boom of the 1920s, and by 1930 Doan Brook's upper watershed was almost completely developed. The total 1930 population of Cleveland Heights and Shaker Heights was 70,000, over eighty percent of the current population.[12] Further growth has been slow, consisting mostly of the gradual addition of more housing in scattered vacant lots, the construction of some additional high-density housing, and the evolution of commercial areas to incorporate more parking and make other adjustments to modern life.

2.6 Preserving the Land: The Story of the Parks

One of the striking features of Doan Brook is the almost continuous line of park land that surrounds the stream from its mouth to Horseshoe Lake. The parks begin at Gordon Park on Lake Erie, continue through Rockefeller and Wade Parks in the lower watershed, climb the escarpment through Ambler Park, pass along the Doan Brook gorge in the western part of the upper watershed, follow the brook along the Lower Shaker Lake and Horseshoe Lake, and extend up the south fork of Doan Brook almost to Marshall and Green Lakes (see Figure 2-8). The nearly unbroken ribbon of green leads us to wonder how such an interconnected system of parks came about.

Preservation of the Doan Brook park land began in 1882 when Jeptha H. Wade presented Wade Park to the City of Cleveland with the provision that the area be permanently maintained as a park. This first donation was followed in 1893 by the donation by William J. Gordon of 122 acres on Lake Erie at the mouth of the brook. Gordon had begun to develop a park there in 1880, with the intent of its eventual donation. Wade's and Gordon's gifts were followed by further donations of land along the brook by Jeptha Wade, the Shaker Heights Land Company, John D. Rockefeller, Laura Rockefeller, Patrick Calhoun, and Martha B. Ambler. The City of Cleveland also bought some parcels of land to complete the park system.

By 1897, enough land had been granted or purchased to allow the formation of a continuous park along Doan Brook from Lake Erie to Horseshoe Lake. Cleveland city planners embraced the idea, and by 1900 a street network

12 The total population of Cleveland Heights and Shaker Heights includes the populations of some areas that are not within the Doan Brook watershed.

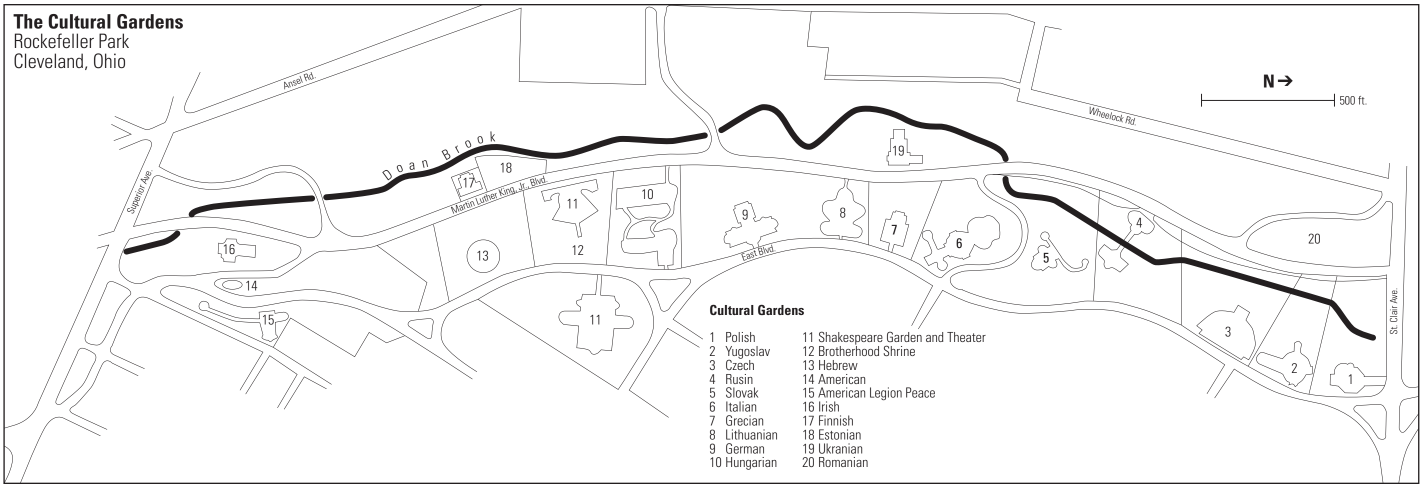


Figure 2-9 Rockefeller Park Cultural Gardens – 1939

linking the parks in the upper and lower watersheds had been designed and built. Stone bridges at Wade, St. Clair, and Superior Avenues had been built to carry streetcars across the brook valley. Shore protection, including three jetties and two piers, had been installed on Lake Erie at Gordon Park. Streetcar lines made the parks in the lower watershed readily accessible to people in rapidly growing downtown Cleveland.

The new parks were evidently a success, since the Rockefeller Park area was reportedly used by almost 44,000 people on one sunny Sunday afternoon in 1896, and Gordon Park became a popular bathing beach. The originally forested area along the brook in the lower watershed was gradually developed as playing fields and picnic facilities.

In 1916, part of Rockefeller Park between Superior and St. Clair was landscaped to form the Shakespeare Garden and planted with English vegetation to commemorate Shakespeare's work. In 1926, an adjacent area was transformed into the Hebrew Garden, and the idea of a series of gardens honoring Cleveland's different ethnic groups and nationalities was conceived. By 1939, a total of twenty different cultural gardens had been landscaped, and the Cultural Gardens were formally dedicated. Figure 2-9 shows the 1939 configuration of the Cultural Gardens. Although the gardens have suffered from some neglect in the past twenty years, interest in reclaiming them has recently arisen.

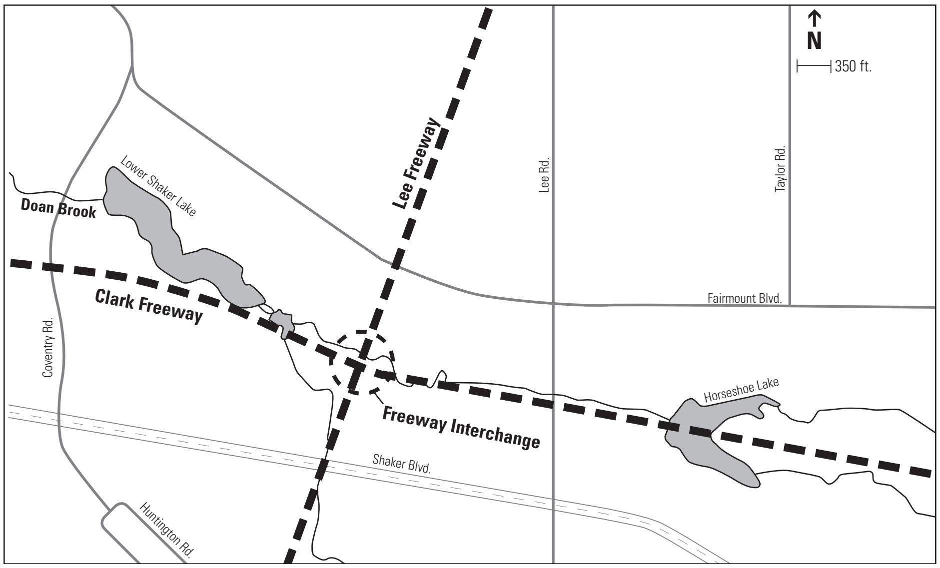
2.7 The Brook in the City: Citizen Activists and the Fight for the Doan

The foresight of Gordon, Wade, Ambler, Rockefeller and others left us an unbroken ribbon of undeveloped land along Doan Brook. This *riparian corridor*[13] has, to some extent, protected the brook as the city grew around it. However, the expanding city has eroded the

The wild romantic valley through which Doan Brook takes its sinuous way from Doan Street to the lake, a distance of three miles, is a natural park as nature has formed and adorned it; a comparatively small expenditure would render it one of the very finest parks in the country.

Annual Report of the Cleveland Parks Commission, 1890

13 A riparian corridor is a strip of undeveloped land immediately adjacent to a stream that buffers it from the surrounding area. See Chapter 4 for more discussion of Doan Brook's riparian corridor.



2-10 Proposed Alignment of the Clark and Lee Freeways

integrity of the original park system. Some threats to the Doan Brook parks have been deflected by the strenuous efforts of citizens who live in the watershed, while efforts to prevent other damage have been less successful.

The construction of the University Circle culvert was the first major break in the chain of the Doan Brook parks. The culvert grew slowly, beginning as one short pipe to carry the brook under a road here, another short pipe under another road there. By 1950, development in University Circle was so dense — there were so many roads and buildings — that the brook had disappeared. The many short culverts had been connected to form the long culvert that now carries the brook for almost a mile between Ambler Park and Rockefeller Park. Over the top of the culvert, the brook's riparian park corridor had become road medians and parking lots, and even the location of the stream was forgotten.

A few years after the slow disappearance of the brook in University Circle, the proposed construction of the Clark (I-290) and Lee Freeways threatened to suddenly engulf most of the upper watershed parks. The alignment of the freeways was to take them directly over the Shaker Lakes (see Figures 2-10 and 2-11). Faced with an obvious assault on a beloved park, the citizens of the watershed took action. In 1965, a group of women from local garden clubs, spearheaded by Mary Elizabeth Croxton, Jean Eakin, and Betty Miller, formed the Park Conservation Committee,[14] an organization dedicated to stopping the freeway construction.

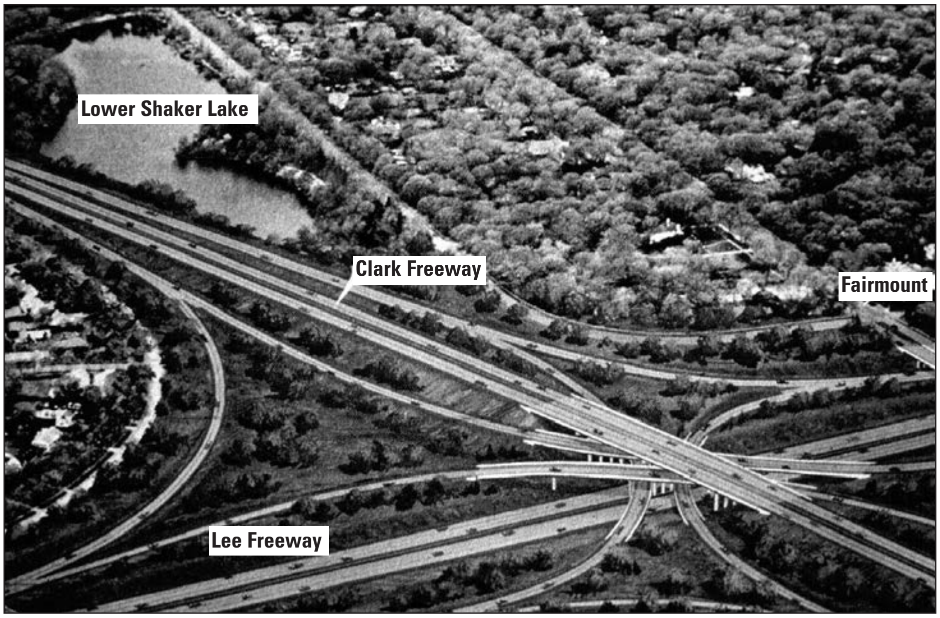
The Park Conservation Committee's opposition to the freeways began with the usual political tactics — they contacted public officials, wrote letters, and held meetings. The committee was not satisfied with the conventional approach, though. To increase the chances that they would succeed in blocking the freeways, they threw the historic Doan Brook parks squarely in front of the freeway-building bulldozers. In 1966, they founded the Shaker Lakes Regional Nature Center,[15] and in 1968 the Nature Center leased 5.5 acres of land at the proposed location of the major freeway interchange.[16] Here they proceeded to build the Nature Center building and associated trails. In 1971 the United States National Park Service, at the urging of the garden club ladies and others, named the Nature Center at Shaker Lakes a National Environmental Education Landmark. City governments in Shaker Heights and Cleveland Heights and other eastside communities rallied around the Nature Center's founders and joined their opposition to the freeways. Ohio's Governor, James Rhodes, withdrew state support for the freeway plan in 1970, and approval for the freeway construction, which had once seemed inevitable, was finally withdrawn in 1972.

Efforts to protect the brook and the adjacent parks from less grave threats have not been so successful, and there has been some slow erosion of the park system over the years. When the storage reservoirs at the Baldwin Filtration plant were built, excavated material was placed in the lower part of Ambler Park, and an additional section of the brook was buried. Some time in the 1970s, an area immediately downstream from the Lower Shaker Lake dam (maintained as a wildflower garden by the Shaker Lakes Garden Club) was filled in, possibly to make the dam more secure. Cleveland also permitted debris from construction in University Circle to be dumped along the south side of the Doan Brook gorge opposite the intersection of Kemper and Fairhill. This dumping, which took place in 1959 and again in 1969, was a poorly-engineered attempt to

14 Sometimes called the Greater Cleveland Committee for Park Conservation.

15 Now called the Nature Center at Shaker Lakes.

16 The interchange was to be located on the site of the current Nature Center, near the intersection of South Park, North Park and North Woodland.



2-11 Clark and Lee Freeway Interchange at Lower Shaker Lake. From the Nature Center at Shaker Lake collection.

repair slope failures (see Section 5.1.4). Citizen opposition eventually helped stop the dumping and forced a proper slope repair, but not until much damage had been done.

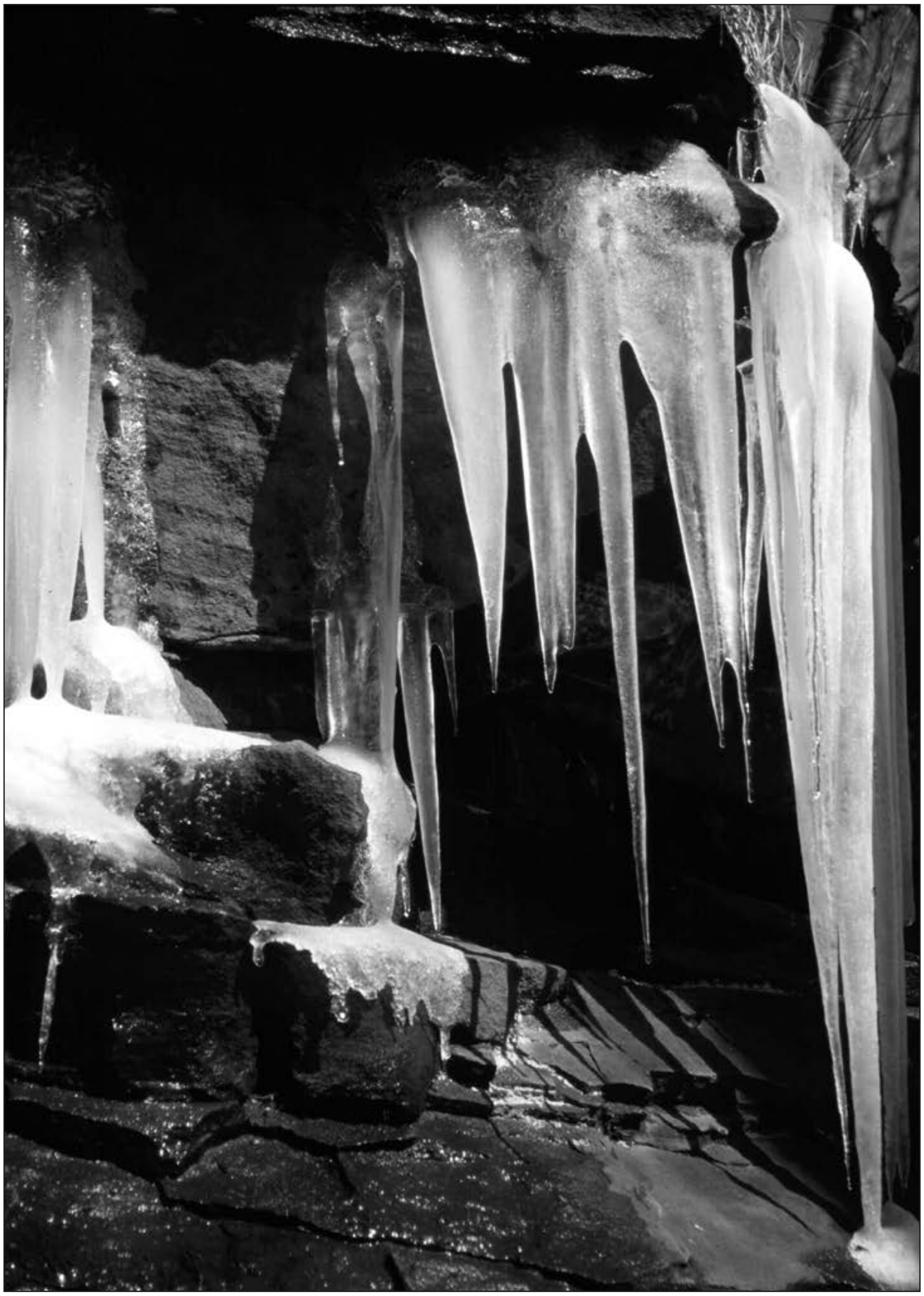
When Interstate 90 was built along the Lake Erie shore, the freeway cut across the brook and divided Gordon Park in half. The park was greatly degraded, and yet another culvert was built to carry the brook under the freeway. In the 1970s, the Corps of Engineers further damaged the brook in Gordon Park by beginning the placement of dredged material in a confined disposal facility[17] on the lake shore at the mouth of the stream. The I-90 culvert was extended to carry the brook under the dredge fill area all the way into Lake Erie. Access to the waterfront was eliminated in a large part of Gordon Park. Local awareness and opposition to the site that had been chosen for the Corps of Engineers dredge spoil area came too late to have any impact.[18]

The latest major project in the Doan Brook parks was built in 1997, when the City of Cleveland built a flood detention structure on the brook in Ambler Park immediately downstream from Martin Luther King, Jr., Boulevard (MLK). This structure was originally to be built upstream from MLK in the heart of the Doan Brook gorge. Citizen action once again changed the fate of the brook, but this time only by a small amount. The citizens and city government of Cleveland Heights opposed the construction of a detention basin on land in the scenic gorge that was leased by Cleveland Heights. Their opposition prompted Cleveland to move the structure downstream from MLK onto City of Cleveland land. As will be discussed in Chapter 7, the need for the detention basin was poorly studied, and its effectiveness in providing downstream flood control will be minimal.

As this account demonstrates, the story of citizen action on behalf of Doan Brook is mixed. Had it not been for the efforts of those who formed the Park Conservation Committee to oppose the freeways, there would be very little of Doan Brook left for us to preserve. However, other assaults on the park corridor have not been stopped by public opposition. Still others have raised little outcry. As the life of the city continues around the brook, proposals for projects that will eat away at the riparian corridor and at the brook itself will continue to arise. Citizens must make the health of the brook a priority if the stream and the park system are to survive and thrive in the future.

17 The confined disposal facility is essentially a landfill for disposal of material that is dredged from the Cuyahoga River and Lake Erie in order to keep navigation channels clear.

18 The complete name of the dredged material disposal facility is the Diked Disposal Facility Site No. 14. The area is commonly referred to as Site 14 or Dike 14.



Groundwater seeping from the Berea Sandstone forms icicles in the old quarry in Doan Brook gorge. Photograph by L. C. Gooch.

Men travel far to see a city, but few seem curious about a river. Every river has, nevertheless, its individuality, its great silent interest. Every river has, moreover, its influence over the people who pass their lives within sight of its waters.

— H.S. Merriman

The Sowers

3 The Shape of the Brook: Physical Features That Form the Stream

If you mention Doan Brook to the average Clevelander, the most likely response will be a blank look and a question: "Doan Brook? Where's that?" Yet, chances are that the person who asks the question has walked or driven along the brook at one time or another. Many know the Shaker Lakes well, occasionally stroll beside the stream in the Cultural Gardens, or fish near the brook's mouth in Gordon Park. Few realize that the stream that flows from the Shaker Lakes is also the heart of the parks downstream.

In this chapter, we begin our exploration of today's Doan Brook by looking at the stream's location and important physical features. To start, we follow the brook from its origins in Shaker Heights to its outlet at Lake Erie, thus placing it in the context of the surrounding landscape. Then, we expand our view to include the brook's watershed — the land that gives water to the stream. Diving beneath the ground surface, we look at the relationship between the brook and groundwater. To complete our understanding of the physical brook, we look at the topography of the stream and its watershed and at the geology that shaped the landscape and gave the brook its character. In later chapters, we will use the physical framework developed here to understand Doan Brook's biology and hydrology and evaluate the impact of human actions, both past and future, on the brook.

3.1 Where Is It? The Brook's Location

The simplest way to describe Doan Brook to most people is to tell them that the brook flows west (toward downtown Cleveland) along North Park Boulevard from Horseshoe Lake and continues along North Park until North Park merges with Martin Luther King, Jr., Boulevard (MLK) (see Figure 3-1). The stream then follows MLK all the way to Lake Erie at Gordon Park.

Some elaboration of this basic description provides a more complete picture of the brook's layout and of how the stream fits into the surrounding city. To place the brook in its surroundings, we will trace it from its upstream end, considering all three branches of its headwaters, and work our way downstream into Lake Erie. Figure 3-1 shows the course of the stream as it is described in the text.

The north and middle branches of Doan Brook flow in from the east to form the "horseshoe" of Horseshoe Lake. The north branch can be traced upstream to its origin by driving east along Shelburne Road from the northern arm of the lake. The modern stream begins south of Shelburne at Warrensville Center Road. The middle branch can be traced from the south arm of the lake by traveling east along South Park Boulevard to the stream's beginning at the intersection of South Park with Shaker Boulevard and Warrensville Center.[1]

Downstream from Horseshoe Lake, the joined north and middle branches flow within the wooded area between North Park and South Park. The brook is visible from either road at the Lower Shaker Lake and can occasionally be glimpsed in other places. Just upstream from the Lower Shaker Lake, the branch that flows from Horseshoe Lake is joined by the south branch of the stream.

1 Originally, the headwaters of all three branches of Doan Brook were considerably farther east. The stream channels were diverted into culverts and filled in during development. See Chapter 5 for more discussion.

Brook Location Facts (see Figure 3-1)

Doan Brook Length:	About 8.4 miles (along the north branch)
Watershed Area:	11.7 square miles 7,500 acres

Location: Doan Brook arises in Shaker Heights (three branches) and flows west and northwest through Shaker Heights, Cleveland Heights, University Circle, and Cleveland. The brook reaches Lake Erie near the eastern edge of Gordon Park in Cleveland. The stream is the center of the Shaker Lakes parks, Ambler Park, Rockefeller Park, and the Cultural Gardens.

Lakes: There are four lakes on Doan Brook: Horseshoe Lake (sometimes called Upper Shaker Lake) at the confluence of the north and middle branches; Green and Marshall Lakes on the south branch; and the Lower Shaker Lake downstream from the confluence of the north and south branches. Two additional lagoons, the Wade Park Lagoon and the Rockefeller Park Lagoon, sit next to the brook. These lagoons are filled from the City of Cleveland drinking water system and drain into the brook.

Culverts: There are two significant culverts on Doan Brook. One, the University Circle culvert, carries the stream for just under a mile from the intersection of Ambleside and MLK to a point behind the Cleveland Museum of Art. The other carries the brook for 3,300 feet beneath I-90 and the U.S. Army Corps of Engineers Site 14 dredge spoil landfill and into Lake Erie.

Doan Brook's south branch originates on the Canterbury Golf Club golf course east of the intersection of South Woodland Road and Belvoir Boulevard. It flows southwest along the west edge of the course until it crosses Belvoir (at Farnsleigh Road), where it enters a culvert that carries it under Van Aken shopping center to the southeast corner of the Shaker Heights Country Club golf course (just west of the intersection of Warrensville Center and Farnsleigh). The stream runs north and west through the golf course until it enters Green Lake southeast of the intersection of South Woodland and Lee Roads. From Green Lake, the south branch continues west into Marshall Lake, then turns north, cutting across a corner of the Shaker Heights High School campus and continuing through the wooded area between South Park and West Park Boulevards. It joins the main stream in the marsh near the Nature Center at Shaker Lakes.

After the confluence in the Nature Center marsh, Doan Brook passes through the Lower Shaker Lake and follows North Park to the merge with MLK. The stream crosses under MLK and parallels the road northeast down the steep hill. At the bottom of the hill (just a little before the intersection of MLK and Ambleside Drive), the brook disappears into a large pipe called the University Circle (or Doan Brook) culvert.

Doan Brook is hidden underground for almost a mile in a series of connected pipes that run along the west edge of the Case Western Reserve University campus and the west side of the lagoon by the Cleveland Museum of Art. The brook emerges from the culvert at the bottom of the hill behind (northwest of) the art museum, near the intersection of East Boulevard and East 105th Street. After a few hundred yards of open channel, the brook dives underground again into a culvert that carries it through the intersection and into Rockefeller Park. The brook then flows through the park, sometimes on one side of MLK and sometimes on the other, almost as far as Lake Erie. Just upstream from the intersection of MLK and Interstate 90, the brook enters yet another long culvert. This final pipe carries the stream for over half a mile under the Corps of Engineers Site 14 dredged material landfill and into Lake Erie.

3.2 Where Does the Water Come From? The Doan Brook Watershed

The three branches of Doan Brook can easily be traced by looking at a map. But where does the water in the brook come from? Doan Brook, like every stream, is surrounded by a *watershed*[2] — that is, an area of land over which water running along the ground surface (called *runoff* or *surface runoff*) will eventually flow into the stream. The watershed's shape, topography, and land use determine the amount and quality of the water in the stream. Any exploration of Doan Brook must therefore encompass the watershed as well as the brook itself. In this section, we look at the watershed outline, defining the part of the landscape that drains into Doan Brook. We will consider the watershed's topography in a later part of this chapter and watershed land use in Chapter 5.

The Doan Brook watershed is an 11.7 square mile area located in Cleveland, Cleveland Heights, and Shaker Heights (Figure 3-1). The watershed is shaped something like a backward comma, with a narrow top along Lake

2 Also called a drainage area or drainage basin.

Figure 3-2 Horseshoe Lake lies at the confluence of the north and middle branches of Doan Brook. Photograph by L. C. Gooch.

Erie to the north, a wider middle, and a somewhat narrow tail that points east.

In the northern part of the watershed, near Lake Erie, almost all drainage reaches the stream from a narrow strip of land between the stream and a point about one half mile to the east. Rain that falls more than a few hundred feet west of the stream flows directly into Lake Erie, without ever entering the brook.

Upstream from University Circle, the watershed turns east and widens out to the north and south, until, at Coventry Road, it extends from near Mayfield Road as far south as Van Aken Boulevard. The watershed then narrows again, until it only includes the area between Fairmount Boulevard (or sometimes a few blocks north) and Van Aken. The eastern boundary of the watershed generally lies between Green and Richmond Roads.

Most runoff reaches Doan Brook via storm sewers, which collect water from yards, rooftops, and streets and give it an underground expressway directly to the stream. Storm sewers in some areas have been rerouted so that they divert water from outside the natural watershed into Doan Brook, thus making the current watershed larger than the brook's original drainage area.[3] Although most runoff reaches the brook via the storm sewers, a small amount of water flows directly to the stream from its immediate surroundings.

3.3 Why Does the Brook Flow When It Isn't Raining? The Contribution of Groundwater

3.3.1 The Influence of the Groundwater System

Just as Doan Brook has a surface water drainage area — an area over which rain that falls and remains on the ground surface flows into the brook — the stream also has a groundwater drainage area.[4] Rain that falls within the groundwater drainage area and soaks into the ground (*infiltrates*) eventually flows to the brook, entering the stream through its bed and banks. Groundwater flow is much slower than surface water flow, since water that is absorbed into the groundwater reservoir is released gradually.

Because of the ground's slow absorption and release of water, the groundwater system is a kind of regulator for flow in the stream. Flood peaks are lowered as water is absorbed into the ground, to be released over a period of hours, days or weeks, long after the peak surface runoff has passed downstream. Some of the water from spring rains is released to the stream during the drier parts of the summer, maintaining flow in the stream (called *base flow*) even when there has been no recent rain. The steady trickle of base flow in Doan Brook during dry periods is critical to the health of the stream's aquatic environment. We will see in Chapter 5 that human activities have changed the brook's groundwater system and the base flow, just as they have changed its surface watershed.

3 Changes to the watershed's original size and shape will be discussed more thoroughly in Chapter 5.

4 Groundwater is the term used to refer to water that soaks into the soil and then flows within the matrix of soil or rock particles. Many people picture groundwater as a series of streams flowing in caverns beneath the ground. This is only rarely the case. Most of the time, and certainly in the Doan Brook watershed, groundwater works its way through the soil or rock itself, winding tortuously among the soil particles or through small fissures in the rock. If you dig into the groundwater zone beneath the Doan Brook watershed, all you will find is wet soil or rock.

Groundwater Use in the Doan Brook Watershed

Water supply in Cleveland is now taken from Lake Erie, so there is little modern groundwater use in the Doan Brook watershed. However, groundwater was once an important resource here. Water from springs or wells was used by many of the early settlers as their primary water supply.

In Wade Park, in what is now part of the Japanese Garden at the Cleveland Botanical Garden, there was a drinking water spring "…to which people from miles around came with jugs, pails and bottles, on foot, with boy's wagons, and in buggies and on bicycles." (Mead 1956).

Shaker Elder James Prescott wrote of the Shaker Mill Family (who lived southwest of the current intersection of North Park and Coventry):

> *They have an excellent spring of pure, soft, water — a never failing spring, coming out from between two sand stones, which has been running for more than fifty years, and how much longer we cannot tell. It is used for washing, bathing, and cooking purposes. It is carried in pipes to the kitchen and pumped into the boilers.*

— James Prescott, 1880

3.3.2 Doan Brook's Groundwater System

Groundwater systems are complicated, and they are hidden, so it is more difficult to define Doan Brook's groundwater drainage area than it is to define its surface watershed. A stream's groundwater drainage area may not be the same as the surface water drainage area. In fact, there are typically several different groundwater systems (or *aquifers*[5]) stacked one on top of the other beneath a single surface watershed. Each of these stacked aquifers, which are separated by almost water-tight layers of rock or clayey soil, may have a different drainage area. That is, infiltrated rainfall may reach each of the stacked aquifers from a different part of the overlying land surface.

Because groundwater systems are hidden and complex, a great deal of study is required to define the precise interactions of groundwater with any given stream. The groundwater systems that underlie the Doan Brook watershed have never been examined in detail, but we can make the following generalizations about the brook's interactions with the local groundwater:

- There is a shallow groundwater aquifer that probably corresponds approximately to the surface watershed in the upper Doan Brook watershed. Water from this shallow aquifer enters the brook through the stream's bed and banks. Most rain that falls in the upper part of the Doan Brook surface watershed and is absorbed into the ground probably ends up in this surface aquifer and eventually flows into Doan Brook. The clayey and silty glacial till soils (see Section 3.5) that make up the aquifer resist the flow of water, so rainfall infiltrates slowly and inches its way through the soil toward the stream.
- There is probably a shallow aquifer in the lower watershed similar to the one in the upper watershed. Soils in the lower watershed are generally thin layers of sand, silt, or clay laid down under ancient lakes (see Section 3.5). Rain will infiltrate into these soils and move toward the stream relatively quickly.
- There are deeper aquifers in rock layers that lie under the shallow soils in the upper watershed. In the far eastern part of the watershed, these rock layers pass completely under the brook and have little or no contact with the stream. As the stream cuts down through the rock in the Doan Brook gorge, water from the aquifers within the rock layers seeps into the stream.[6] The water that emerges in the gorge originally enters the aquifers where the rock layers are near the surface or in contact with another aquifer. Flow into the bedrock aquifers occurs in many places over an area much larger than the Doan Brook surface watershed. The deeper rock layers found under the upper watershed are absent beneath the lower watershed.

To summarize, there are shallow aquifers in the upper and lower Doan Brook watersheds and also some deeper aquifers beneath the upper watershed. The shallow aquifers absorb and slowly release some of the rain that falls in the watershed, reducing flood flows and increasing flows during dry periods. Because of differences in the upper and lower watershed soils, the shallow aquifer in the upper watershed will absorb less rainfall and release it more slowly than the shallow aquifer in the lower watershed. The deeper aquifers also contribute to dry weather flow by carrying some water from both inside of and outside of the surface watershed to the brook.

5 An aquifer is a layer of soil or rock that is capable of transmitting significant quantities of water. Some material, such as clay, can transmit very little water and will not generally be thought of as an aquifer. Other material, such as sand, gravel, or sandstone, can transmit significant quantities of water.

6 Groundwater can be seen seeping from the rock layers in the sides of the Doan Brook gorge and on the face of the steep hill between the lower and upper watersheds.

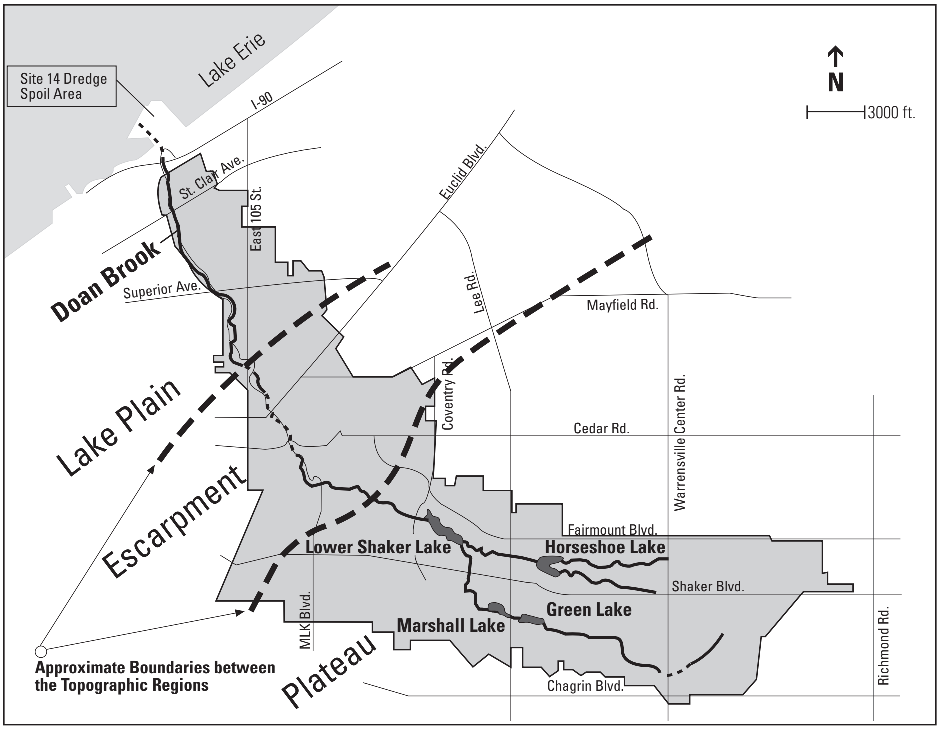


Figure 3-3 Topographic Regions of the Doan Brook Watershed

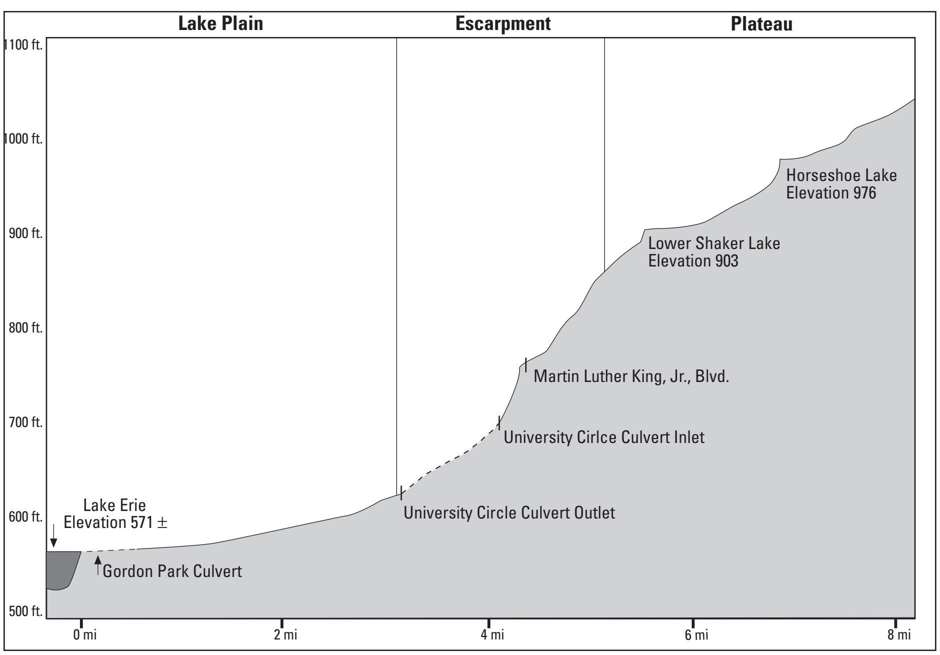


Figure 3-4 Profile of Doan Brook

3.4
How Is It Shaped? Brook and Watershed Topography

Over the millenia, Doan Brook and the glaciers that preceded it have shaped the land of the Doan Brook watershed into the topography we see today. The brook, like any stream, has an intimate relationship with the surrounding land. The topography shapes the brook, determining how much water flows to the stream, how much energy the stream can gather as it runs downhill, and how much water the stream must carry in a flood. At the same time, the stream shapes the topography, cutting channels, ponding to fill flood plains, and eroding waterfalls. A good understanding of the stream and watershed topography is needed if one is to grasp how the stream will behave in a drought or in a flood.

The Doan Brook watershed is made up of three distinct areas, each of which has its own character (see Figures 3-3 and 3-4). These areas are:

- The **Lower Watershed**, or **Lake Plain**, is the relatively flat area that immediately adjoins Lake Erie, extending as far south as the hill just northwest of the Cleveland Museum of Art. The watershed here is generally level and prone to puddles, with soils made up of layers of fine sands, silts, and clays. Occasional ridges parallel to the Lake Erie shore break the otherwise uniform terrain. Doan Brook takes a meandering course through a broad, shallow valley across the Lake Plain.
- The **Escarpment** (formally called the Portage Escarpment) is the sloped section of land that joins the Lake Plain with the higher ground to the south and east. Along Doan

Experiencing Topography Firsthand: The Watershed by Bicycle

For a bicyclist, the intersections of the Lake Plain with the Escarpment and the Escarpment with the Plateau are easy to identify. If you begin in the Lake Plain at Lake Erie and ride away from the lake along the Doan Brook (following the Martin Luther King, Jr., Boulevard (MLK) bike path), the riding is flat and easy — almost effortless. Easy riding continues until you reach the traffic circle at the intersection of East Boulevard, East 105th Street, and MLK.

At this point, you have come to the intersection of the Lake Plain with the bottom of the Escarpment, and you are about to begin scaling the Escarpment. The climb starts with the short, sharp hill that leads to Wade Park. Past University Circle, you continue to climb, pausing to catch breath on an occasional level spot. First you must overcome the main face of the Escarpment — the long steep hill along Edgehill Road, MLK, Cedar Road, or Fairhill Road. Above the main face, you have a more gradual climb until you reach a point where the land begins to level off. This point, which is generally a bit west of Coventry Road, is the intersection of the Escarpment and the Plateau.

Once you have reached the Plateau, the land begins to roll a bit, but maintains a gentle uphill trend to the watershed boundary. If you continue riding east to a point just west of Richmond Road, you will suddenly find yourself coasting down hill as you cross the watershed boundary into the Chagrin River watershed or one of the other adjoining watersheds.

Brook, the Escarpment extends from the base of the hill northwest of the Cleveland Museum of Art to a point near the intersection of Bellfield Avenue (Roxboro School) and North Park Boulevard. Watershed slopes in the lower part of the Escarpment are relatively gentle, while steeper and longer slopes are found as you move farther up. The soils along the Escarpment are generally thin tills or silty clay, with shale or sandstone bedrock exposed in many places along the stream. Rainfall runs quickly into the brook from the steep Escarpment slopes, and the stream channel takes an almost straight track down the hill from the Plateau.

- The **Plateau** includes the entire upper watershed above the uphill edge of the Escarpment. This part of the watershed, which is the northwest margin of the Appalachian Plateau, is characterized by rolling topography and thin clayey silt glacial till soils. Bedrock is generally shale, with some sandstone. Along the brook, the upper watershed begins at a point near the intersection of Bellfield and North Park. The boundary between the Escarpment and the Plateau runs northeast and southwest from this point. Although the land is steeper here than in the Lake Plain, slopes are gentle enough that the brook cuts a winding channel through the broad, shallow valley of its flood plain.

The shape of Doan Brook results from the watershed's topography. The moderate slopes of the Plateau and the shallow slopes of the Lake Plain allow the brook to meander and create shallow valleys. The steep Escarpment leads to a straight, fast-flowing stream that has carved out a gorge as it cut its way down to the Lake Plain. In the next section, we will explore

Figure 3-5 Doan Brook cascades over the edge of the Berea Sandstone as it works its way down the Portage Escarpment. Photograph by L. C. Gooch.

how the watershed's three distinct topographic regions were formed. The impact of this topography on the stream's behavior is one of the topics of Chapter 7.

3.5 The Bones of the Doan: Watershed Geology and Soils

The geology of a watershed is the framework upon which watershed topography is built. Although details of Doan Brook's geology may be of interest primarily to geology buffs (who should see Appendices E and F), a basic understanding is a useful underpinning for an effort to manage the watershed.

The three topographic regions of the Doan Brook watershed, the Lake Plain, the Escarpment, and the Plateau, were created by the intersection of the uplifted Appalachian Mountains to the east with the gouged-out basin of the ancestor of today's Lake Erie. About 600 million years ago, all of northeast Ohio was covered with an intermittent inland sea. When the predecessors of today's Appalachian Mountains began to rise to the east, soil eroded from the mountains and was carried into the sea and deposited in a series of layers of mud, silt, and sand. Erosion continued for many millions of years. Over time, buried layers of sediment were compressed into rock, becoming the layers of sandstone and shale that now underlie the upper watershed and can be seen in the Doan Brook gorge.

Eventually (about 300 million years ago), the sea retreated for the last time. Long after this, beginning about 2 million years ago, glaciers advanced from the north. They enlarged existing river valleys to create the basins of the ancestral Great Lakes, gouging Lake Erie into the still rising edge of the Appalachian Mountains. As the mountains rose, they elevated the layers of sedimentary rock laid down by the inland sea, thus creating the Plateau topographic region. The advancing glaciers cut through the sedimentary rock to carve the edge of the lake into the Plateau.

When the glaciers finally retreated, only about 15,000 years ago, they left a layer of jumbled clay, silt, and sand called *glacial till* on the surface of the Plateau's shale and sandstone. This glacial till forms the soil and shallow subsurface material of the upper watershed. As the glaciers continued to retreat, the ancestor of Lake Erie was trapped between the edge of the glacier to the north and the edge of the Appalachians to the south. The lake, much larger than today's Lake Erie, carved a series of cliffs into the edge of the Appalachian Plateau. These cliffs, at the intersection of the Plateau and the ancient lake, are the topographic region that is now called the Escarpment.

As the lake ate at the edge of the Plateau, new sediments were carried from the uplands and deposited in the lake, forming the layers of silt, sand, and clay that we now find beneath the lower watershed. Over time, the lake retreated toward its current shore, leaving the flat Lake Plain crossed by a series of ridges that attest to the locations of past shores and beaches.

Red-tailed hawk at the Nature Center at Shaker Lakes. Photograph by L. C. Gooch.

While quite small I went with my father and other men from the village to shoot pigeons from the bank or ridge overlooking what is now the Art Garden and lake. This ridge, opposite Wade Park Manor, was at that time rather an open grove with some very fine chestnut and other forest trees upon it. This was when those beautiful birds, the passenger pigeons, still flew in countless millions, at times shutting out the sunlight, as they sometimes flew in strata, seven or eight deep, thus causing midday twilight, while the sound of their myriad wings was like surf on the shore.

— Charles Asa Post

Doans Corners and the City Four Miles West

4

Who Else Lives Here? The Natural Environment of the Brook

As we have seen, the nearly impenetrable forest interspersed with impassable swamps of the natural Doan Brook watershed did not please the first settlers. They did their best to tame the land as quickly as possible. By the mid 1800s, much of the forest was gone, along with much of the wild community that had inhabited it. By the early twentieth century, the urbanization of the area was complete. The watershed's original explorers would hardly have recognized it.

In the midst of the urban development, the philanthropists and park planners preserved a bit of open land in the line of parks that extends along Doan Brook from Lake Erie to Horseshoe Lake (see Figure 2-8). Some of these parks were landscaped and have been intensively managed; other areas were either left relatively undisturbed or have drifted back to an unmanaged condition. The ribbon of park land along the brook forms its riparian corridor — the strip of undeveloped land immediately adjacent to the stream that buffers it from the surrounding city. Doan Brook's riparian corridor is the watershed's only link to its original wilderness. Some of the watershed's native vegetation still survives there, and the corridor is home to a surprising variety of wildlife. The vegetation and wildlife that make their homes along the brook and in the stream itself are the subject of this chapter.

4.1 Vegetation Along the Brook and in the Watershed

The Doan Brook riparian corridor hosts a variety of plant associations, including woodlands, marshes, landscaped picnic areas, manicured cultural gardens, decaying orchards, turf, and riparian and aquatic vegetation. Vegetation in the urban areas that surround the brook is similar to vegetation in the riparian corridor, but the urban plant communities are even more heavily influenced by deliberate planting and landscaping.

The watershed's vegetative communities can usefully be divided into three areas that correspond to its topographic regions: the upper watershed, or Plateau; the Escarpment; and the lower watershed, or Lake Plain.[1] Even in the least disturbed parts of the brook's riparian corridor, clearing, planting, and the invasion of naturalized *exotic species*[2] have changed the vegetation. However, the dominant vegetation in any area is still heavily influenced by the basic environmental conditions that vary with the topography: climate, soil, and the types of native vegetation that colonized the area after the retreat of the last glaciers 15,000 years ago. The plants found in each vegetative region under current conditions and when Moses Cleaveland arrived are discussed briefly here. Detailed results of a number of vegetation surveys are included in Appendix G.

- **Vegetation of the upper watershed** — In the upper watershed, the Doan Brook riparian corridor is home to dense, tall-treed forest, the marshes associated with the Shaker Lakes, and the extensively planted areas around the lakes. In the forested areas, two general vegetative associations dominate: forests of drier, upland areas, and forests of wetter, lowland areas.

1 The watershed's topographic regions are discussed in Chapter 3, and their locations are shown on Figures 3-3 and 3-4.

2 A variety of non-native species (called exotic species) have been imported to the area either deliberately or accidentally. Some of these have become nuisances, spreading quickly and crowding out native plants. Such rapidly spreading, aggressive, non-native species are generally referred to as invasive exotics.

The Pre-Settlement Forest

In the 1940s, Arthur B. Williams of the Cleveland Museum of Natural History surveyed historical records and the remaining old-growth trees of Cuyahoga County to develop a picture of what the forests of the county would have looked like when Moses Cleaveland arrived in 1796. This discussion of the original forests of the Doan Brook watershed is based on Williams' research (Williams 1949), with some input from naturalists from the Nature Center at Shaker Lakes.

Upper Watershed

In the drier parts of the upper watershed, the forests that Moses Cleaveland found consisted of a beech-sugar maple climax forest, in which these two species made up almost ninety percent of the trees. Red maples, tuliptrees, white ashes, cucumber-trees, and tupelos were found scattered among the dominant species. The forest that now lies along the brook between Horseshoe Lake and the Nature Center most closely resembles the native upland forest.

In swampy areas of the upper watershed, the forest was dominated by American elms, black ashes, and red maples, with swamp white oaks, basswoods, and bitternut hickories in smaller concentrations. Willows were found along stream banks where enough light filtered through the trees.

Escarpment and Gorge

Near the Escarpment edge, where the soil becomes drier, the pre-settlement beech-maple forest of the upper watershed was replaced by white oaks and chestnuts, with red, scarlet, and chestnut oaks, shagbark and pignut hickories, and sassafras in smaller numbers. Near the bottom of the Escarpment slope, where moisture increases again, the old forest regained a character closer to that of the beech-maple forest on the Plateau. Hemlocks dominated the cool, dark ravine of the Doan Brook gorge. Yellow and black birches, tuliptrees, basswoods, and some beeches or maples were also found in the ravine.

Lower Watershed

The native forests in the lower watershed were mixed, with drier areas such as old beach ridges and valley slopes resembling the Escarpment forest and moist bottomlands resembling the forests of the upper watershed swamps. Silver maples, black walnuts, and butternuts were also present, as were stands of pin oaks with occasional tupelos. Beech-maple forest could be found on the slopes of the brook valley.

Figure 4-1 This photograph of the Doan Brook gorge near North Park Boulevard and Delaware Road in 1894 demonstrates that the land was almost completely cleared by early settlers. Photographer unknown. From the Nature Center at Shaker Lakes collection.

The largest area of relatively undisturbed upland forest in the upper watershed lies along the brook between Horseshoe Lake and the Lower Shaker Lake. Northern red oaks, beeches, and sugar maples are the dominant trees here, with a significant number of tuliptrees and a variety of other trees.[3] This area was probably almost completely cleared for farmland and lumber by the Shakers. The current woodland thus dates from about 1900, but it nonetheless hosts some magnificent trees. The red oaks and tuliptrees found here are typical of the early development of this type of forest, while the beeches and sugar maples will dominate the forest when it becomes fully mature. If left to themselves, the trees of this area will some day resemble those found by Moses Cleaveland.

A representative stand of wet, lowland forest lies along the brook immediately south of the Nature Center at Shaker Lakes. The bottomland along the stream is dominated by

3 See the tables in Appendix G for the scientific names of the trees mentioned.

Figure 4-2 A Canada goose browses on garlic mustard near the Nature Center at Shaker Lakes. Garlic mustard is an invasive exotic plant that is now common along Doan Brook. Photograph by L. C. Gooch.

silver maples, cottonwoods, and pin oaks, while the drier slopes of the valley provide habitat for northern red oaks, hemlocks, white oaks, and hickories.

Understory trees and bushes throughout the unlandscaped parts of the upper watershed include a variety of dogwoods, American hornbeams, hophornbeams, alders, blackberries, and viburnums. The upper watershed is also home to a wide range of wild flowers and other ground covers. Exotic invasives such as Japanese knotweed, garlic mustard, and yellow iris are prominent. Native plants such as poison ivy, jewelweed, hepatica, solomon's seal, spring beauty, and trillium can also be found. The wetland areas at the upstream ends of Horseshoe Lake and the Lower Shaker Lake are dominated by cattails and are home to a variety of wetland vegetation such as invasive purple loosestrife, nightshades, hairy willow herb, and cord grass.

- **Vegetation of the Escarpment and the Doan Brook gorge** — The forest along the Doan Brook riparian corridor continues as the stream descends the Escarpment, but the character of the vegetation changes. Near the upper edge of the Escarpment (approaching from the east), the slope of the land steepens and the channel of Doan Brook begins to deepen until it becomes the gorge. The increasing slopes and the ravine create two different environments for vegetation. On the slopes of the Escarpment and the sides of the ravine, runoff is rapid, and the shallow soils have limited water-holding capacity. Here, the vegetation is characteristic of relatively dry environments. By contrast, the heart of the Doan Brook gorge is cool and relatively moist, since the gorge sides shield vegetation from sunlight and groundwater seeps from the exposed bedrock layers.

The forest along the dry Escarpment edge and upper slopes of the gorge is dominated by red, white, and chestnut oaks, with some cucumber-trees and shagbark hickories. The forest here is quite similar to the pre-settlement forest, except that the chestnuts that were once prominent are gone, having succumbed to the blight that began in the 1920s.

Within the ravine itself, red and sugar maples dominate, along with red oaks, tuliptrees, cherries, and yellow birches. In wetter parts of the ravine, cottonwoods, sycamores, and green ashes join the maples and cherries, while tuliptrees, birches, and oaks are generally absent. There are still remnants of the hemlocks that once dominated the ravine, but their ranks have thinned since the dense surrounding forest was cleared, reducing the deep, cool shade in which hemlocks thrive.

Understory saplings and shrubs generally consist of honeysuckles, viburnums, and cockspur thorn on the Escarpment. In the ravine, these species are joined by dogwoods, hornbeams, buckthorn, cranberry, poison ivy, and similar species. Herbaceous

Pre-Settlement Wildlife

When the first Europeans arrived in the Doan Brook watershed, they found abundant wildlife, including deer, bear, wildcat, wild turkey, and passenger pigeons, as well as a few elk and bison. Rattlesnakes were evidently common, since they figure prominently in almost every early account. In 1797 the surveyors found that grilled rattler was quite tasty, at least when other food ran short. Smaller and less disconcerting animals were undoubtedly also abundant, although early settlers rarely found them worthy of mention. Melinda Russell remembered bears, wolves, and rattlesnakes from 1813:

…the bears killed a nice shoat in harvest time… the wolves came into enclosures for four winters but the sheep fold was built so high that they could not get over it…Rattlesnakes were common, and surprised us often, but only one ever came within six feet of the house.

— Melinda Russell, 1880

Reports of large wildlife ceased by the mid 1800s. However, the brook continued to support abundant fish life well into the nineteenth century, as remembered by Asa Post (referring to events that happened in about 1860):

In the spring, the suckers came up the brook from Lake Erie to spawn; great schools of them. How they got above the [Cozad and Crawford mill] dams, I don't know, but I saw them up near Cedar Road with men and boys by torchlight, catching them on the "riffles" in such numbers that they were carried off in gunny sacks.

— Charles Asa Post, 1930

Figure 4-3 Virginia waterleaf at the Lower Shaker Lake wildflower garden. Photograph by L. C. Gooch.

plants are found mostly in the ravine and include nightshades, avens, asters, garlic mustard, jumpseed, jewelweeds, knotweeds, etc. Where the ravine floor becomes swampy, marsh vegetation such as smartweed and swamp dock can be found.

- **Vegetation of the lower watershed** — Remnants of the lower watershed's native forest can still be found in Rockefeller Park. American elms, black ashes, silver maples, pin oaks, and tupelos make up much of the level woodland along the brook, while beeches, sugar maples, tuliptrees, cucumber-trees, white ashes, and tupelos are found in some areas on the sloping valley sides. The tops of the valley sides and the sandy remains of lake beach ridges are home to oaks (black, white, red, and scarlet) and tuliptrees. The chestnuts that were once found on the tops of slopes and on the beach ridges are gone, and many American elms have fallen to Dutch elm disease. Although there are a number of native trees along the brook in the lower watershed, Rockefeller Park has been heavily landscaped and planted since before 1900, and non-native trees have been introduced. As a result, the part of the lower watershed along the brook offers the opportunity to see interesting non-native species as well as remnant stands of native vegetation.

  Understory vegetation in the lower watershed consists of dogwoods, hornbeams, viburnums, rhododendrons, azaleas, and honeysuckles, as well as a number of other introduced plants. Non-native ground covers such as English ivy, myrtle, and pachysandra dominate the herbaceous vegetation.

4.2 Wildlife Along the Brook and in the Watershed

The riparian corridor along Doan Brook is relatively small, and it is isolated by the surrounding city. It is, nonetheless, home to a variety of birds, mammals, and reptiles. An hour's spring stroll along the brook can reveal warblers and woodpeckers among the trees, waterfowl dabbling and diving in the lakes while heron fish nearby, a bird of prey soaring overhead, muskrat and turtles in the marsh, and an occasional browsing deer. The presence of so many different species indicates that the brook is an important ecological resource. The surprising lack of some other species shows the impact of the surrounding city. The species that are present and those that are absent are explored in the following sections.

Figure 4-4 American phoebe chicks beg for food near the Lower Shaker Lake dam. Photograph by L. C. Gooch.

4.2.1 Birds

Over 161 species of birds were documented along the upper Doan Brook between 1997 and 1999; 217 species have been sighted there since 1966 (see Table G-5 in Appendix G). The Site 14 area on Lake Erie at the mouth of the brook offers an even wider variety of birds, with 266 species documented there since 1980. Many species of birds, including most of eastern North America's brightly colored warblers, use the brook's riparian corridor as a migration stop during the spring and fall. Waterfowl ranging from the ubiquitous mallard to gaudy wood ducks, three species of mergansers, gadwalls, a variety of other ducks, coots, several species of grebes, and an occasional loon pause at the Shaker Lakes in the early spring and late fall. Red-tailed hawks breed around the lakes and probably in the lower watershed as well. Other raptors ranging from sharp-shinned and Cooper's hawks to an occasional osprey and a rare bald eagle (seen in the fall of 1999) hunt along the stream corridor.

Common birds that frequent suburban gardens, such as chickadees, nuthatches, blue jays, house sparrows, and house wrens, make up most of the birds that nest along the brook. However, some birds that require less suburban habitats can be found breeding in some parts of the watershed. In recent years green heron, killdeer, spotted sandpiper, and belted kingfisher have bred at the Shaker Lakes. Red-headed, red-bellied, downy, and hairy woodpeckers nest in snags and dead trees that are left standing in the brook corridor. Eastern wood peewees, great crested flycatchers, and red-eyed vireos also nest in the more wooded areas. Carolina wrens have joined the many song sparrows and red-winged blackbirds breeding in the marsh and scrub near the Nature Center for the past few summers. Beautiful wood ducks as well as mallards and Canada geese raise their young on the Shaker Lakes.

As more and more of the land along the migration pathways of North America's birds is developed, small areas like the land surrounding Doan Brook become increasingly important to successful bird migration. Although none of the species that are regularly seen along Doan Brook are listed as threatened or endangered, some of the warblers and other birds that make use of parks appear to be declining in numbers,[4] making it important to preserve migratory as well as breeding habitat.

4.2.2 Mammals

The riparian corridor along Doan Brook provides a small haven in an urban setting and is home to a variety of mammals (see Table G-6 in Appendix G). Many of these animals — opossum, raccoon, fox squirrel, eastern chipmunk, skunk, and woodchuck — are commonly found in the suburbs. Others are more surprising. In recent years, a small population of white-tailed deer has made its home along the brook in spring and fall, apparently breeding in the immediate area. Flying squirrels were found between the Nature Center and Lee

4 It is difficult to assess whether observed declines and increases in species numbers have long-term significance or are simply the result of periodic fluctuations in bird populations. However, northeast Ohio's habitat for migrating birds has indisputably decreased as suburban land use has increased.

Macroinvertebrates: Water Quality Canaries

Macroinvertebrates are invertebrates (animals without backbones) large enough to be seen without a microscope. Macroinvertebrate species include aquatic insect larvae, crustaceans, aquatic worms, and shellfish, among others. They live on the bottoms of lakes and in streambeds, and form an important link in the ecology of any body of water. Just as a healthy canary indicates a mine with good air quality, a healthy macroinvertebrate community indicates a stream with good water and habitat quality. As a result, macroinvertebrate surveys are often made as part of an effort to assess the health of a stream.

Road during a survey made in 1979. Three species of bat and several species of mole and shrew are also present. A careful observer can routinely see muskrat swimming in the brook and occasionally spot a red fox. Finally, coyotes are considered possible but unconfirmed along the brook.

4.2.3 Reptiles and Amphibians

A detailed survey made in 1979 revealed unexpectedly low populations of amphibians and reptiles along Doan Brook (see Table G-7 in Appendix G for survey results). Red-backed and two-lined salamanders were present in small numbers; however, the dusky salamander and spotted newt, which would be expected, were absent. A few frogs and toads were present, but numbers were again small, and those found were believed to be releases. Only small numbers of snakes were found, in contrast to the large numbers of rattlesnakes and other snakes reported by early settlers.[5] Unlike other reptiles and amphibians, turtles were abundant and varied in the Shaker Lakes. Many representatives of both native and non-native species were found during the survey.

Although no detailed studies of the reptile and amphibian population have been performed since 1979, the findings of the 1979 study appear to remain valid. A few green frogs are audible around the Lower Shaker Lake in the spring and summer, and many turtles are visible in both lakes. Salamanders, snakes, and toads remain rare.

Several factors may account for the low numbers of reptiles and amphibians. Many of these animals lay their eggs directly in the waters of the brook. Water contamination from heavy spring salt runoff from the surrounding roadways may have a primary role in preventing them from breeding. Generally poor water quality in the brook may also have a negative impact, as may elimination of pools in the flood plain where some of these animals breed. Frequent flooding that washes out the flood plain pools may also be a factor. Finally, these species are not highly mobile, and the isolation of the Doan Brook riparian corridor, cut off from other natural areas by the surrounding suburbs, makes the recruitment of new individuals difficult once a population has been destroyed. It is possible that early clear-cutting by the Shakers eliminated the habitat for some species, and some may have been wiped out by much poorer water quality in the 1960s and 1970s. Once eliminated, reptiles and amphibians cannot readily recolonize Doan Brook without human intervention.

4.3 Who Lives in the Brook? Lake and Stream Dwellers

The primary inhabitants of Doan Brook and its lakes are a variety of turtles (discussed in Section 4.2), a few pollution-tolerant fish, and a number of small creatures called macroinvertebrates that dwell in the streambed and on the lake bottoms. Fish species that have been observed in the Shaker Lakes in recent years include green sunfish, fathead minnow, and goldfish. Shiners and common carp were noted in the brook upstream from Martin Luther King, Jr., Boulevard in 1994. Table G-8 in Appendix G lists the observed fish species. All of these fish are usually found in stressed aquatic environments. Causes of stress in Doan Brook include relatively poor water quality (discussed in Chapter 6) and very low flows

5 Rattlesnakes have been largely extirpated in northeast Ohio.

Figure 4-5 A white-tailed deer at the Nature Center at Shaker Lakes. Photograph by L. C. Gooch.

during dry periods. In addition, the physical barriers to fish migration from Lake Erie (such as the culvert at the mouth of the brook, the University Circle culvert, and the Shaker Lake dams) and the physical modifications to the stream channel, particularly in Rockefeller and Ambler Parks, make it difficult or impossible for fish to migrate into the brook from Lake Erie as they once did. Because of these barriers, aquatic species that may have been eliminated by past poor water quality cannot reestablish themselves naturally. Finally, frequent high flows make it difficult for aquatic plants and animals to become established.

The macroinvertebrate community in Doan Brook was examined at one site in 1974 and at a number of sites in 1998. Similar surveys of the Shaker Lakes were made in 1973, 1974, 1979, and 1998. The surveys of the brook found a variety of organisms, including aquatic worms, flatworms, leeches,[6] mollusks, crustaceans, sponges, and a number of insect larvae (see Tables G-10 and G-11 in Appendix G). As is discussed further in Chapter 6, the type and number of macroinvertebrates found indicate that conditions in the brook range from poor, largely in the upper watershed, to good downstream from the Lower Shaker Lake and in the lower watershed.

Samples taken in the Shaker Lakes indicate that the macroinvertebrate community in the lakes is less diverse and includes fewer organisms than the stream community, probably as a result of muddy lake bottom conditions that do not encourage macroinvertebrate success.

4.4 Who Might Live Here? Habitat Potential of the Brook and Its Surroundings

In 1977, the Institute for Environmental Education compiled a list of 31 fish species that probably inhabited Doan Brook under original stream conditions (see Table G-9 in Appendix G). A similar list compiled in 1994 identified twelve species that might once have been found in the gorge upstream from Martin Luther King, Jr., Boulevard. The Institute for Environmental Education also identified a number of frog, salamander, and reptile species that might be expected along the brook but were either absent or present only in very small numbers. Additional bird species and larger numbers of birds might be found in the lakes if the aquatic environment improved. A few additional mammals might also inhabit the riparian corridor under the best of conditions, but the capacity of the relatively small and isolated corridor along the brook to support more or larger mammals is limited.

Tapping the full habitat potential of Doan Brook will require improvement in both water quality and physical habitat. As is discussed in later chapters, restoring the urban brook will require a watershed-wide effort that involves a few large projects and a sustained program of smaller projects carried out over many years. Even after restoration, the brook will remain an urban

6 Leeches in Doan Brook and the Shaker Lakes are not primarily those that prey on mammals, but rather those that prey on other invertebrates.

The New Fish in the Brook

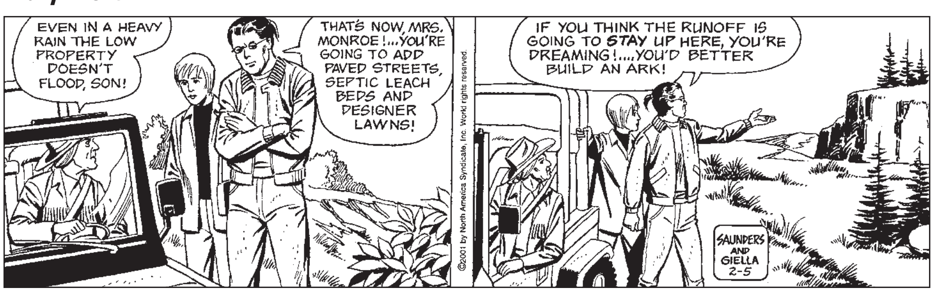
In 1999, researchers from John Carroll University restocked Doan Brook with three species of native fish: creek chub, blacknose dace, and stoneroller minnow. All three species were released into the stream between the Nature Center at Shaker Lakes and Horseshoe Lake. After the summer of 2000, the creek chub were thriving and the other two species were holding their own downstream from Lee Road, suggesting that Doan Brook may now be able to support fish that are slightly less pollution-tolerant than green sunfish and carp. Further restocking with other species is proposed if these three continue to thrive (Coburn 2000).

Figure 4-6 A fox squirrel along Doan Brook. Photograph by L. C. Gooch.

stream, surrounded and affected by the city. Because of this, conscious protection of existing habitats, creation of new protected habitat area, and restocking with selected species will be needed if we are to realize the ecological promise of the brook and its riparian corridor.

Channelized section of Doan Brook in Rockefeller Park. Photograph by L. C. Gooch.

Mary Worth



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5

The first four chapters of this handbook highlight some of the changes that Doan Brook has undergone since Nathaniel Doan first settled on its banks. Human actions have altered the stream in ways that dominate its present-day character. Understanding the behavior of the modern brook requires understanding the impact of urbanization on the stream and its watershed. More important, preserving the stream requires understanding how and why the construction of our city has degraded it. In this chapter we will explore the nature of urbanization in the Doan Brook watershed, and we will look at the ways that the city has changed stream flows and water quality.

5.1
How Have We Changed the Brook? Alterations to the Stream Shape

As soon as people settled near Doan Brook, they began to mold the stream to suit their use and convenience. The changes that they made fall into four main categories: construction of dams and lakes; diversion of the stream into underground culverts; construction of rigid channels to confine the brook to a set course; and other alterations to the stream channel shape.

5.1.1
Dams and Lakes

The most conspicuous change to the pre-settlement brook was the construction of the four lakes in the upper watershed. Although they now seem like part of the natural landscape, the Lower Shaker Lake, Horseshoe Lake, Green Lake, and Marshall Lake are all manmade. Each one submerged a portion of the natural stream valley, and each has a significant impact on the downstream brook.

A fifth dam was built in 1997 to create the flood detention basin just downstream from Martin Luther King, Jr., Boulevard. This dam does not form a permanent lake, and most of the time the stream passes unchecked through the opening at its base. In a large flood, however, the structure will temporarily detain and slowly release some water, thus reducing the peak flow downstream.[1, 2]

5.1.2
Culverts and the Vanishing Brook

A look at an older map of Doan Brook reveals a longer stream with many more fingers and branches than the Doan Brook of today (see Figure 5-1). The headwaters of the brook in 1900 extended about a mile farther east than the stream's current sources. During the development of Shaker Heights and Cleveland Heights, the upstream reaches of the brook's three branches, together with a number of smaller tributaries, were diverted into underground storm sewers,[3] and the stream channels were filled to allow houses and streets to be built where the stream had been. The most significant of the vanished tributaries were a stream that fed into the south fork just south of Shaker Boulevard, a tributary that ran down the Escarpment where Cedar Road now lies, and a tributary that cut northwest across Cleveland Heights to join the Cedar Road stream at Euclid

1 The effectiveness of the detention basin is discussed in Chapter 7.

2 Two other ponds in the watershed, the Wade Park Lagoon and the Rockefeller Park Lagoon, are not actually on Doan Brook. They sit next to the stream and drain into it, but they are filled with City of Cleveland water.

3 The distinction between a culvert and a storm sewer is somewhat arbitrary, since both serve as underground conduits for water that would naturally flow on the surface. In general, an underground pipe is called a culvert if it carries a stream from one stretch of above-ground channel to another stretch of above-ground channel. If there is no stream channel at the upstream end of a pipe, it is usually referred to as a storm sewer.

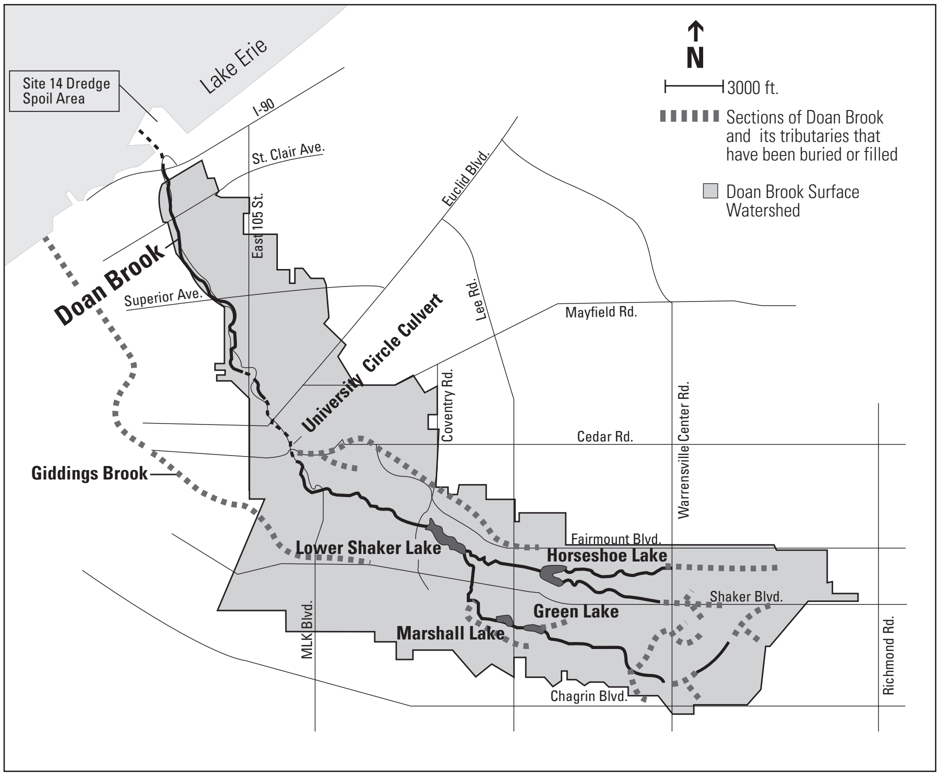

Figure 5-1 Original Doan Brook and Tributaries

Heights Boulevard. Large storm sewers now feed into the brook in these locations, carrying water that once flowed in open channels.

Just as tributaries to the brook were buried in storm sewers as the city grew, some stretches of the brook itself were forced underground into culverts to make way for roads and buildings. The University Circle culvert, the largest and longest culvert on Doan Brook, carries the main stream channel almost a mile (5,160 feet) between the base of the Escarpment (near the intersection of Martin Luther King, Jr., Boulevard and Ambleside Drive) and the northwest side of the Cleveland Museum of Art. There are two other long culverts on the main channel in the lower watershed: a 650-foot culvert that begins about 1,000 feet downstream from the outlet of the University Circle culvert and carries the stream under the Cancer Survivors' Monument, Liberty Boulevard, East 105th Street, and Hough Avenue; and a 3,300-foot culvert near the brook's mouth that carries the stream beneath Interstate 90 and the Corps of Engineers Site 14 dredge spoil area into Lake Erie. Many smaller culverts and bridge openings along the brook constrain the stream to a narrow path as it passes beneath a road or other obstruction.

5.1.3
Channelization: The Inflexible Stream

Some reaches of Doan Brook, although not confined in culverts, have been transformed into rectangular channels lined by vertical stone walls. The brook has been channelized along much of its two-mile course through Rockefeller Park, where water spreading onto the flood plain or a naturally meandering stream might threaten the road. Reinforced rectangular channels have also been built in Ambler Park and in isolated locations in the upper watershed.

5.1.4
Other Stream Channel Changes

Some sections of Doan Brook that have not been confined in channels or culverts have nonetheless been modified. In some places, one or both of the banks has been reinforced to prevent the stream from meandering. Fill material has been added along the stream in some other areas. The most obvious fill area lies along the south side of the Doan Brook gorge opposite the intersection of Kemper and Fairhill Roads. Erosion that began there in the late 1950s threatened to undermine the pavement on Fairhill Road. Beginning in 1959, the eroded side of the gorge was repeatedly "repaired" by dumping loose excavated material and construction debris. This material was itself unstable, leading to repeated slope failures, some blockage of the brook channel, and the erosion of significant amounts of fill material that was carried downstream by the brook.[4] The unstable section of the bank was finally effectively stabilized in 1976 by the construction of a *gabion*[5] retaining wall and placement of properly compacted fill material on a stable slope behind the wall.

4 Dumped debris may have been substantially responsible for the clogging of the University Circle culvert that contributed to severe flooding in 1975.

5 Gabions are rock-filled wire mesh cages that are frequently used in stream bank stabilization.

The Impact of Change

Lake Construction

Physical Impacts: The Doan Brook lakes slow flood waters from the upper watershed and store some water during a flood, so that the peak of the flood downstream from the lakes is lower, later, and spread out over a longer time than it would otherwise be.

Biological Impacts: The lakes affect the biology of the stream in a number of both positive and negative ways. They increase the downstream water temperature (a negative impact) and block any possible fish migration upstream from the dams. They provide an environment for wetland formation and a habitat for waterfowl. They collect and concentrate pollution from the watershed and allow sediments and organic matter to settle out, resulting in generally cleaner water downstream; however, large amounts of organic matter may be discharged at some times of the year, and water quality in the lakes themselves tends to be poor. In addition, the lakes attract large numbers of nuisance waterfowl (such as Canada geese) that pollute the water with their feces.

Culverts

Physical Impact: Where they are installed, culverts completely destroy the stream's habitat and aesthetic value. In addition, water flows more quickly in a culvert or storm sewer than it does in a natural channel. Because of this, water reaches the remaining natural stream more quickly, resulting in higher and sharper peak flows that occur sooner after rain begins.

Biological Impact: Culverts provide poor habitat for stream-dwelling organisms. Water in them flows at a relatively uniform depth, and they are periodically flushed out by high flows. They block light from the stream and stifle plant growth. Long culverts block the migration of aquatic organisms, including fish seeking to spawn in a flowing stream. Culverts also eliminate riparian corridors and their wildlife habitat and pollution-filtering capacity.

Channelization

Physical Impact: Conventional channelization confines the stream to a rectangular channel with a uniform water depth across the entire channel width. The channel will have relatively shallow flow most of the time and will have high-velocity, relatively deep flow during flooding. Less complete modification of the stream will have similar but less extreme impacts. Channels along Doan Brook were designed for much lower flows than are now common, and they therefore overflow regularly.

Biological Impact: Channelized streams do not readily develop the patterns of pools and riffles that are conducive to healthy aquatic environments. Regular flooding scours the entire channel and washes out aquatic organisms before they are well established. Channelization also isolates the stream from the flood plain, eliminating the riparian habitat and the water quality benefits of the riparian zone. Finally, flood plain pools that allow some aquatic organisms to breed do not form adjacent to channelized streams.

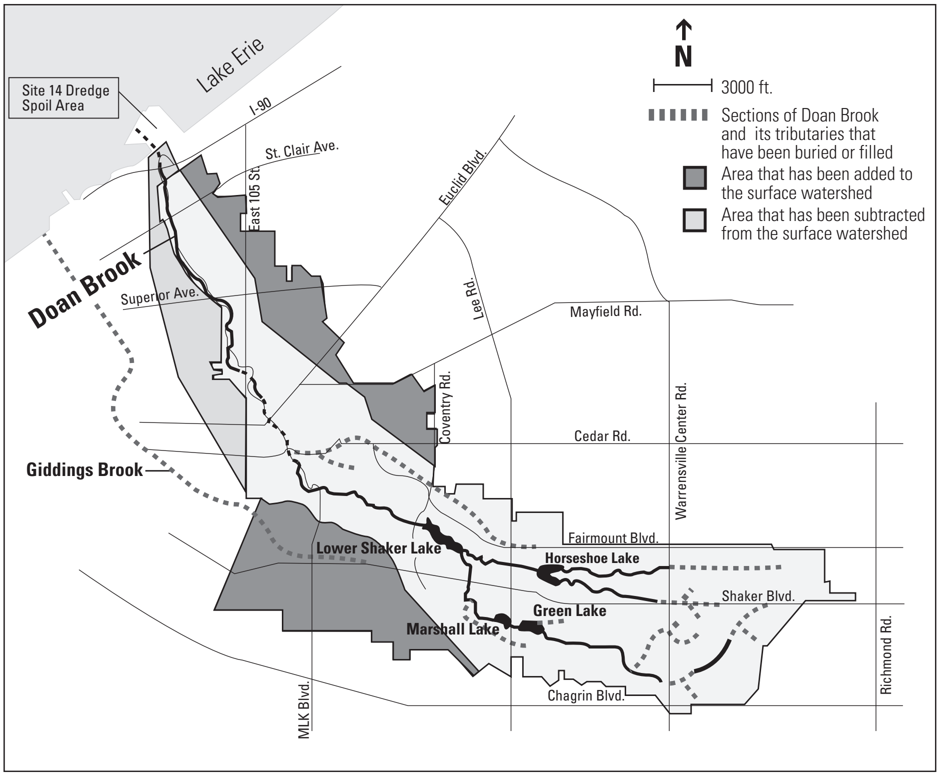

Figure 5-2 Original Doan Brook Watershed

5.2 Moving and Shaking in the Watershed: Changes in the Brook's Drainage Area

Just as the Doan Brook channel has been altered to accommodate the human environment, the brook's watershed was manipulated during the transformation of the forest into the city. Two kinds of changes to the watershed are significant: alterations to the size and shape of the land area that drains into Doan Brook and alterations to the surface of the land within the watershed. Each of these changes has a major impact on flow in the brook, particularly during floods.

5.2.1 Changes in the Watershed Land Area

It may seem unlikely that human activities can change the shape of the land enough to significantly alter the size of the area that sends runoff to a stream. Surprisingly, though, changes to an urban stream's watershed are not unusual. Drainage area changes usually occur when storm sewers or manmade channels reroute water that once flowed into one stream so that it flows into another. This kind of storm sewer rerouting has increased the size of the Doan Brook watershed by almost 21 percent.

Topographic maps that would allow an exact delineation of the Doan Brook drainage area in 1799 do not exist, but a reasonable estimate of the watershed's original outline can be made using maps from the 1920s and 1930s. Figure 5-2 shows the areas where there is a significant difference between the original and present watersheds.

As the figure indicates, a large area has been added to the southwest corner of the upper watershed. This 1.8 square mile area was once part of the drainage area of Giddings Brook (the stream immediately west of Doan Brook), but was diverted into Doan Brook via a storm sewer rerouting at some time prior to the 1960s. In addition, the lower watershed appears to have gained some land along its east side, while losing some land along its west side, with a resulting net increase in watershed area of about 0.2 square mile. Taken together, these changes to the Doan Brook watershed have increased its area by 21 percent, from an original area of approximately 9.7 square miles to its current area of 11.7 square miles.

5.2.2 Changes in the Nature of the Land

While changes to the size and shape of the watershed have had an impact on Doan Brook, changes to the nature of the watershed surface have had an even more profound effect. The dense forest that covered the area before Nathaniel Doan and the Shakers arrived responded to rainfall very differently from the modern urban landscape of parking lots, streets, driveways, rooftops, and lawns. Estimates of the fraction of the Doan Brook watershed that is *impervious*[6] indicate that about 28% of the area is now covered with

6 Impervious area is land surface that allows little or no water to infiltrate into the ground. Paved areas and building roofs are the primary impervious surfaces in most urban watersheds.

The Impact of Change

Changes in Watershed Size and Shape

The most obvious impact of the increase in the Doan Brook watershed area is a corresponding increase in the amount of water that flows into the stream. The additional flow to the brook during heavy rains will increase the frequency and severity of downstream flooding. The flow from the Giddings Brook watershed enters the brook in University Circle (see Chapter 7), which tends to increase flooding in University Circle and farther downstream. Where the stream is not channelized, the brook will erode its bed and banks to adjust to the increased flow. This erosion leads to high sediment loads in the stream and generally degrades the stream's habitat. The channelized stretches of Doan Brook in the lower watershed cannot change to adjust to the increased flow. As a result, the stream overflows more often.

The increased flooding from the Giddings Brook watershed is more than it might otherwise be because of the watershed's shape. The upper part of the Giddings Brook area lies on the moderately sloped western edge of the Plateau; however, the western part of the area lies on the steep upper edge of the Escarpment. Because this land is steep and heavily urbanized, storm runoff will flow very quickly to the brook, resulting in a short, sharp peak flow and further increasing the maximum flood flow in University Circle and the lower watershed.

Changes in Watershed Surface

Physical Impact: Rainfall flows off a paved surface more quickly and in larger quantities than it would flow from a forest floor. At the same time, less rainwater is absorbed into the ground to replenish groundwater and be slowly released to the stream at a later time. The urbanization of the Doan Brook watershed surface has thus had two main impacts: it has increased the speed and degree of flooding and decreased the groundwater-fed flow in the brook during dry periods.[7] A rough estimate of the impact of urbanization on Doan Brook flow indicates that in an average year, the runoff from a given area is as much as **three times greater than it was before development. A five-year flood[8] may be four times larger than it was in Nathaniel Doan's time.** Where it can, the stream erodes its bed and banks to accommodate the higher flows.

Biological Impact: The water that flows to Doan Brook from the urban surface of its watershed carries a wide variety of contaminants. Runoff from streets carries oil, grit, road salt, and traces of other manmade chemicals. Runoff from lawns carries fertilizers, pesticides, and domestic animal waste. Runoff from construction sites carries sediment. Additional sediment is generated as the brook erodes its bed and banks in response to higher flows. Contamination flowing into the brook has a significant impact on water quality, but the impact is perhaps less than might be feared. Water quality in the brook is discussed in detail in Chapter 6.

More frequent and severe floods wash out stream and flood plain habitats, making it difficult for aquatic organisms to become established. Lower flows that may occur during dry periods also eliminate aquatic habitat.

7 Decreases in dry-weather flow may be offset by runoff from human activities such as washing cars and watering lawns.

8 See Appendix H for the definition of the five-year flood.

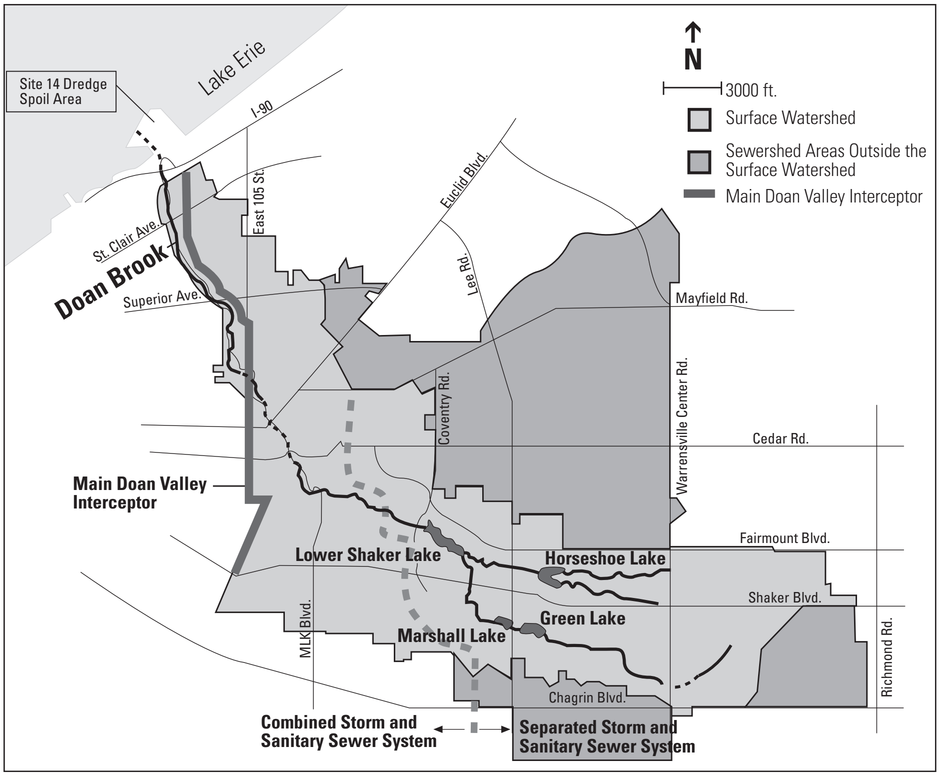

Figure 5-3 Doan Brook Sewershed

buildings or pavement. Land that has not been paved altogether has generally been transformed from deep forest with a forest floor covered in leaf litter to manicured lawns with relatively few trees and little underbrush. Rainfall quickly runs off the modern landscape, leading to more frequent Doan Brook flooding.

5.3 Where Do the Sewers Fit In? The Sewershed and Storm Sewer Drainage

Anyone who has followed the water quality debate in recent years is aware that overflows of sanitary sewage into streams and lakes — generally called Combined Sewer Overflows, or CSOs — are a major water quality concern in older urban areas. CSOs are, in fact, the major single cause of poor water quality in Doan Brook. How did a sewer system that allows sanitary sewage to discharge to Doan Brook come about, and why weren't such discharges corrected long ago?

As people developed the Doan Brook watershed, they found it necessary to move the streams and rivulets that ran to Doan Brook underground and out of the way. Over time, a sometimes-confusing web of culverts and sewers grew beneath the city to replace the streams. During the city's early life, sanitary sewage was drained directly into this pipe network, and the combined stormwater and sanitary sewage was discharged straight into streams and Lake Erie. When it became evident that we could not continue to dump our sewage directly into streams and the lake, the combined sanitary and storm sewers were diverted so that the combined sewage could be treated before it was discharged to Lake Erie. Unfortunately, the combined sewer system and the sewage treatment plants could not be made large enough to treat all the surface runoff from even a small storm. Combined sewer systems are therefore designed to overflow, sending mixed sanitary sewage and stormwater back to the streams and the lake whenever it rains more than a few drops.

Sewer systems for newer developments were designed to keep sanitary sewage and stormwater in separate pipes, diverting sanitary sewage for treatment and discharging storm flows to surface streams. However, the cost of replacing the old combined systems was too high, and they stayed in place.

Because different parts of the sewer system in the Doan Brook watershed were built at different times, there are both combined (storm and sanitary together) and separated (storm and sanitary kept apart) sewer systems in the watershed. The following sections describe the separated and combined sewer systems and their interactions with each other and with Doan Brook.

5.3.1 The Sanitary Sewer System and the Sewershed

Figure 5-3 shows that the *sewershed* associated with Doan Brook is larger than the surface watershed. For Doan Brook, the sewershed is defined as the area over which the sanitary sewers drain to the *Doan Valley Interceptor (DVI)*, a large combined sewer line that roughly parallels Doan Brook in the lower watershed between East 105th Street and I-90.[9] Some areas in the upper sewershed that send surface water to adjacent streams nonetheless contribute sanitary sewage to the DVI.[10] About 8.4 square miles that are not in the surface watershed send sanitary sewage to the DVI, making the total sewershed area about 20.1 square miles.

5.3.2
Separated Storm and Sanitary Sewers: The Upper Watershed

In most of the upper watershed, where the sewer systems are newer, the sewers are designed to keep sanitary sewage separated from stormwater runoff. Ideally, the sanitary sewer system carries only sanitary sewage, which it diverts to a sewage treatment plant (the Northeast Ohio Regional Sewer District's Easterly Wastewater Treatment Center in this case), while the storm sewer carries the storm runoff to the brook. Figure 5-3 shows the part of the Doan Brook watershed that has separate sanitary and storm sewers. Unfortunately, the separate sanitary sewer system from the upper watershed empties into the Doan Valley Interceptor, which is part of the lower watershed combined sewer system (described in the next section). Thus, sewage that is kept out of the brook by the upper watershed's separate sewers may nonetheless contaminate the stream in the lower watershed, as described below.

Why Does the Storm Sewer Stink? Problems with Separated Sewers

If the sewers in the upper Doan Brook watershed separate sanitary sewage and storm runoff, why does the storm sewer outlet in the Nature Center marsh (for example) sometimes stink of sewage? In a perfect world, the separate systems would be just that — separate, without any chance of accidental mixing between storm flows and sanitary sewage. In the real world, sanitary sewage finds a number of pathways to the storm sewers:

- Older designs of separate systems typically allow mixing when there is a minor disruption of the system. For example, water from an overflowing storm sewer may flow into the sanitary sewer, causing it to become too full. An over-full sanitary sewer is designed to relieve itself back to the storm sewer or directly to surface water. (The alternative would be for the sewage to back up into your basement.)
- Heavy rain can overtax the sanitary sewers even if they do not directly receive storm sewer overflow. The pipes that carry sanitary sewage are rarely completely watertight, and as they age they can allow a great deal of water to enter. Infiltration of groundwater into a sanitary line during a storm can overfill the sanitary system, causing spills to surface water.
- Blocked or damaged pipes may also cause sanitary sewage to back up into the storm system.
- Finally, there are occasionally accidental or deliberate illegal connections of sanitary lines from buildings directly into the storm sewers. A number of such connections have been identified in the upper Doan Brook watershed, but the process of correcting them has been slow.

9 The DVI empties into the Easterly Interceptor Sewer near I-90. The Easterly Interceptor carries its flow to the Northeast Ohio Regional Sewer District's Easterly Wastewater Treatment Center, which is located near Lakeshore Boulevard and East 142nd Street.

10 For example, surface water from most of the part of Cleveland Heights that lies northeast of the intersection of Fairmount Boulevard and Coventry Road drains into Dugway Brook (the stream that runs through Lakeview Cemetery). However, sanitary sewage from this neighborhood drains into the Doan Valley Interceptor.

Who Owns the Sewers?

Sanitary and *combined* sewers that intercept the sewage at your curb are owned by your city, which is responsible for their maintenance. When sanitary sewers from several cities combine, or when a sewer line crosses from one city into another, the Northeast Ohio Regional Sewer District takes responsibility. *Storm* sewers that collect surface runoff are almost always owned by individual cities.

The Impact of Change: Sewers

Physical Impact: The storm sewer system in the upper watershed and the combined sewer system in the lower watershed change the points at which stormwater runoff enters Doan Brook. As a result, the sewer system affects the amount of water flowing in the stream at any point. During periods of high rainfall, this may lead to more flooding in some areas and less in others. During periods of very light rain, the combined sewer system in the lower watershed may reduce inflow to the brook by diverting runoff that would otherwise flow to the stream.

Biological Impact: The combined sewer system and, where the system is damaged, the storm sewer system, carry human waste and household chemicals to the brook, as well as providing a conduit for contaminated runoff from streets and yards. The inflow of sanitary sewage to the brook is the stream's greatest single water quality problem, particularly in the lower watershed.

5.3.3 The Combined Sewer System: The Lower Watershed

In the lower watershed, where the sewer system is generally older, the storm and sanitary sewers are combined into a single pipe (see Figure 5-3). In dry weather, the combined sewer system carries sanitary sewage and any surface water runoff to large *interceptor sewers*, which divert the flow to the Easterly Wastewater Treatment Center for treatment. As a result, both sanitary sewage and urban runoff (which may contain lawn chemicals, oil from streets, or other contamination) are treated during dry weather and during very small storms. During slightly larger storms, however, the combined sewer system is overwhelmed by the storm runoff. When this happens, excess flow consisting of mixed stormwater and sanitary sewage overflows the sewer system and is released to the brook. Under the conditions that existed in the year 2000, the combined sewer system generally released its contaminated mix to Doan Brook more than 60 times each year.

5.3.4 Flowing into the Doan: Where Storm and Combined Sewers Feed the Brook

In order to understand flood flows or water quality problems in Doan Brook, it is necessary to understand where flows from different parts of the watershed enter the stream. Since the brook's modern tributaries are mostly storm or combined sewers, an examination of the sewer maps is required. Figure 5-4 shows where the watershed's large sewers feed the brook, together with the approximate land area that drains to each outflow. Table 5-1 summarizes the information in tabular form. In the part of the watershed with separate sewer systems (generally the upper watershed), the outlets shown flow from the separated storm sewers. In the combined sewer area, the outlets shown flow from the combined system.[11, 12]

Figure 5-4 and Table 5-1 show that runoff from much of the upper watershed (a total of 3,190 acres) passes through the Lower Shaker Lake. Almost three quarters of this area is also in the watershed of Horseshoe Lake (1,200 acres) or Green and Marshall Lakes (1,140 acres). Thus, runoff from about 43 percent of the total watershed area of 7,500 acres passes through the Shaker Lakes. Two other sections of the upper watershed, totaling approximately 470 acres, contribute runoff to the brook between the Lower Shaker Lake and the entrance to the University Circle culvert.

The remaining runoff from the upper watershed is carried down the Escarpment in storm or combined sewers and discharged to the brook near University Circle. Runoff from a 670-acre area in Euclid Heights (the wedge of land within the watershed west of Coventry Road and north of Doan Brook) is collected in a sewer that runs down Cedar Glen (the Cedar Glen sewer) and enters the University Circle culvert near the point where MLK crosses under the railroad tracks. Runoff from a large area (approximately 1,000 acres) south of the brook and west of Van Aken Boulevard is collected in a storm sewer that joins the University Circle culvert just downstream from the culvert inlet. Much of this 1,000-acre area was originally part of the Giddings Brook drainage area, and this storm sewer is therefore called the Giddings Brook culvert.

Farther downstream from the inlet to the University Circle culvert, runoff from the Lake Plain (lower watershed) begins to enter the

11 The combined sewer system is a complex network of interlocking pipes, and inflow to the brook from a given outlet will depend on many factors. Figure 5-4 shows approximate drainage areas that are generally correct but far from precise.

12 Instead of showing the outflow point of every storm sewer that flows to the brook, Figure 5-4 consolidates the outflows so that the watershed is broken up into significant drainage areas and outflow points. For example, there are several storm sewer outflows to the north and middle forks of Doan Brook upstream from Horseshoe Lake, but the watershed map shows only a single, large area contributing to the lake. The drainage area is shown this way because Horseshoe Lake, like most lakes, controls flow from the area that lies upstream. As a result, a fairly complete understanding of the behavior of the stream can be obtained by lumping the upstream area into a single unit that contributes flow at the lake.

Table 5-1	Summary of Estimated Doan Brook Drainage Areas[13]		
Location	**Drainage Area[13] Entering (acres)**	**Cumulative Drainage Area (acres)**	**Notes**
Horseshoe Lake	1,200	1,200	
Green and Marshall Lakes	1,140	1,140	
Lower Shaker Lake	850	3,190	
Just D/S from Lower Shaker Lake	320	3,510	
Lower Shaker Lake to MLK Detention Basin	150	3,660	
Giddings Brook Culvert	1,000	4,660	Formerly part of the Giddings Brook watershed. Enters University Circle culvert just downstream from the culvert inlet.
Cedar Glen Sewer	670	5,330	Enters University Circle culvert a short distance downstream from the culvert inlet.
Euclid Avenue	230	5,560	
East 105th Street	820	6,380	
Rockefeller Park	1,120	7,500	

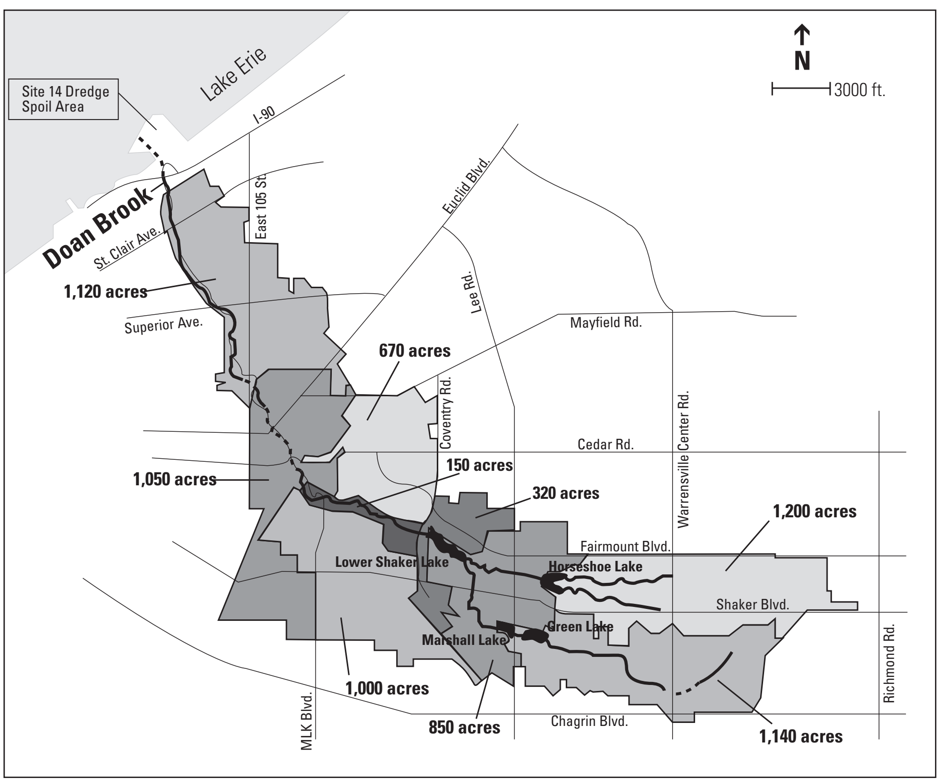

Figure 5-4 Doan Brook Subwatersheds

13 Drainage areas are approximate. Information on surface watershed areas sometimes conflicts. The data presented here represent good estimates of Doan Brook drainage areas.

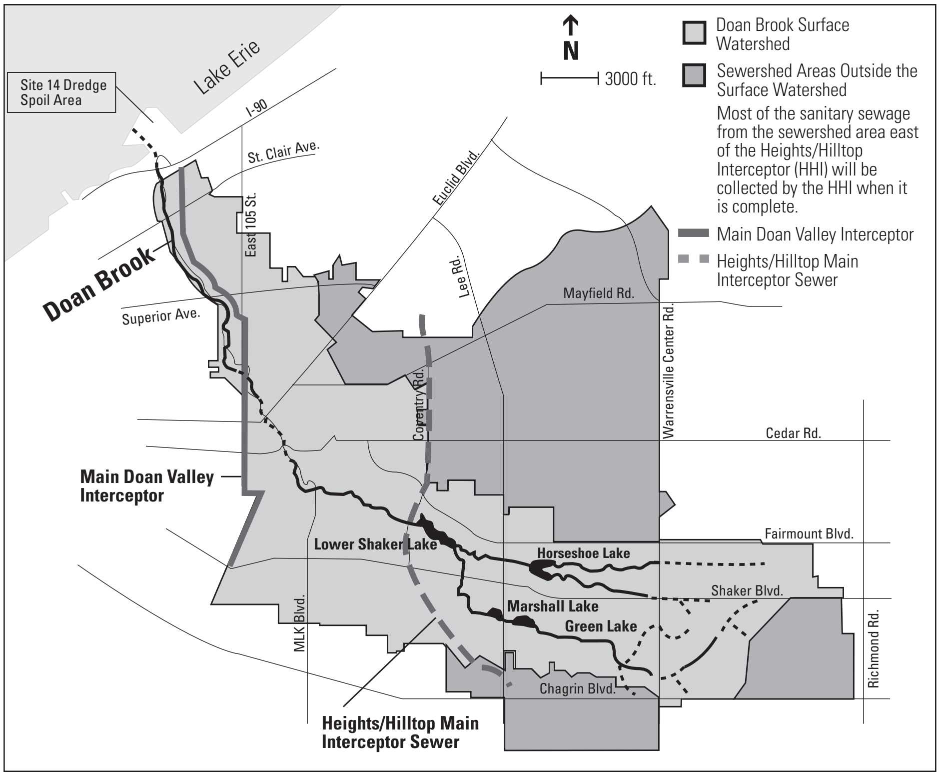

Figure 5-5 Heights/Hilltop Main Interceptor

brook. Runoff from this area reaches the stream through three main inlets and a number of smaller ones. About 230 acres south of Euclid Avenue drain into the University Circle culvert at Euclid. A strip of land along the west edge of the watershed and a smaller area north of Euclid drain into the stream at East 105th Street, adding a total of 820 acres. The remaining downstream area (1,120 acres) drains into the brook at a number of points in Rockefeller Park.

5.3.5
Change in Progress: The Impact of the Heights/Hilltop Interceptor

As this handbook is being prepared, a new interceptor, the Heights/Hilltop Interceptor Sewer (HHI), is under construction in the upper watershed. One purpose of this system of deep underground sewers is to gather sanitary sewage from the Doan Brook sewershed east of Coventry Road (see Figure 5-5), divert it away from the Doan Valley Interceptor combined system, and carry it directly to the Easterly Wastewater Treatment Center.

The completion of the HHI[14] will reduce the amount of combined sewage that reaches Doan Brook by about 50%. Although this sewage diversion will reduce the levels of bacterial contamination in the brook, it will not solve the stream's water quality problems (see Chapter 6). Because the HHI is designed to intercept sanitary sewage (rather than stormwater flow) from the separate sewer area, the volume of storm flows into the brook will not change much after the completion of the interceptor sewer. The lower watershed's combined sewer system will still discharge combined sewage into the brook many times each year — whenever there is significant rainfall — but the fraction of sanitary sewage in the combined sewage mix will be less.

5.4
What Difference Does it Make? Summarizing the Impacts of Change

This chapter began with the assertion that Doan Brook today bears little resemblance to the stream of 200 years ago and has reviewed the transformation wrought by urbanization. The condition of today's brook can be summarized as follows:

- Doan Brook has more total flow and more frequent, larger floods than it did a relatively short time ago. The combined effect of the larger watershed and more impervious area in the watershed leads to an increase of about four times in average annual flow and an increase in the five-year peak flow of about five times. The brook erodes its bed and banks as it tries to adjust its size and shape to its new flow regime.
- The upper watershed's four lakes and, to a lesser extent, the MLK detention basin store

14 The portion of the HHI in the Doan Brook watershed is expected to be partially in service by the end of 2001. The system is expected to be complete some time in 2005.

and slowly release water during floods. They reduce the peak flows downstream and partially counter the higher flood peaks that result from urbanization of the watershed.

- Doan Brook is confined to a rigid channel or culvert in many places and therefore constrained to flow in a straight path within defined limits or to completely overflow its channel and flood its surroundings. The channels were designed for yesterday's flows, so today's runoff leads to frequent floods. The fixed channels thwart the stream as it works to adjust to today's conditions.
- Runoff to Doan Brook from its urban watershed carries a variety of contaminants, including sanitary sewage. The runoff degrades the stream's water quality. Frequent flows that scour the channel, the culverts, and the lined channel sections combine with poor water quality to yield an aquatic environment poor in both species diversity and numbers of individual organisms.
- Long culverts in the lower watershed and dams in the upper watershed prevent free movement of fish and other aquatic organisms from Lake Erie into Doan Brook.

This summary of the effect that urbanization has had on Doan Brook paints a grim picture of the health of the stream. While it is true that the ecosystem of the brook is unlikely ever to regain the diversity and purity that Moses Cleaveland's surveyors found, an understanding of the negative impacts of urbanization must be balanced by an appreciation for the brook's remaining assets. As Chapter 4 demonstrates, much of Doan Brook is still surrounded by a riparian corridor that preserves a bit of wild landscape and provides habitat to a fair variety of wildlife. The Shaker Lakes, although they are not natural features, provide a migration stop for many species of waterfowl and other birds and are an active breeding area for still others. The challenge for stewards of the urban brook is to manage the stream to take best advantage of its strengths and minimize the impact of its urban setting. Approaches to watershed management that can be used to maximize the potential of Doan Brook are discussed in Chapters 8 and 9.

A black-crowned night-heron fishes amidst overgrown duckweed in the Lower Shaker Lake. Photograph by L.C. Gooch.

When you defile the pleasant streams
And the wild bird's abiding place,
You massacre a million dreams
And cast your spittle in God's face.

— John Drinkwater

Olton Pools: To the Defilers.

6 Is It Polluted? Water Quality in the Brook

Urbanization of Doan Brook and its watershed has harmed water quality in the brook in many ways (see Chapter 5). In this chapter, we will review data from the stream and lakes to determine how serious the damage is. We will also discuss the sources of the observed contamination and explore some approaches to improving water quality.

6.1 How Dirty Is the Brook? What Water Quality Measurements Show

Water quality in Doan Brook has been of interest to local residents and government agencies since the late 1960s. A somewhat bewildering array of water quality tests has been made at different times and places over the past thirty years. Most of the resulting data are summarized in Appendix I. The most comprehensive and most recent study was performed in 1998 as part of the Northeast Ohio Regional Sewer District's evaluation of the Doan Brook watershed.

The results of Doan Brook water quality tests — made at different places and different times using different sampling and analysis techniques — can be difficult to interpret. This discussion examines information about the brook's water from the following angles in an effort to make sense of all the data:

- Water quality in the brook was evaluated separately from water quality in the lakes, since the lake and stream environments lead to different chemical and bacterial concentrations.
- Four categories of water quality parameters were considered:
    - Nutrients (primarily phosphorus, ammonia, and other forms of nitrogen);
    - Bacteria (fecal coliform and *E. coli*);
    - Metals (copper, lead, cadmium, etc.) and other miscellaneous contaminants (chiefly chlorides);
    - Manmade toxic organic compounds (pesticides, herbicides, PCBs, etc.).
- Water quality was evaluated for changes over time.
- Water quality was evaluated for changes along the length of the brook.
- Water quality was compared to the water quality in natural (unpolluted) streams in Ohio.
- Water quality was compared to Ohio EPA water quality criteria that are applicable to Doan Brook.[1]

What the water quality data tell us about the brook and the lakes is discussed in detail in the following subsections, and Section 6.2 outlines the effects that contamination has on the stream. The picture that emerges shows a stream that is heavily contaminated with nontoxic compounds that are typical of urban runoff. The data do not show significant toxic contamination or other contamination that would have a long-lasting, difficult-to-remedy impact on the stream if the inflow of new contamination stopped.

1 Data were generally compared to the water quality criteria for the maximum allowable level in the stream. The resulting assessment of whether a given criterion is violated is not precise but should be generally correct. In some cases, violation of a water quality criterion may be indicated when none occurred.

6.1.1 Water Quality in the Brook

Table 6-1 summarizes the fraction of Doan Brook stream samples that contained concentrations of selected chemicals or bacteria greater than those found in unpolluted streams. Table 6-2 summarizes violations of Ohio EPA water quality criteria.[2] Looking at all of the water quality data from the different perspectives outlined in Section 6.1 leads to the following conclusions:

- **Comparison to Concentrations in Natural Waters** — Water in Doan Brook has consistently elevated levels of nutrients (phosphorus, ammonia, and other forms of nitrogen), chlorides, iron, and bacteria. Concentrations of copper, chromium, zinc, and lead are also elevated at times.
- **Comparison to Water Quality Criteria** — The brook's water violates Ohio EPA water quality criteria for bacteria in all samples taken during wet weather and in many dry weather samples as well. Criteria for a number of metals (copper, zinc, and sometimes lead) are also consistently violated during wet weather sampling. There are occasional violations of other criteria during dry weather.
- **Toxic Contamination** — Concentrations of toxic metals (lead, arsenic, mercury, etc.) in brook samples are generally comparable to those found in unpolluted streams, although lead concentrations are sometimes elevated, particularly in wet weather. No samples from the brook have been analyzed for toxic organic compounds (PCBs, herbicides, pesticides, etc.). Because there are no major industrial sources for these chemicals in the watershed, it would be surprising to find them in significant concentrations. Low concentrations of pesticides and herbicides from lawn and golf course runoff may be present. However, limited lake sampling in the early 1970s (see Section 6.1.2) found no detectable concentrations of pesticides or herbicides.
- **Variation Along the Length of the Brook (1998 Data)** — Although water quality varies along the brook, the variation is less consistent than might be expected, given that the upper brook is in a separated sewer area and the lower brook in a combined sewer area with frequent overflows. During dry weather, bacteria levels appear to be somewhat higher upstream from Horseshoe Lake and along the lower brook than they are elsewhere. Differences in dry weather concentrations of nutrients and metals are insignificant. However, the impact of the lower brook's combined sewer system is evident during wet weather,[3] when there are much higher bacteria and nutrient concentrations along the lower brook than in the upper watershed.
- **Variation Over Time** — Because very few data were collected prior to 1987, it is difficult to evaluate long-term water quality trends in the brook. Limited bacteria sampling in 1966–67 and 1973–74 (See Appendix I) appear to show much higher bacteria levels in the brook than current samples. Phosphorus and ammonia data from the 1960s also appear to indicate higher concentrations than current sampling.[4] No clear trends emerge in data collected since 1987.[5]

Taken together, Doan Brook stream sampling data indicate the impact of non-toxic urban runoff — elevated nutrients and chlorides, bacteria, and a few common metals. The effects that these contaminants have on the stream are discussed in Section 6.2. The stream's aquatic community is somewhat more diverse than might be expected in such an urban setting, possibly because of the intact riparian corridor that lines the brook in many places. The contamination that is present in the brook is reversible. If contamination stops flowing to the stream, a healthy ecosystem will begin to restore itself in a remarkably short time.[6]

6.1.2 Water Quality in the Lakes

Water quality information for the Shaker Lakes (see Appendix I) leads to the following conclusions:

- **Comparison to Concentrations in Natural Waters** — Water in all of the Shaker Lakes has consistently elevated concentrations of nutrients and iron. Although concentrations of these chemicals in the Lower Shaker Lake and in Horseshoe Lake are sometimes within the range of concentrations found in natural waters, they are almost always high enough to stimulate excessive plant growth. Bacteria levels in the lakes are considerably lower than those in the brook, but bacteria concentrations are still elevated, as are those of iron. Concentrations of metals other than iron and of other contaminants in the lakes are not significantly elevated.
- **Comparison to Water Quality Criteria** — Data from the 1998 lake sampling indicated few violations of water quality criteria. The only violations were for *E. coli* in some August samples from the Lower Shaker Lake.

2 See Appendix I for the data that were used to create the summary tables and reach the conclusions stated in the text.

3 Wet weather data are available only from NEORSD 1998 sampling points 1 through 4 (sampling point 1 is near the mouth of the brook; sampling point 2 is at the University Circle culvert outlet; sampling point 3 is downstream from Coventry Road; and sampling point 4 is on the south fork upstream from the Lower Shaker Lake).

4 A reduction in phosphorus is to be expected, since the use of phosphates in detergents was banned in the 1980s.

5 Prior to 1997, contamination levels were consistently much higher at NEORSD sampling point N-17 (just downstream from the outlet of the University circle culvert) than they were at other sampling points. In 1996, a major sanitary sewer blockage that fed sewage from the Cedar Hill area directly into the culvert was discovered and repaired. Subsequent sampling (1997 and 1998) has shown concentrations at N-17 that are comparable to those elsewhere along the brook.

6 Physical barriers, the physical condition of the stream, and the past elimination of some species of organisms would limit the stream's recovery. See Chapters 5 and 8.

Table 6-1 Percentage of Samples With Concentrations That Are Significantly Greater Than Those in Unpolluted Streams (Selected Contaminants)

Sample Location and Time	Values Significantly Greater Than Natural Waters											
	# of Samples*	Ammonia	Phosphorus	Nitrates	TKN**	Chlorides	Copper	Chromium	Zinc	Iron	Lead	Fecal Coliform	E. Coli
1987–1997:												
Near the Mouth of the Brook	13	•••••••••	•••••••		••••	••••••••		••		••••••••••	•	•••	••••••
University Circle Culvert Outlet	13	••••••••••	••••••••••		•••••••••	••••••••		••	••	•••••••••	•	•••••••••	••••••••••
North Fork U/S from Lower Lake	14	••••••••	•		••	••••••	•	•		••••••••••	•	•	••••••
South Fork U/S from Lower Lake	14	•••••••			••	••••••	•	•		•••••••••	•		••
1998 Wet Weather:												
Near the Mouth of the Brook	3	••••••••••	••••••••••		••••••••••		••••••••••		••••••••••	••••••••••	••••••••••	••••••••••	••••••••••
University Circle Culvert Outlet	3	••••••••••	•••••••		••••••••••		••••••••••	•••••••	••••••••••	••••••••••	••••••••••	••••••••••	••••••••••
Between Culvert Inlet and Coventry	3	••••••••••	•••••••		•••••••		••••••••••		•••••••	••••••••••	••••••••••	••••••••••	••••••••••
South Fork U/S from Lower Lake	3	••••••••••	•••••••		••••••••••		••••••••••	•••	••••••••••	••••••••••	••••••••••	••••••••••	••••••••••
1998 Dry Weather:												
Near the Mouth of the Brook	8			•••••		••••••••••				••••••••••		•••	•••••••
University Circle Culvert Outlet	8		••	••••••••		••••••••••				••••••••••		•••••••	••••••••••
Between Culvert Inlet and Coventry	8	•••••	••••							••••••••••		•	•••
North Fork U/S from Lower Lake	9	••••	•••	•••••						••••••••••		•	•••
South Fork U/S from Lower Lake	9	••	••	•••	••	••••••••••				••••••••••		••••	••••••••
U/S from Horseshoe Lake	9	••••••	••••••••	••••••••	••••	••••••••••	••			••••••••••	••	••••••	••••••••••

• The number of dots is proportional to the fraction of the samples that has concentrations higher than those in natural waters.

* Not all parameters were sampled for all sampling events.

** Total Kjeldahl Nitrogen.

Table 6-2	Percentage of Samples That Violate Water Quality Criteria*								
Sample Location and Time	**Water Quality Violations**								
	# of Samples**	Dissolved Oxygen	Phosphorus	Copper	Zinc	Iron+	Lead	Fecal Coliform	E.Coli
1987–1997:									
Near the Mouth of the Brook	13	••	•					•••	••••••
University Circle Culvert Outlet	13	•••			•			•••••••••	••••••••••
North Fork U/S from Lower Lake	14			•				•	••••••
South Fork U/S from Lower Lake	14	•		•					••
1998 Wet Weather:									
Near the Mouth of the Brook	3			••••••••••	••••••••••			••••••••••	••••••••••
University Circle Culvert Outlet	3			••••••••••	••••••••••		•••••••	••••••••••	••••••••••
Between Culvert Inlet and Coventry	3			••••••••••	•••••••		•••	••••••••••	••••••••••
South Fork U/S from Lower Lake	3			••••••••••	••••••••••		•••••••	••••••••••	••••••••••
1998 Dry Weather:									
Near the Mouth of the Brook	8							•••	•••••••
University Circle Culvert Outlet	8							•••••••	••••••••••
Between Culvert Inlet and Coventry	8							•	•••
North Fork U/S from Lower Lake	9							•	•••
South Fork U/S from Lower Lake	9							••••	••••••••
U/S from Horseshoe Lake	9			••		••		••••••	••••••••••

• The number of dots is proportional to the fraction of the samples that violates the criteria.

* The analysis used to determine when water quality violations for metals occurred is not precise. It should give a generally correct evaluation of the occurrence of violations but may show some violations when none occurred.

** Not all parameters were sampled for all sampling events.

+ Some violations for iron during wet weather are shown on the tables in Appendix I. While these samples exceeded the 30-day maximum concentration for iron (the only criterion for this metal), they are maximum concentrations rather than 30-day averages and probably do not indicate an actual violation.

- **Toxic Contamination** — Horseshoe Lake and the Lower Shaker Lake were sampled for a number of toxic organic compounds (chiefly pesticides and herbicides) in 1973. No detectable concentrations were found. No elevated concentrations of toxic metals have been found in the lake waters.
- **Variation Among the Lakes** — There is little clear variation in the water quality in the four Doan Brook lakes. Careful examination of the 1998 data indicates that there appears to be some tendency for water quality to be slightly poorer in the upstream lakes — Green Lake and Horseshoe Lake — than in Marshall Lake and the Lower Shaker Lake. In general, phosphorus concentrations appear to be slightly higher in the south fork lakes — Green and Marshall Lakes — than in Horseshoe Lake and the Lower Shaker Lake.
- **Variation Over Time** — Too few water quality data were collected from the Shaker Lakes before 1998 to allow any valid assessment of changes in lake water quality over time.

Because the lakes have high concentrations of nutrients, algae and other water plants grow in great abundance. These plants deplete the oxygen supply in the water, resulting in very low

Figure 6-1 Lower Shaker Lake when the lake was drained in 1998, looking west from the Larchmere Road bridge. Lake drainage revealed deep sediment deposits and a great deal of trash. Hay bales near the center of the picture were placed to protect the mud flat at the lake's east end. Photograph by L. C. Gooch.

dissolved oxygen levels in the deeper parts of the lakes during the summer. Because of the excessive plant growth and resulting low dissolved oxygen, the lakes are classified as *eutrophic* or *hypereutrophic*. Only very stress-tolerant fish, macroinvertebrate, amphibian, and plant communities can survive in the resulting lake environment.

6.1.3 Sediment Contamination

Sediment samples taken from the Shaker Lakes indicate that concentrations of a number of metals, including copper, zinc, iron, lead, and arsenic, may be somewhat elevated in the lake sediments. Levels were higher in samples taken during the 1970s than in more recent samples. NEORSD's 1998 sampling showed that lead was slightly elevated in sediments from Horseshoe Lake and the Lower Shaker Lake and that copper was slightly elevated in sediments from Horseshoe Lake.[7] Bacteria concentrations were extremely elevated in samples taken from the Lower Shaker Lake in 1973.[8]

Sediment samples taken from the brook streambed (collected only in 1998) had lower metal concentrations than samples of the lake sediments. Concentrations in these samples were generally in line with metal concentrations in natural soils, although elevated lead concentrations were found in two samples, one collected near the mouth of the brook and one collected on the north fork of the brook upstream from Horseshoe Lake.

6.2 Why Does It Matter? The Impact of Contamination

We now have a list of the contaminants that are present in Doan Brook and its lakes and sediments. How do these contaminants affect the stream and the creatures that live in and around it? This question is best answered by looking again at the groups of contaminants we used to evaluate water quality — nutrients, bacteria, metals and other miscellaneous contaminants, and toxic organic compounds.

- **Nutrients** are necessary for all plant growth. When they are present at moderate levels they allow a healthy aquatic environment to develop. When their concentrations are high, however, they promote excessive growth of algae and other nuisance vegetation, which in turn depletes oxygen in the water, stifles more desirable plants, makes the water cloudy (turbid), and kills all but the hardiest fish and other aquatic organisms. The impact of high nutrient concentrations is most pronounced in Doan Brook's lakes, where it can lead to foul odors, unsightly algae on the water surface, and the death of many fish.
- High **bacteria** concentrations, like excessive nutrients, lead to low oxygen levels in the stream and lakes. They can also be directly toxic to aquatic organisms or transmit disease to animals that depend on the brook. In addition, they make the brook unsafe for human contact — it is no longer wise to wade, swim, or fish in Doan Brook because of the high bacteria levels that are frequently present.

7 Sediment in the Lower Shaker Lake was sampled in 1995 to determine whether there were any toxic metals or organic contaminants that would require that sediment dredged from the lake be classified as a hazardous waste. The only toxic chemical detected in this test was barium, found at levels far below hazardous concentrations. Because the test procedures used to classify a material as a hazardous waste are quite specialized, results from these tests cannot be directly compared to other sediment data.

8 Sediment bacteria concentrations have not been evaluated since 1973; however, bacteria concentrations in lake sediments are probably still elevated.

- **Metals** such as lead, copper, and zinc, and **chlorides** can be directly toxic to aquatic plants and animals.
- **Toxic organic compounds** can kill aquatic plants and animals even when they are only present in very low concentrations. Although pesticides, herbicides, and other toxic organics do not appear to be present at detectable levels in Doan Brook, testing has been limited.

Contaminated sediments have the same kinds of impacts as contaminated water, except that the organisms that are affected are those that live or feed on the brook and lake bottoms. In addition, sediments sometimes store contamination that may be released back into the water when the bottom is disturbed. It is thus possible that contamination collected at the bottom of the Doan Brook lakes could continue to pollute the water for some time even if new pollutants no longer flowed into the stream. This "contaminant recycling" might increase the time that it takes for water quality to improve once contaminant inflows are reduced.

6.3 Where Does the Pollution Come From? Contaminant Sources

The contaminants that make their way into Doan Brook begin at every home, lawn, golf course, and small business in the watershed. Sanitary sewage that enters the stream during wet-weather overflows or as a result of improper sewer connections (See Chapter 5) carries a significant amount of bacteria and some household chemicals into the brook. Runoff from lawns carries fertilizers, pesticides, herbicides, and domestic animal waste into the stream. Streets and driveways contribute road salt, grit, oil, gasoline, and other waste chemicals. Wild animals living in and adjacent to the brook also contribute bacteria-laden feces to the stream. The discussion below looks at the relative importance of different sources of bacteria, nutrients, and other contamination.

6.3.1 Sources of Bacteria

Under the conditions that exist in the Doan Brook watershed today, sanitary sewer overflows are the most significant single source of bacterial contamination to the brook. The Heights/Hilltop Interceptor Sewer (HHI), when complete, will divert a significant volume of sanitary sewage away from Doan Brook. In fact, the completion of this project and other smaller on-going projects will cut the amount of combined sewage that reaches the stream approximately in half. Unfortunately, a large volume of combined sewage will still flow into the brook after these projects are finished. Even after the HHI is in place, the volume of combined sewage that reaches the brook will be on the order of 400 million gallons per year. That is enough sewage to fill the Lower Shaker Lake 25 or 30 times or to fill the Cleveland Browns' football stadium with a column of water that would dwarf downtown's 948-foot-tall Key Tower.

Even more perplexing, water quality modeling of Doan Brook indicates that the bacteria concentrations in the brook would violate water quality regulations at least 70% of the time *even if there were **no** combined sewers overflowing into the brook.* This means that enough bacteria are carried into Doan Brook by surface water runoff that the Ohio EPA would not consider it safe to wade or swim in the brook much of the time. These bacteria probably originate mostly in domestic and wild animal waste.

Although animal waste was certainly present in the Doan Brook watershed before urbanization, its impact on the stream has increased in a number of ways. First, there are far more domestic animals in the watershed than would be here under natural conditions.[9] While responsible owners take care of their pets' waste (by picking it up and either throwing it in the trash or flushing it down the toilet), most domestic animal waste is left on the ground and finds its way to the brook. Second, our management of the land on the watershed's golf courses, around the Shaker Lakes, and around the Wade Park and Rockefeller Park Lagoons has created extensive lawns adjacent to the water, an environment that is very attractive to Canada geese. Beautiful though they are, the geese produce large quantities of feces and probably contribute significantly to bacteria levels in the brook. Finally, many of the watershed's natural mechanisms for filtering and removing bacteria (slow runoff, pools, wetlands, and vegetation growth at the water's edge) have been destroyed by urbanization, so that any bacteria on the watershed surface have a relatively unobstructed path to the brook.

6.3.2 Sources of Nutrients

Sanitary sewage, the primary source of bacterial contamination in Doan Brook, is also a significant source of the nutrients flowing into the stream. However, surface runoff from the watershed plays an even larger role as a nutrient source than as a source of bacteria. Golf course and park managers in the watershed regularly apply fertilizers to their fairways and

9 Dogs, in particular, generate a large quantity of bacteria-laden waste. Data indicate that the average dog produces almost as much fecal material each day as the average human, and that dog feces are higher in fecal coliform and fecal streptococci bacteria than human waste.

lawns. Homeowners do the same. The chemicals that nourish the grass — primarily nitrogen and phosphorus — are the same chemicals that cause eutrophication (due to overstimulated plant growth) in the watershed's lakes. Fertilizers may be applied in a way that minimizes the amount that is washed into streams, but some nutrients are inevitably carried to the brook. Improper application (too much fertilizer or application immediately adjacent to a stream) or application just before a heavy rain makes the problem even worse.

6.3.3 Sources of Other Contamination

As the water quality sampling results indicate, Doan Brook has relatively low levels of contaminants other than bacteria, nitrogen, and phosphorus. Some sources of other contamination are:

- Road salt used for de-icing and then washed from the roads into the brook contributes chlorides that may pose a significant threat to sensitive forms of aquatic life.
- Sediment from road grit or construction sites, as well as material eroded from the brook's bed and banks by high flood flows, clouds the brook's water.
- Copper may come from wearing automobile brake pads. Leaded gasoline was a major source of lead until it was banned in the 1970s. Both of these metals are present in elevated concentrations in brook sediments.
- Watershed residents sometimes dump toxic chemicals — usually automobile oil or antifreeze — down storm sewer grates. This deliberate dumping may be a significant source of toxic chemicals.
- Toxic contaminants from household chemicals find their way to the brook through the sanitary sewers. Some toxics are present in storm runoff as well.
- Storm runoff probably carries moderate amounts of toxic chemicals that have been applied to lawns and golf courses as pesticides and herbicides.

6.4 Solutions to Doan Brook Pollution

Pollution reaches Doan Brook via one of two avenues:

- Combined sewer overflows (CSOs);
- Surface water runoff.

Adequate control of combined sewer overflows will require additional large projects like the on-going construction of the Heights/Hilltop Interceptor sewer. The requirement that sewer overflows be controlled is already in place,[10] and the authority and responsibility for minimizing CSOs in the Doan Brook watershed lies with the Northeast Ohio Regional Sewer District (NEORSD). NEORSD's 1998 Doan Brook watershed study was undertaken largely to determine what additional CSO controls are needed. Work that NEORSD is expected to do as a result of their study is described in Chapter 8.

Unlike CSO control, reduction of the contamination that reaches Doan Brook via surface water runoff cannot be achieved by a few large projects. We have seen that significant quantities of bacteria and nutrients come from sources spread over the watershed. The work required to control this contamination must also span the watershed. Like improvement of the watershed's ecology, improvement in the quality of surface runoff will require many small changes in both facilities and behavior that are carried out over the entire watershed and implemented over a number of years. Measures that might improve water quality and development of the watershed management plan that will be needed to support water quality restoration are discussed in Chapters 8 and 9.

10 Such requirements are part of federal and state EPA regulations on CSOs formulated under the federal Clean Water Act.

The Lower Shaker Lake dam overflows into North Park Boulevard. August 31, 2001. Photograph by L.C. Gooch.

For it was rather exciting. The little dry ditches in which Piglet had nosed about so often had become streams, the little streams across which he had splashed were rivers, and the river, between whose steep banks they had played so happily, had sprawled out of its own bed and was taking up so much room everywhere, that Piglet was beginning to wonder whether it would be coming into ***his*** *bed soon.*

— A.A. Milne

Winnie-The-Pooh

7

Most of the time, Doan Brook seems a peaceful, harmless trickle. We cross it without a thought. Most of us don't even really know that it is there. Sometimes when it rains, though, Doan Brook wakes up and gives us a shake to remind us of the power that it has to shape the land. Then, briefly, the brook mocks our efforts to control it. It turns roadways into whitewater rapids; it forces its way into buildings and destroys their contents; it erodes its banks, threatening the streets that run along them; it eats at the dams that we have thrown across its path.

Concern about flooding along Doan Brook rises and falls with the flood waters. Each large flood generates a wave of interest and a call for action. By the time a study is made and a solution proposed, the sense of urgency created by the flood has receded. Funding is hard to come by, and work is postponed. In effect, the community's decision over the years has been that we can live with an occasional flood along Doan Brook. This chapter explores the nature, origins, and impacts of Doan Brook's floods.

7.1 A History of Doan Brook Floods

The earliest reported flood on Doan Brook occurred in 1901, when a flash flood roared down Cedar Hill from the Heights. Entire neighborhoods were inundated. Flooding was relatively rare in 1901, but high water has been a regular occurrence since the 1920s, when true urbanization of the upper watershed began. Readily available flood records are incomplete, but it seems that at least once each decade the brook erupts above ground in University Circle, reminding us that it once flowed there. Significant floods left 10 to 11 feet of water in the Circle in 1959 and 1975. Lesser floods in 1962, 1976, during the 1980s, and in 1994 also inundated the area. General flooding in the lower watershed was reported in 1929, during the 1940s, and in 1956. Table 7-1 summarizes records of the more damaging floods.

The worst Doan Brook flood occurred in August 1975, when a man was swept to his death in a culvert near the intersection of East 105th Street and East Boulevard. With University Circle under eleven feet of water, the Sears Library and other buildings at Case Western Reserve University (CWRU) were flooded, causing the destruction of 11,850 books and damage to almost 100,000 other books and maps. Other University Circle buildings were also flooded, and there was extensive destruction in the parks both upstream and downstream from University Circle. Both of the Shaker Lake dams were damaged, with severe damage at Horseshoe Lake. In addition, erosion of the stream bank in the Doan Brook gorge threatened Fairhill Road near its intersection with Kemper Road. Total monetary losses from this flood were estimated at over $10,000,000.

Although other floods have not been as serious as the one in August 1975, news of flooding along the brook has been a recurring refrain. Water has flowed over Horseshoe Lake dam at least four times, resulting in serious damage and subsequent repairs to the dam. Repairs made in 1997 were intended to make the dam safer during future overtopping. The brook banks near Fairhill and Kemper were damaged repeatedly by flood erosion between 1959 and 1976, when a definitive slope repair was

Table 7-1	An Incomplete History of Doan Brook Flooding	
Date	**Description**	**Technical Data**
1901	A flood roars down Cedar Hill and inundates entire neighborhoods.	
June 1929	A flood washes out some sections of the retaining walls along Doan Brook.	
1940s	Horseshoe Lake dam overtops and the south end of the embankment washes out.	
1956	Eleven floods between May and August seriously damage the stream banks, retaining walls, and adjacent developments within the City of Cleveland.	For a Single Storm (date unknown): Rainfall: 3" Peak flow = 2,500 cfs
June 1, 1959	A major flood leaves water 10 feet deep in University Circle. Horseshoe Lake dam partially fails. The bank of the brook along Fairhill just downstream from Kemper erodes so that the north curbing of Fairhill is exposed.	Rainfall: 3" in < 1 hr. Peak flow = 18,000 cfs Return Period = 50 yr.
June 4, 1962	Flooding leaves 3 to 4 feet of water in University Circle.	Rainfall: 1.5" in < 1/2 hr. Return Period = 10 yr.
July 28, 1964	A more minor flood occurs, bringing the Lower Shaker Lake dam close to overtopping.	
July 17, 1968	A relatively minor flood washes away the banks along Fairhill Road to within 6 feet of the pavement at one point. There is also damage at Fairhill and East Blvd.	
August 24, 1975 August 29-31, 1975	A rainfall of 6 inches falls on the Doan Brook watershed and results in a flood depth of 11 feet in low areas of University Circle. The storm causes severe flood damage and is followed by a second storm and flood of nearly equal magnitude 4 days later. A man swept into a culvert near East 105th Street and East Boulevard is killed during the first storm. The stream bank near the intersection of Fairhill and Kemper Roads fails due to erosion. Horseshoe Lake dam is severely damaged by overtopping.	First Storm: Rainfall: 3.25" in < 1 day at the Lower Lake; over 6" in some areas. Return Period = 50 yr. Second Storm: Rainfall: 3.5" in 3 days at Lower Lake.
July 14, 1976	The University Circle area floods with several feet of water. Horseshoe Lake dam overtops and is severely eroded, leaving the downstream side of the stonework exposed.	Rainfall: 3.5" to 4.5"; time unknown, but < 1 day.
July 1990	Flooding along the lower brook, including a drowning.	
August 13, 1994	A storm causes traffic disruption and property damage in University Circle and damage to Horseshoe Lake dam.	

performed. Minor damage to bridges and retaining walls and disruption of traffic along Martin Luther King, Jr., Boulevard is a regular occurrence in the lower watershed. After the 1975 flood, CWRU decided that it was best to simply get out of the brook's way and moved facilities that could be damaged out of the reach of the flood waters. They also installed water-tight "submarine" doors to keep the brook out of some buildings. Partly as a result of this action by CWRU and partly because subsequent floods have been less severe, no major damage has been caused by more recent floods.

7.2 Where Does the Water Come From? Watershed Runoff Patterns

The history of Doan Brook flooding makes it clear that the most damaging floods along the brook occur at University Circle. Flooding there results from a combination of the hydrology of the watershed and the design of the University Circle culvert, which periodically interact to dump an overwhelming quantity of water into University Circle.

The Circle lies at the base of the Escarpment and near the middle of the Doan Brook watershed.[1] Water in the brook (as it passes through the University Circle culvert) originates in five distinct areas:

- The Plateau upstream from the Lower Shaker Lake (57% of the University Circle watershed);
- The Plateau that drains to the brook between the Lower Shaker Lake and the Martin Luther King, Jr., Boulevard (MLK) detention basin (9% of the University Circle watershed);
- The Plateau and Escarpment that were part of the former Giddings Brook drainage area (18% of the University Circle watershed);
- The Plateau and Escarpment that drain to the Cedar Glen storm sewer (12% of the University Circle watershed);
- The Lake Plain and Escarpment that drain to the Euclid Avenue storm sewer (4% of the University Circle watershed).

When the brook enters the University Circle culvert, it carries runoff from the Plateau that originates both upstream and downstream from the Lower Shaker Lake. Just downstream from the main culvert inlet, two large storm sewers — the Giddings Brook culvert[2] and the Cedar Glen sewer — connect with the main University Circle culvert. These two storm sewers carry the runoff from the former Giddings Brook watershed and the Euclid Heights area, respectively. A third storm sewer intersects the main culvert at Euclid Avenue. The total drainage area that contributes flow to University Circle is approximately 5,560 acres, or 74 percent of the Doan Brook watershed. (See Figure 5-4 and Table 5-1 for a summary of drainage areas at critical points in the watershed.)

Because of the Shaker Lakes, flow from the Plateau upstream from the Lower Shaker Lake reaches University Circle much later than flow from areas downstream from the lake. In fact, runoff from the area upstream from the lakes plays a minor role in University Circle flooding. The slope of the land and the density of the urban area are moderate upstream from the lakes, so water collects relatively slowly. More important, runoff must pass through the lakes before it reaches University Circle. The lakes play a critical role by storing and slowly releasing water that flows through them (see *What Do the Lakes Do?*). As a result, downstream floods are much smaller than they would otherwise be.[3]

Unlike water that flows through the lakes, water that originates downstream from the Lower Shaker Lake finds few barriers in its path as it flows toward University Circle. The areas that drain into the downstream brook channel and into the Cedar Glen sewer and the Giddings Brook culvert are the denser urban neighborhoods that lie on the western edge of the Plateau and on the Escarpment. Water from these areas collects quickly and takes an unobstructed path through the storm sewer network to the brook at University Circle.[4] As a result, the sharp, high flood peaks from these areas (which together make up about 39 percent of the watershed at University Circle and 28 percent of the brook's total drainage area) reach the stream much sooner than the flow making its way through the Shaker Lakes. Figure 7-1 is a schematic representation of the timing and magnitude of flows from upstream and downstream from the Lower Shaker Lake as they reach University Circle. It clearly shows the relative contributions of runoff that originates upstream and downstream from the lakes.

7.3 Why Is There a Flood? The Brook Under Duress

The reasons that the fast-flowing runoff from the uncontrolled areas of the Plateau and Escarpment so often overwhelms the brook at University Circle can be summarized in two phrases: *Giddings Brook* and *the impact of urbanization*. As Chapter 5 discusses in detail, the urban watershed, with its abundant buildings, pavement, and storm sewers, sends far more water into Doan Brook than flowed into the brook under pre-development conditions. The average annual runoff to the stream from a given area may be three times as great as it was in Nathaniel Doan's time, and a five-year flood[5] may be four times as large. The extra watershed area added by the diversion of Giddings Brook into Doan Brook further increases floods, so that the annual runoff is as much as four times greater and the five-year flood may be increased by a factor of five.

The culverts and channels that were built in the lower Doan Brook watershed beginning in the late 19th century might have been adequate to carry the brook before urbanization and before the Giddings Brook diversion, but

1 See Chapter 3 for a discussion of watershed topography and the definition of the Escarpment and other topographic regions.

2 This culvert runs down Baldwin Road and is sometimes called the Baldwin Road culvert or sewer.

3 For example, during a moderate flood that might occur once in five years, the Shaker Lakes are estimated to reduce the peak flow from the upstream watershed by about one-half and to delay the peak flow downstream from the Lower Shaker Lake for over two hours.

4 Runoff that does not pass through a lake or other structure that would slow and reduce the peak flow is referred to as uncontrolled runoff. Areas that are not upstream from a control structure such as a dam or detention basin are called uncontrolled drainage areas.

5 See Appendix H for a definition of the 5-year flood.

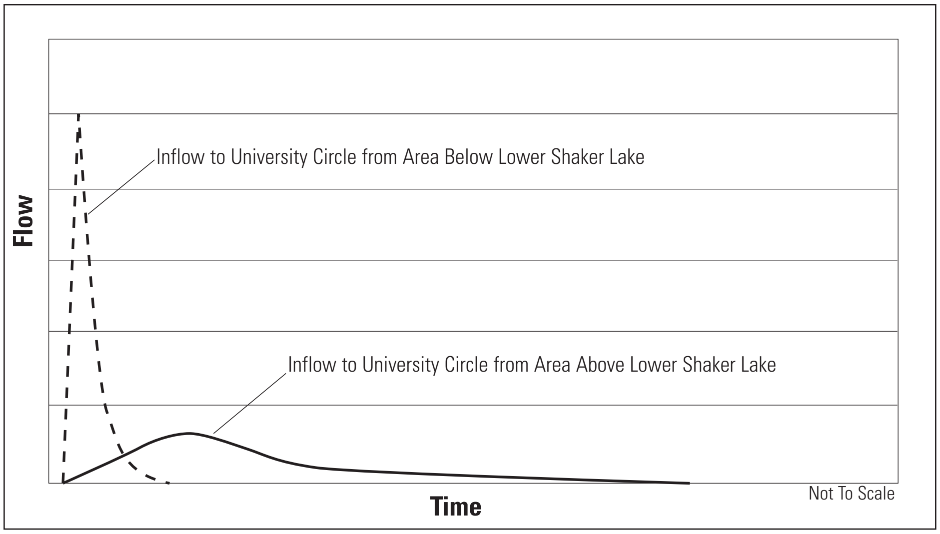

Figure 7-1 Typical Flows at University Circle

they cannot carry the modern runoff.[6] We have built around and on top of the brook, so that any adjustments the stream tries to makes to accommodate larger flows are destructive — they erode banks, threaten roadways, and overtop the Shaker Lake dams. In short, there are frequent floods along Doan Brook because we have caused more water to flow to the brook and we have given the stream less room to carry the flow.

7.4 How Strong Are the Dams? The Safety of the Shaker Lake Dams

In the late 1970s, the Ohio Department of Natural Resources (ODNR) and the U.S. Army Corps of Engineers evaluated the Horseshoe Lake and Lower Shaker Lake dams to see whether or not they were in danger of failing and to assess the danger that a dam failure would create. They concluded that the failure of either of the dams could cause serious property damage and some risk to human life. This risk would stem from the inundation of roads and bridges and from high water in the University Circle area as the flood wave from the dam failure moved downstream. The agencies determined that both dams were subject to failure by overtopping[7] during the *Design Flood* — a flood one-half the size of the *Probable Maximum Flood*.[8] Because of the risk created by failure of either dam, they were given "high" hazard rankings by the Corps of Engineers. Because both dams were considered to have a reasonable possibility of failure, the agencies indicated that action was needed to protect them.

Several measures have been taken since the initial evaluation of the dams to increase their safety. The Horseshoe Lake dam was repaired in 1995 by filling a low spot on its crest, paving the pathway across the crest, and placing large rock *riprap*[9] on the dam's downstream face. This was intended to protect the dam by eliminating a low spot that would overtop before the rest of the dam, by reinforcing the crest against erosion, and by making the downstream face more erosion resistant. The Lower Shaker Lake dam has also been repaired. Fill was placed on the downstream face of the dam north of the outlet channel, and some additional work was done to reinforce the downstream slope near the ruin of the Shaker sawmill. In 1999, the stonework in the dam's spillway was repaired, and an outlet was installed in the lake so that the water level could be lowered to allow future dam inspections.

ODNR has continued to express concern about the condition of both of the Shaker dams and the possibility that either dam could be seriously damaged or fail as a result of overtopping. After their most recent formal inspection in May 1996, ODNR required minor, routine repairs to both dams. These minor repairs appear to have been completed since. More significantly, ODNR required that studies be performed to evaluate the size and design of emergency spillways that would prevent overtopping during the Design Flood. Action on this last requirement has been slow.

7.5 How Big Is the Pipe? The University Circle Culvert and the Downstream Channels

When Doan Brook floods, the University Circle culvert overflows. The 5,160-foot-long culvert that carries the brook from the intersection of Martin Luther King, Jr., Boulevard (MLK) and Ambleside Drive past the Cleveland Museum of Art is actually a series

6 In fact, the first sign that urbanization was overwhelming the rigid channels in the lower watershed came as early as 1929, when a flood washed out part of the channel. The first enlargements to the channel in Rockefeller Park were made in 1932 and 1940.

7 A dam is "overtopped" when water flows over the dam at a point where it is not designed for overflow. Overtopping is dangerous to an earth dam because it causes erosion and may carry away enough of the dam to create a channel and lead to an uncontrolled release of the water in the reservoir.

8 The Probable Maximum Flood, or PMF, is defined as "…the flood that can be expected from the most severe combination of critical meteorologic and hydrologic conditions that are reasonably possible…" in a given area (National Research Council, 1988). In other words, the PMF is the worst flood that can be imagined if science is used to guide the imagination. The Design Flood is the flood that a structure must, by regulation, be designed to withstand. The Design Flood for Ohio dams with a high hazard ranking is one-half of the PMF.

9 *Riprap* is rock with a controlled range of sizes that is designed to protect the underlying soil from erosion.

What Do the Lakes Do? Lake Sedimentation and Flood Storage

When flooding and the Shaker Lakes are discussed, two topics often come up: 1) the lakes' ability to reduce downstream flooding, and 2) sediment in the lakes. How do lakes reduce downstream flooding? Does sediment in the lakes change their flood control potential?

When the weather is dry, lakes store water at or below the elevation of the lowest open outlet. For Horseshoe Lake, that elevation is the lip of the semi-circular overflow spillway at the dam. For the Lower Shaker Lake, that elevation is the top of the stone spillway under the "Lovers' Lane" bridge at the west end of the lake. Sediment generally accumulates in the lakes below the dry weather lake elevation (that is, below the crest of the spillway).

When a storm begins, water starts to flow into the lake faster than it can flow out over the spillway, and the water surface in the lake rises (see Figure 7-2). As the water surface goes up, the flow out of the lake (over the spillway) increases. The elevation of the lake at the end of the storm and the peak outflow from the lake depend upon the balance of the rate of inflow, the water surface elevation, and the outflow rate during the storm. The lakes slow and reduce downstream flood peaks by forcing water to leave the lake more slowly than it flows in and thus storing water during the storm.

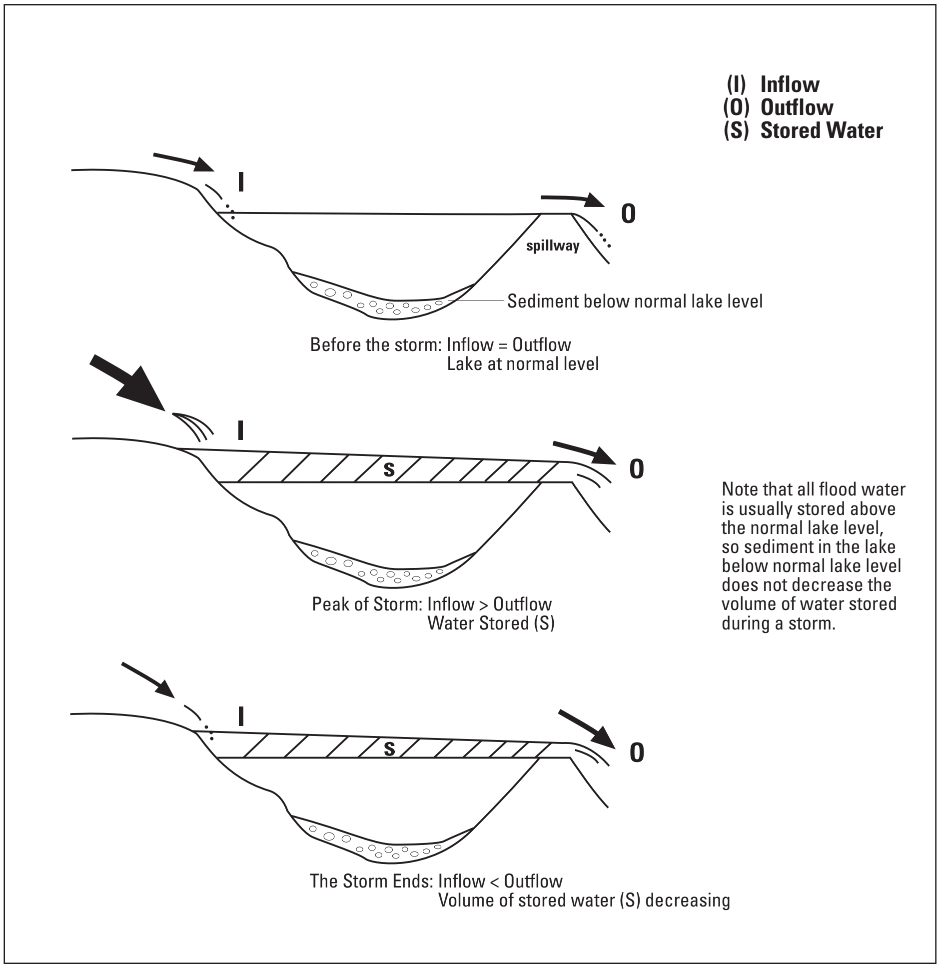

Figure 7-2 Lakes: Sediment Storage and Storm Flows

The ability of the Shaker Lakes to ease flooding in University Circle *is **not** increased by dredging the lakes*. Dredging has no impact on flood control because the volume of water stored during a storm is the volume contained in the layer of water *between the lakes' water surface at the beginning of the storm and the water surface at the end of the storm*. This layer of water lies above the spillway elevation and is not filled as sediment accumulates.

The storage and slow release of storm water by the Shaker Lakes plays an important role in reducing flooding at University Circle. Although periodic dredging is necessary to preserve the health and aesthetics of the lakes, dredging (or failing to dredge) has no impact on University Circle flooding.[10]

10 If lake dredging were to be used in combination with a program that kept the lakes almost empty during dry periods, dredging could change the lakes' ability to store flood water. It is very unlikely that the Shaker Lakes will ever be managed in this way.

of shorter culverts that were pieced together over the years as the stream was pushed farther and farther out of sight. The result of the culvert's piecemeal construction is a pipe with different shapes and sizes and different capacities along its length. Illustrations that show the profile and shape of the culvert are included in Appendix H.

Whenever the culvert's capacity is exceeded, water in the pipe begins to flow under pressure, backing up in the pipe and eventually flooding up through manholes and then into streets and buildings. If the culvert is completely overwhelmed, as in the 1975 flood, it can no longer carry the water that rushes down the Escarpment, and Doan Brook once again flows above ground through University Circle. Estimates indicate that the culvert can carry no more than about 2,000 cfs[11] without some flooding. When the culvert is partially blocked with debris, as it frequently is, its capacity is reduced, and flooding will occur at lower flows.[12]

Estimates made in the 1960s indicate that the capacity of the culvert will be exceeded more than once every two years. More recent estimates suggest that the culvert's capacity will only be exceeded once in about every ten years. The history of flooding at University Circle suggests that the true frequency of flooding may be somewhere between these two estimates: minor flooding seems to occur every three to five years, with a significant flood about one year in six.[13]

The culverts and stone-lined channels along MLK downstream from University Circle are also too small for the urban brook. The capacity of the channels varies along the stream, as does the amount that the stream must rise before it flows out of the park and onto the adjacent roadway. The most frequent flooding occurs near the downstream end of the brook, between St. Clair Avenue and the Conrail Railroad tracks. Here, recent estimates indicate that the brook can be expected to leave a foot or more of water in the road for a short time as often as once a year. Once in ten years, this area and the area upstream from St. Clair can be expected to be several feet under water. Once in 50 years, flooding can be anticipated along much of MLK downstream from Euclid Avenue.

The culvert that carries Doan Brook under I-90 and Site 14 into Lake Erie was designed to carry the flow generated by the 100-year storm.[13] Recent calculations did not include storms larger than the 50-year storm, but they confirm that the culverts have enough capacity to carry the 50-year flow.

7.6
What Can We Do? Solutions to Flooding

We began this chapter by saying that the community has, over the years, decided to live with occasional flooding on Doan Brook. Most of the work done in recent years, aside from the construction of the Martin Luther King, Jr., Boulevard (MLK) detention basin and occasional removal of debris from the University Circle culvert, has concentrated on restoring flood-damaged sections of the channel to their previous condition. Little effective work has been done to address the underlying causes of flooding. Given that Doan Brook is a confined stream in a fully developed watershed, what can we do to reduce flooding in the future? How important is it to prevent future floods?

Floods in an urban stream can be reduced in three basic ways: by *reducing runoff (the inflow to the stream)* ; by *storing and slowly releasing runoff*; and by *increasing the capacity of the stream* so that it can carry higher flows without flooding. We will look at each of these approaches in general terms here, saving more detailed discussion of actual measures that might be taken for Chapter 8.

- *Reducing runoff* — Once a watershed is fully urbanized, as the Doan Brook watershed is, it is difficult to make dramatic reductions in runoff. However, small measures can be taken throughout the watershed to reverse some of the impacts of urbanization. These include (among others): redesigning parking lots so that they encourage infiltration rather than runoff; re-landscaping with natural vegetation that retains rainfall; and disconnecting downspouts from storm sewers so that water can run onto the ground surface and infiltrate.
- *Storing and slowly releasing runoff* — Lakes and other impoundments store and slowly release stormwater runoff. The Shaker Lakes effectively perform this function for much of the upper watershed, and the MLK detention basin was an attempt to increase the storage and slow release of some of the inflow to Doan Brook between the lakes and University Circle. Additional flood storage capacity could be added to the Doan Brook watershed by building either a few large impoundments or a number of small impoundments.

  Large flood storage projects tend to be just that — large — and adding new large impoundments in an urban area like the Doan Brook watershed is difficult and expensive. New flood storage capacity would be most effective in the uncontrolled part of the watershed upstream from University

11 Cubic feet per second. A basketball's volume is about one cubic foot. Imagine basketballs flowing past you at the rate of 2,000 per second.

12 Flooding in University Circle is exacerbated by the fact that Euclid Avenue is higher than the streets upstream, so that a sort of lake is formed upstream from Euclid Avenue when the brook escapes from the culvert.

13 See Appendix H for an explanation of how floods are estimated and definitions of the 50- and 100-year floods.

Impact on Flooding: What Does the MLK Detention Basin Do?

In 1997, the City of Cleveland took advantage of some available funding and built a flood detention basin on Doan Brook just upstream from the entrance to the University Circle culvert (immediately downstream from MLK). Although the basin was intended to reduce the five- and ten-year floods in the lower watershed, subsequent studies performed during the NEORSD Doan Brook Study have shown that the basin will have little or no impact on floods that occur less than about once in ten years, and will have significant impact only during very large floods (as large or larger than a flood that would occur once in fifty years). How, then, did the basin come to be built?

To answer this question, we must look at the history of flood studies on Doan Brook. The first major study of Doan Brook flooding was performed by Stanley Engineering Company in 1964. Not surprisingly, the study concluded that flooding in University Circle came primarily from three sources: runoff directly to the brook downstream from the Lower Shaker Lake; the Giddings Brook culvert; and the Cedar Glen sewer. A smaller contribution to flooding came from the Euclid Avenue sewer. Construction of a detention basin on Doan Brook *upstream* from MLK (on Cleveland land that is leased by Cleveland Heights) was recommended as one of a number of measures that could be taken to alleviate University Circle flooding.

As proposed in the Stanley report, the detention basin had the potential to reduce the peak flow in University Circle by about 23 or 24% during a five- to ten-year flood by using MLK as a dam to back water up into the Doan Brook gorge. Even with this much flow reduction, the Stanley detention basin would not have eliminated flooding in University Circle during the five- to ten-year floods unless it was combined with a number of other proposed measures, including enlargement of the University Circle culvert.

Over thirty years after the detention basin was originally proposed, the City of Cleveland began to move ahead with a detention basin project almost identical to that originally recommended by Stanley. Significant opposition from the public and the Cleveland Heights city government arose because of the unavoidable damage to the Doan Brook gorge (see Chapter 2), and because of questions about whether the basin would, by itself, make a worthwhile reduction to downstream floods. In response, Cleveland moved the basin downstream from MLK onto City of Cleveland land that is not leased by Cleveland Heights. The design of the basin was significantly changed, so that the restriction to the outflow and the volume of water that would be detained were dramatically less than those proposed by Stanley. Hydraulic calculations performed to evaluate the new design do not seem to have accounted for the fact that the redesigned basin and outlet provided much less flow restriction and flood storage than the original design. In addition, analyses made as part of the NEORSD Doan Brook Study suggest that inflows to the basin will be somewhat lower than those estimated by Stanley. Because of the design changes and the lower inflows, the detention basin is expected to have little or no impact on the five- to ten-year events for which it was built and to have no significant impact on flooding in University Circle except during floods that occur less frequently than once in fifty or 100 years.

Figure 7-3 The flood detention basin on Doan Brook just downstream from Martin Luther King, Jr., Boulevard. Photograph by L.C. Gooch.

Circle. This is the heavily urban area in the Cedar Glen sewer and Giddings Brook watersheds, where it would be almost impossible to build a new lake or detention basin.

It would be somewhat easier to add a number of small storage and release areas in the uncontrolled Doan Brook watershed upstream from University Circle. For example, small ponds and wetlands could be added in open areas adjacent to the stream or in road medians. New parking lot designs could include storage that would delay runoff from small and moderate storms. A sustained effort to install small retrofit storage areas in the Giddings Brook culvert and Cedar Glen sewer watersheds could have a significant cumulative impact on flooding.

- *Increasing the capacity of the stream* — Regardless of the number of new storage basins and the reduction in runoff that is achieved in the Doan Brook watershed, it is unlikely that we can reduce the flow in the stream enough to prevent relatively frequent flooding in University Circle and Rockefeller Park unless we also increase the capacity of the culverts and the channels.

  The capacity of the University Circle culvert could be increased by simply installing a larger pipe, or by "daylighting" the brook; that is, by building a new above-ground channel in University Circle. Either approach would be expensive and difficult in such a heavily urban area. Increasing channel capacity in Rockefeller Park would be easier in some places but would conflict with the road or with the historic Schweinfurth bridges in others.

Figure 7-4 Erosion around the end of the trash rack upstream from Martin Luther King, Jr., Boulevard is one result of high flows in Doan Brook. Photograph by L. C. Gooch

For flood control, as for many other problems faced by Doan Brook, there is no single easy solution. Coordinated implementation of many measures over many years will be needed to decrease flooding. In addition, it will be necessary to evaluate the importance of preventing an occasional flood and weigh it against the importance of other changes that might, for example, improve the brook's water quality or aquatic habitat. The process of evaluating options and priorities and developing a watershed management plan is the subject of Chapters 8 and 9.

A jack-in-the-pulpit growing in a wild area along the Doan Brook. Photograph by L. C. Gooch.

Our conservation must be not just the classic conservation of production and development, but a creative conservation of restoration and innovation. Its concern is not with nature alone, but with the total relations between man and the world around him. Its object is not just man's welfare but the dignity of man's spirit.

— Lyndon B. Johnson

Message to Congress, February 8, 1965

8

What Can We Do? Doan Brook Restoration

The last several chapters have outlined a sometimes disturbing picture of the problems of Doan Brook. In a nutshell, the brook now runs through a heavily urban area, and it suffers from all of the maladies that can be expected in an urban stream. It has too much water during floods and too little during droughts; its waters are polluted by the city around it; it is buried and confined; its aquatic community is poor. Unlike many similar urban streams, though, much of the brook still runs through a relatively undisturbed riparian corridor that hosts a wide variety of birds and animals and preserves some of the stream's native beauty. What avenues can we now take to make the most of the brook's assets and minimize its defects? How can we preserve the Shaker Lakes, the gorge, and Rockefeller Park for future generations? What is already being done? In this chapter we will explore the physical measures that might be taken to restore the brook. The political and social process of making restoration a reality is the subject of Chapter 9.

8.1
Simplifying the Problem: Getting a Handle on What Doan Brook Needs

The array of problems that confronts Doan Brook can be bewildering. How can the problems be organized so that we can begin to formulate solutions? In order to avoid being overwhelmed as we sort through alternatives for Doan Brook restoration, it is useful to keep the following three categories of problems in mind:

- **Problems of Hydrology** — Flooding, too little water during dry periods, undersized existing channels and culverts, and the condition of the Shaker Lake dams.
- **Problems of Water Quality** — Contamination in the brook and the Shaker Lakes.
- **Problems of Habitat** — Physical and chemical conditions in the brook and its surroundings that are detrimental to healthy aquatic and riparian ecosystems.

Issues associated with Doan Brook hydrology, water quality, and habitat are detailed in Chapters 7, 6, and 4, respectively. Table 8-1 presents a working summary of Doan Brook's problems sorted into these three categories. As the table shows, the three categories interact with each other. For example, hydrologic problems and poor water quality contribute to poor habitat; elevated sediment levels created by hydrologic problems cause poor water quality. We will use the three categories as a framework for evaluating Doan Brook restoration measures, keeping in mind the interactions among different kinds of problems and the likelihood that a restoration measure that helps in one area may also help in another.

8.2
What Are We Trying to Accomplish? The Target of Restoration

Before we plunge into a discussion of the many options for restoring Doan Brook, it is useful to consider briefly what it is that we are trying to accomplish. What exactly do we mean by stream restoration?

In a general sense, stream restoration means returning a stream to the condition it was in before humans settled in its watershed.

Table 8-1 Summary of Doan Brook's Problems

Problem	Source of the Problem							
	Hydrology						Water Quality	
	Giddings Brook Div.	Increased Runoff	Lakes	Stream Modifications	Culverts	Decreased Infiltration	CSOs	Contaminated Runoff
Hydrologic Problems:								
Damaging Floods	○	○	+	○	○			
Dam Safety		●	+					
Inadequate Channel or Culvert Capacity	○	○	+	○	○			
Stream Channel and Bank Erosion	○	○	+	○				
Low Dry Weather Flows						●		
Poor Water Quality:								
High Bacteria Levels							○	○
High Nutrient Levels							○	○
Elevated Salt Levels								●
Elevated Sediment Levels	○	○	+					○
Trace Contamination							○	○
Increased Temperature			○	○				
Degraded Habitat:								
Low Species Diversity	○	○		○	○	○	○	○
Lake Eutrophication							○	○
Poor Physical Habitat	○	○		○	○	○		
Blocked Migration Pathways			○	○	○			

● Entire Source
○ Partial Source
+ Helps the Problem

However, it is unrealistic to think that a stream in a heavily urban watershed like Doan Brook's can be completely restored through human efforts. Such a complete restoration would require drastic reduction of the number of people in the watershed and destruction of the buildings and streets we've created, followed by a period of many years during which the natural ecosystem could reestablish itself. So, when we talk about restoring Doan Brook we are talking about moving the stream back toward its original condition without expecting ever to achieve a stream that could be mistaken for the undisturbed brook.

As we begin, we must decide what aspects of the brook's character we will try to restore. Do we want flows in the stream to return to predevelopment levels? Or do we want to make a more moderate reduction in flow and, at the same time, adjust the stream channel so that it can both carry the flow and accommodate a healthy ecosystem? Do we want to prevent any reasonable possibility of flooding that will have impact on humans, or do we want to live with some flooding? Do we want lakes that are aesthetically pleasing and that continue to be so for the next generation? Do we want a stream in which we can safely wade and fish? Do we want a self-sustaining ecosystem so that there will be fish to be caught? How much can we afford to do?

Figure 8-1 Canoeing on the Lower Shaker Lake — ca. 1900. Postcard from the collection of the Shaker Historical Society, Nord Library, Shaker Heights, Ohio.

Obviously, there are many possible targets for restoration. Setting goals for Doan Brook will need to involve many people so that different perspectives and interests are considered. The necessary goal setting is part of the watershed planning process discussed in Chapter 9.

8.3 What Methods Are Available? The Universe of Restoration Techniques

The list of actions that could be taken to preserve and restore Doan Brook — that is, to improve its hydrology, water quality, or habitat — is long. Restoration projects may be large, aiming to make a substantial change with one action and requiring strong political backing and significant financial resources. They may be small, seeking to make a slight improvement or to address the problems of a small part of the watershed and requiring less political unanimity and more modest financing. Or, they may muster the efforts of many individual citizens of the watershed and seek to improve the condition of the brook by the cumulative effect of many very small actions.

Any given restoration project, whether large, small, or the cumulative result of citizen action, can improve the brook by one of several mechanisms:

- It can reduce or eliminate the source of a problem (**source reduction**). For example, reducing fertilizer use reduces a source of nutrients to the brook.
- It can treat existing contamination by diverting it from the watershed for treatment elsewhere, by treating it before it reaches the brook, or by treating it within the brook itself (**treatment**). Diversion of sanitary sewage from the brook to the wastewater treatment plant is the major treatment approach now used for Doan Brook. Treatment techniques such as the construction of treatment wetlands[1] could be used within the watershed.
- It can divert or delay flow in the brook (**flow control**). The Shaker Lake dams and the Martin Luther King, Jr., Boulevard (MLK) detention basin are examples of flow control projects.
- It can improve the condition of the stream channel (**channel restoration**). The biorestoration[2] of some of the stream banks downstream from the University Circle culvert is an example of channel restoration.
- It can maintain existing features that are critical to the stream (**maintenance**). Preservation of the Shaker Lakes is an example of maintenance.

The following three sections look at some of the restoration techniques that would have significant impact on problems of hydrology, water quality, and habitat, respectively. Many methods appear in more than one section, since many approaches to restoration address more than one kind of problem. A technique that helps solve more than one problem is discussed in each appropriate section. The final section of this chapter summarizes all of the restoration methods and offers a first attempt at an evaluation of the different approaches. The list of techniques presented here is not complete. Other approaches that deserve consideration will arise as work on the Doan Brook watershed management plan goes forward.

Because there are so many possible approaches to Doan Brook restoration, it is difficult to summarize them effectively. Brief descriptions of the more significant restoration methods are given in the text, with a more thorough discussion of

1 Wetlands provide a natural filter for contaminated water, causing some contamination to settle out and absorbing other contamination (particularly nutrients) into their vegetation. Properly designed and maintained wetlands can effectively treat non-toxic contamination.

2 Stream channel biorestoration involves using plantings, tree stumps, and other natural materials to stabilize eroded channel banks and beds. Channels are designed to mimic natural channel shapes, and the restoration is intended to create both a stable channel and good habitat in the stream. The Holden Parks Trust has installed biorestoration pilot projects on Doan Brook just downstream from the University Circle culvert outlet and west of the Rockefeller Park Lagoon.

Table 8-2	Measures for Hydrologic Restoration of Doan Brook			
Measure	**Project Type**	**Impact**	**Practical?**	**Cost**
Redirect Giddings Brook	large	significant	no	$$$$
Large New Stormwater Detention	large	significant	difficult-no	$$
Parallel Stormwater Culvert	large	significant	difficult-no	$$$$
Enlarge Rockefeller Park Culverts	large	significant	fairly	$$$
*[4] Reinforce Dams Against Failure	small	significant	yes-fairly	$$–$$$
Stormwater Retrofits	small	med.- signif.	yes-fairly	$–$$$
Daylight Brook in University Circle	large	medium	difficult	$$$–$$$$
Enlarge University Circle Culvert	large	medium	fairly	$$$
Keep University Circle Culvert Clear of Debris[5]	large	medium	yes	$$
Enlarge Cedar Glen Sewer	large	medium	fairly	$$$
Enlarge Rockefeller Park Channels	large	medium	fairly	$$
Revise City Codes to Require BMPs[6]	small	medium	yes	$
Redesign MLK Detention Basin Outlet	small	medium	yes	$
Stream Channel Restoration	small	medium	fairly-difficult	$$–$$$
Improve Golf Course Maintenance	small	minor	yes	$–$$
Downspout Disconnects	citizen	minor	fairly-no	$
Rain Barrel Use	citizen	minor	yes	$
Alternative Landscaping	citizen	minor	fairly	$

Practicality: yes = highly practical – easy to implement; fairly = practical – not easily implemented; difficult = may be practical, but will be very difficult to implement; no = not practical.

Cost: $ = inexpensive; $$ = expensive; $$$ = very expensive; $$$$ = prohibitively expensive.

each technique included in Appendix J. The text also explores the advantages and disadvantages of key techniques. Those who wish to have a thorough understanding of methods that might be used to restore Doan Brook will need to consult the appendix as well as the text and tables.

8.3.1 Hydrologic Restoration

Table 8-2 summarizes some of the measures that might be used to improve hydrologic conditions in Doan Brook. In broad terms, the brook's hydrology could be improved by decreasing the size of periodic high flows, by providing more channel capacity, and by increasing dry weather flow. The more significant specific approaches to improving the hydrology of the brook are:

- **Source Reduction** — Reducing excess runoff, the main source of the brook's hydrologic problems, involves either reducing the impervious area of the watershed or providing specific mechanisms that encourage rainfall to infiltrate into the ground. Relatively few restoration techniques involve true hydrologic source reduction. Some stormwater retrofits[3] may reduce runoff either by replacing a previously impervious surface (like a conventional parking lot) with a more pervious one (like a parking lot with pervious pavers) or by trapping runoff in a pond, sand filter, or wetland and allowing it to infiltrate over time. Some citizen actions, such as rain barrel use, downspout disconnects, and alternative landscaping will encourage infiltration and decrease runoff from private property. The cumulative impact of stormwater retrofits and citizen action over the entire watershed could be significant. However, the low permeability soils of the Doan Brook watershed (especially of the upper watershed) make source reduction more difficult here than it is in many places. Because of the soil's low permeability, water will run off of a turf lawn quickly, especially where the soil has been compacted by heavy equipment during building construction.
- **Flow Control** — Flow control, coupled with channel restoration, is the approach to hydrologic restoration that is most likely to make a significant difference in destructive flooding along Doan Brook. There are two main approaches to flow control: *diversion* and *detention followed by slow release*.

  Diversion involves simply directing flow away from the main channel of the brook either into another watershed or into storm sewers that bypass the brook. Examples of diversion include:

  - Redirecting the flow from the Giddings Brook watershed away from Doan Brook. Although this may seem like an appealing idea, the Giddings Brook watershed is as urban as the Doan Brook watershed,

3 Stormwater retrofits are generally small stormwater management facilities that are added to a developed watershed. Examples of stormwater retrofits include a small detention pond or wetland at a tributary culvert outlet, a detention pond and infiltration area in a roadway median, and a sand filter that catches runoff from a parking lot. Generally, each stormwater retrofit is intended to improve water quality or decrease peak outflow from a small subwatershed.

4 *Projects that are in progress are marked with an asterisk.

5 The culvert is now cleaned at irregular intervals.

6 BMPs are best management practices that are the most effective and practical approaches to meeting environmental quality goals.

and it is very unlikely that it would be possible and feasible to build a re-diversion that did not create more problems than it solved.

- Diverting high flows into a storm sewer that runs parallel to the brook. This could be considered for the lower brook; however, because flood flows are large, it would be extremely costly to build a parallel storm sewer large enough to have much impact on a flood of any size. This approach might, however, be feasible if the brook could be "daylighted"[7] in the University Circle area, where the existing University Circle culvert could then be used to carry high flows.

Stormwater detention (followed by slow release) involves building some form of either above-ground or underground storage for stormwater. The Shaker Lakes are existing examples of stormwater detention, and they play a critical role in reducing flooding along Doan Brook. The MLK detention basin was also intended as a stormwater detention facility, but it is generally ineffective in its current configuration (see Chapter 7).

Examples of new stormwater detention facilities that might be built in the Doan Brook watershed include large above-ground basins, underground storage, modification of the MLK detention basin outlet to increase the basin's efficacy, and stormwater retrofits such as small wetlands or ponds and rooftop runoff storage areas for buildings. As is discussed in Chapter 7, it would be very difficult to find space for large new above-ground or underground storage facilities in the watershed. Stormwater retrofits are therefore likely to be the most effective approach. Modification of the MLK detention basin outlet would also provide some additional stormwater detention at very low cost.

- **Channel Restoration** — Culvert enlargement and channel restoration could, if coupled with source reduction and flow control measures, decrease the damage to the brook channel and surroundings that is caused by excess flows. Increasing the capacity of the University Circle culvert, shorter culverts in Rockefeller Park, and feeder storm sewers would likely decrease flooding in the areas around the culverts, but it would not provide much benefit to the stream. Modification of channels in Rockefeller Park to achieve a more natural channel configuration or "daylighting" the brook in University Circle could be done in a way that decreases flooding, strengthens eroded areas, and improves channel habitat.
- **Maintenance** — Maintenance of the Shaker Lakes and their dams is critical to preventing Doan Brook flooding from becoming much worse. Proper maintenance of the University Circle culvert to keep it clear of debris would reduce the frequency of flooding in University Circle.

Some reduction of peak floods in the brook or some adjustment of the channel and culverts so that they are better suited for the flows they now receive is needed if the brook is to maintain a healthy ecosystem. Some would argue that better flood control is also needed so that the brook will cause less damage and inconvenience, particularly in University Circle and Rockefeller Park. No single restoration method will bring Doan Brook back into harmony with the volume of water that it now receives from the watershed. Instead, a combination of techniques that reduce the flow volume and increase the stream capacity may restore some balance to the brook's hydrology.

8.3.2 Water Quality Restoration

Table 8-3 summarizes techniques that might be used to improve water quality in Doan Brook. In general, water quality in the brook can be improved by diversion and treatment of contaminated flow, by in-stream treatment, or by reduction of contamination sources within the watershed. Some approaches to water quality restoration for Doan Brook are:

- **Source Reduction** — There is no effective way to reduce the sources of contaminants that flow to Doan Brook through the sanitary sewer system. Sanitary sewer flows can be controlled, diverted and treated in a variety of ways (see below), but there are few ways to reduce the amount of wastes that we put into the sewers in the first place.[8]

  Contaminant sources in stormwater runoff, unlike those in sanitary sewage, can be effectively reduced. For example, cities in the watershed can decrease the amount of salt that reaches the stream by using alternative deicers or simply by using less salt. They can reduce bacteria by instituting programs that encourage pet owners to pick up pet waste and discourage nuisance waterfowl around the stream.[9] They can also dredge the lakes on a regular basis. Lake dredging eliminates contaminants that may otherwise re-enter the aquatic ecosystem when sediments are disturbed. This kind of contaminant recirculation can be a significant source of nutrients. While the other approaches discussed

7 "Daylighting" refers to re-building an above-ground channel for the brook where it is currently confined to a culvert. The Case Western Reserve University Master Plan calls for the restoration of Doan Brook to an above-ground park in the area adjacent to the university campus.

8 One important source of phosphorus (a nutrient) that entered the brook mostly through the sanitary sewer system was greatly reduced when phosphate detergents were banned in the 1980s.

9 Geese can be discouraged by eliminating lawn area at the water's edge and allowing taller vegetation to grow adjacent to the lakes. Appropriately chosen vegetation can provide good habitat for other wildlife as well as discouraging geese.

Table 8-3	Measures for Water Quality Restoration of Doan Brook			
Measure	**Project Type**	**Impact**	**Practical?**	**Cost**
*[4] Heights/Hilltop Interceptor	large	significant	fairly	$$$
High Flow CSO Storage	large	significant	fairly	$$$
High Flow CSO Treatment	large	significant	fairly	$$$
Stormwater Retrofits	small	significant	yes-fairly	$–$$$
Lake or Stream Biofiltration	small	significant?	yes-difficult	$–$$$
Improve Golf Course Maintenance	small	significant	yes	$–$$
Protect Riparian Corridor	small	significant	yes	$
* Cleaning Pet Waste[10]	citizen	significant	yes	$
* Optimize the Existing Sewer System	large	medium	yes	$
Revise City Codes to Require BMPs	small	medium	yes	$
* Channel Stabilization	small	medium	fairly	$$–$$$
* Stormwater Outfall Monitoring	small	medium	yes	$
* Sanitary Sewer Maintenance	small	medium	yes	$$
* Lake Dredging	small	medium	fairly	$$$
Alternative Road Deicing	small	medium	yes	$$
Discourage Nuisance Waterfowl	small	medium	yes-fairly	$
Increase Riparian Vegetation	small	medium	yes	$
Erosion Control During Construction	small	medium	yes	$
Alternative Landscaping	citizen	medium	fairly	$
* Proper Auto Waste Handling	citizen	medium	yes	$
Proper Car Wash Practices	citizen	medium	yes	$
Reduce Lawn Fertilizer, Pesticides and Herbicides	citizen	medium	yes	$
* Proper Yard Waste Disposal[10]	citizen	medium	yes	$
* Reinforce Dams Against Failure	small	med.-neg.	yes-fairly	$$–$$$
Aquatic Plant Management	small	medium	fairly	$
* Lake Aeration	small	minor	yes	$
* Street Litter and Debris Cleanup	small	minor	yes	$
Catch Basin Inspection and Cleaning	small	minor	yes	$
Downspout Disconnects	citizen	minor	fairly-no	$
Rain Barrel Use	citizen	minor	yes	$
* Household Hazardous Waste Disposal[10]	citizen	minor	yes	$

Practicality: yes = highly practical – easy to implement; fairly = practical – not easily implemented; difficult = may be practical, but will be very difficult to implement; no = not practical.

Cost: $ = inexpensive; $$ = expensive; $$$ = very expensive; $$$$ = prohibitively expensive.

[10] At least one of the cities in the watershed has an existing program requiring or encouraging appropriate action on this measure.

could be implemented by the cities without great cost,[11] lake dredging can be expensive.

Golf courses in the watershed could contribute to source reduction by using less fertilizer, using low phosphorus fertilizers,[12] and reducing pesticide and herbicide use. Given that two golf courses make up much of the land along the south branch of Doan Brook, the contribution of good golf course maintenance to the health of the brook could be significant. Homeowners throughout the watershed could have similar impacts on nutrients, pesticides, and herbicides by reducing or eliminating the use of fertilizers and other chemicals on their lawns and by planting alternative forms of vegetation.

- **Treatment and Flow Control** — Diversion and treatment of sanitary sewage is the single action that can most improve Doan Brook water quality. The water quality in the stream already benefits greatly from the diversion of the bulk of the watershed's sanitary sewage for treatment at the Easterly Wastewater Treatment Center. The Heights/ Hilltop Interceptor (HHI), when in service,[13] will divert even more sanitary sewage for treatment.

  Substantial periodic overflows from the combined sanitary and storm sewer system in the lower watershed will continue even after the HHI is complete. The primary purpose of NEORSD's Doan Brook watershed study was to evaluate the best means of further reducing these combined sewer overflows. Alternatives under consideration include construction of a tunnel in the lower watershed to temporarily store some CSOs and divert them to the Easterly Wastewater Treatment Center, installation of several small treatment facilities in the lower watershed to treat combined sewage before it is discharged to the stream, and construction of a number of CSO storage facilities in the lower watershed.[14]

  Although the HHI and additional CSO controls will significantly improve water quality in the lower watershed, they will not address contamination from stormwater runoff in the upper watershed. Treatment methods that could restore water quality in the upper watershed include in-stream treatment (by lake aeration, biofiltration, stormwater retrofits, or aquatic plant removal), runoff filtration before it reaches the brook (by increasing riparian vegetation or installing filtering wetlands or runoff traps), regular street sweeping, frequent inspection and cleaning of storm sewer catch basins, and collection of various yard and household wastes for treatment or other disposal before they reach the brook. Finally, bacteria discharges to the brook can be substantially reduced by a coordinated program that detects and corrects illicit sanitary sewer connections that now discharge directly to the storm sewers.

- **Channel Restoration** — Channel stabilization can improve water quality in the brook by reducing erosion of the bed and banks and thus reducing the sediment load in the stream.

- **Maintenance** — Maintenance of existing facilities that contribute to good water quality in the brook is an important part of improving water quality. Proper monitoring and maintenance of the sanitary sewer system is particularly critical. NEORSD currently has a monitoring program in place, and NEORSD and the cities repair the sewers when a problem is detected. In addition, NEORSD plans to optimize the existing sewer system to make maximum use of its storage and diversion capacity.

Attention to sewer monitoring and maintenance and the elimination of phosphate detergents have already left Doan Brook with much better water quality than it had in the 1960s and 1970s. A recent system analysis and further repairs by NEORSD resulted in still more improvement. Ohio EPA clean water regulations require that NEORSD control CSOs to the extent feasible, and further reduction in CSOs will be accomplished first by the completion of the HHI and then by additional CSO controls in the lower watershed. These large projects will go a long way toward improving the brook's water quality, but they will not be sufficient to achieve a genuinely healthy stream. Restoring water quality sufficiently so that the stream can support a healthy ecosystem will depend on small projects and citizen actions spread throughout the watershed.

8.3.3 Habitat Restoration

Habitat restoration in Doan Brook depends heavily upon reducing flooding, redesigning the channel to accommodate larger flows, and improving water quality. As long as aquatic organisms are damaged by dirty water and swept away by high flows, the stream habitat will remain fair at best. Methods of decreasing flooding, restoring the channel, and improving water quality are discussed in the two previous sections. A few more measures that can be taken to improve habitat in other ways are discussed below. All approaches to habitat restoration are summarized in Table 8-4.

- **Flow Control** — Some flow control measures, such as stormwater retrofits and enlargement of the Rockefeller Park chan-

11 Deicer cost may vary and switching to an alternative to salt could be fairly costly.

12 Shaker Heights Country Club currently uses low phosphorus fertilizer.

13 The HHI in the Doan Brook watershed should be partially in service by the end of 2001 and complete by 2005.

14 The most likely alternative is the construction of a large-diameter CSO storage and diversion tunnel in the lower watershed.

Table 8-4	Measures for Habitat Restoration Along Doan Brook			
Measure	**Project Type**	**Impact**	**Practical?**	**Cost**
Daylight Brook in Gordon Park	large	significant	difficult-no	$$$$
Stream Channel Restoration	small	significant	fairly-difficult	$$–$$$
Lake or Stream Biofiltration	small	significant?	yes-difficult	$–$$$
Protect Riparian Corridor	small	significant	yes	$
Parallel Stormwater Culvert	large	medium	difficult-no	$$$$
Daylight Brook in University Circle	large	medium	difficult	$$$–$$$$
Stormwater Retrofits	small	medium	yes-fairly	$–$$$
*[4] Channel Stabilization	small	medium	fairly	$$–$$$
* Lake Dredging	small	medium	fairly	$$$
* Lake Aeration	small	medium	yes	$
Enc. Native Species and Disc. Invasive Exotics	small	medium	fairly-difficult	$$
Species Reintroduction	small	medium	fairly-difficult	$
Alternative Road Deicing	small	medium	yes	$$
Improve Golf Course Maintenance	small	medium	yes	$–$$
Increase Riparian Vegetation	small	medium	yes	$
* Reinforce Dams Against Failure	small	med.-negative	yes-fairly	$$–$$$
* Heights/Hilltop Interceptor	large	minor	fairly	$$$
High Flow CSO Storage	large	minor	fairly	$$$
High Flow CSO Treatment	large	minor	fairly	$$$
Redirect Giddings Brook	large	minor	no	$$$$
Large New Stormwater Detention	large	minor	difficult-no	$$
Enlarge Rockefeller Park Channels	large	minor	fairly	$$
Revise City Codes to Require BMPs	small	minor	yes	$
* Stormwater Outfall Monitoring	small	minor	yes	$
* Sanitary Sewer Maintenance	small	minor	yes	$$
Aquatic Plant Management	small	minor	fairly	$
Discourage Nuisance Waterfowl	small	minor	yes-fairly	$
* Street Litter and Debris Cleanup	small	minor	yes	$
Catch Basin Inspection and Cleaning	small	minor	yes	$
Erosion Control During Construction	small	minor	yes	$
Flow Augmentation	small	minor	fairly	$$
Downspout Disconnects	citizen	minor	fairly-no	$
Rain Barrel Use	citizen	minor	yes	$
Alternative Landscaping	citizen	minor	fairly	$
* Proper Auto Waste Handling[10]	citizen	minor	yes	$
Proper Car Wash Practices	citizen	minor	yes	$
* Household Hazardous Waste Disposal	citizen	minor	yes	$
* Cleaning Pet Waste[10]	citizen	minor	yes	$
Reduce Lawn Fertilizer, Pest. and Herbicides	citizen	minor	yes	$
* Proper Yard Waste Disposal[10]	citizen	minor	yes	$

Practicality: yes = highly practical – easy to implement; fairly = practical – not easily implemented; difficult = may be practical, but will be very difficult to implement; no = not practical.

Cost: $ = inexpensive; $$ = expensive; $$$ = very expensive; $$$$ = prohibitively expensive.

Figure 8-2 The Site 14 dredge spoil disposal area at the mouth of Doan Brook has become outstanding migratory bird habitat. Preservation of this habitat could be part of Doan Brook restoration. Photograph by L. C. Gooch.

nels, can be done in a way that provides good aquatic habitat as well as runoff detention and treatment or increased flow capacity. Where practical, these measures should be designed to provide habitat as well as to serve their primary functions. Augmentation of stream flows during dry weather could also be used to improve in-stream habitat.[15]

- **Channel Restoration** — Improvement to the channel and the riparian corridor would, if done properly, significantly improve aquatic habitat. In particular, daylighting the brook through the Site 14 dredge spoil area in Gordon Park would reconnect the brook with Lake Erie and eliminate a major migration barrier, as well as providing additional channel habitat. Unfortunately, such reconnection would be very costly and is probably not practical.[16]

  Daylighting the brook in University Circle would also remove a major migration barrier and provide more channel habitat. Bringing the brook above ground through University Circle may be easier than daylighting it through Gordon Park, but it would still be a very difficult and costly undertaking. Restoration of the stream channel to a more natural shape through Rockefeller Park, Ambler Park, and along other channelized sections of the stream would be more practical and would reduce the impact of high flows on aquatic organisms. Maintaining and improving the riparian corridor would provide wildlife habitat and help keep stream temperatures in an appropriate range.

- **Maintenance** — Maintenance measures such as lake dredging, encouraging native species and discouraging exotic species, and possible species reintroduction could help invigorate the stream's ecosystem.

Once water quality is improved, flood peaks reduced, and stream channels redesigned to better convey high flows, the aquatic habitat in the stream will begin to restore itself, even without further human intervention. Some additional work, such as channel restoration, daylighting the brook and perhaps species reintroduction may be worthwhile to achieve a truly diverse ecosystem. Plans for habitat improvement should be made with the awareness that the brook will remain an urban stream and may be somewhat limited in its ability to support a natural habitat.

8.4 Narrowing the Choices: Sketching a Restoration Plan

Table 8-5 gathers together all of the alternatives for stream restoration that have been discussed in this chapter. It indicates whether each restoration method would improve the brook's hydrology, water quality, or habitat, and it shows what mechanism the method would use to achieve improvement. Finally, it rates each measure as to its practicality and cost.

The list shown in Table 8-5 is not exhaustive, and the assessments of practicality and cost are not definitive. Other approaches to stream restoration are possible and will undoubtedly be considered as Doan Brook watershed

15 The usual approach to flow augmentation is the release of clean (usually treated) water directly into the stream. This kind of sustained release to the Doan Brook could be quite expensive, since it would use water that was pumped from Lake Erie and treated to drinking water standards, and it would use the water during dry summer months when demand is greatest. A more practical approach to flow augmentation in Doan Brook would be to release some untreated Lake Erie water from the Baldwin Filtration Plant directly to the brook.

16 As the bird surveys discussed in Chapter 4 demonstrate, Site 14 already harbors an extraordinary variety of bird life. There is interest in preserving it as a bird and wildlife sanctuary as well as interest in developing it as a park, so that the area could provide either developed or undeveloped park land even if the brook remained underground.

What the Law Requires: Actions by NEORSD and the Cities

NEORSD: NEORSD is responsible for reducing Doan Brook CSOs to meet the requirements of the federal Clean Water Act. The current construction of the HHI is their first response to CSO regulations. The completion of this project and the optimization of the existing sewer system will reduce CSO discharges to the brook to about half their current level. However, regulations require that NEORSD further reduce CSOs to the extent practical. To meet this requirement, they will undoubtedly move forward with additional CSO reductions. Likely measures include some combination of CSO diversion, storage, and treatment in the lower watershed, as is discussed in Section 8.3. These measures will be designed to handle storms that occur three to four times each year. They are expected to further reduce CSOs to less than half of their volume after the completion of the HHI (to about 20% of their current volume).

The Cities: U.S. EPA's Phase II Storm Water Program requires that cities like Cleveland Heights and Shaker Heights (Cleveland is largely covered under CSO regulations) take steps to reduce contamination in stormwater runoff discharged from separate storm sewer systems. Storm Water Management Programs are to be in place by 2007. "Minimum controls" that must be part of the programs include:

- Public education about steps citizens can take to reduce stormwater pollution.
- Public involvement and participation in developing and implementing a Storm Water Management Plan.
- Elimination of illicit sanitary sewage discharges to the stormwater system.
- Revision of city ordinances to require that construction site sediment runoff be controlled.
- Revision of city ordinances to require that new developments and redeveloped areas incorporate stormwater best management practices.
- Minimization of stormwater pollution from city operations such as park maintenance and city vehicle maintenance.

These required measures include many of the restoration options for Doan Brook that are discussed in Section 8.3. If the cities do a thorough job of designing and implementing their Storm Water Management Programs, Doan Brook will undoubtedly benefit. If they use the requirements of the Phase II Storm Water Program as an opportunity to focus on Doan Brook restoration, benefits will be even greater.

planning progresses. New, more thorough assessments of practicality and cost will be made. The table may nonetheless be useful as a first tool for sorting out restoration measures that may be of use for Doan Brook. The table and other information about restoration alternatives for the brook lead to a few conclusions:

- Once NEORSD and the cities have taken legally required measures to control CSOs and improve stormwater quality (see sidebar), further improvement to Doan Brook will essentially be the responsibility of the citizens and the city governments. NEORSD may take some further action and may work with the cities on other projects, but they will have fulfilled their primary responsibility for control of sanitary sewage.
- The costs of flooding along Doan Brook are not high, particularly since Case Western Reserve University has moved sensitive facilities out of harm's way. Because flood damage is not expensive, there is little motivation for building costly flood control measures. Measures that reduce flooding will therefore need to be combined with other benefits such as aesthetic improvements to the stream and habitat restoration.
- A number of measures that would benefit the brook, such as daylighting the brook through Gordon Park and University Circle and restoring the Rockefeller Park channels, would also benefit the parks and communities along the stream. Because these projects will be expensive, it will be necessary to work with all interests — advocates of the parks, advocates of the communities and institutions, and advocates of the stream — to make the projects a reality.

Table 8-5 Summary of Doan Brook Restoration Techniques

Measure	Practical and Cost Effective?	Impact of Measure			Improvement Mechanism				
		Hydrology	Water Quality	Habitat	Source Red.	Treatment	Flow Control	Chan. Improv.	Maintenance
Large Projects:									
*[4] Heights/Hilltop Interceptor	fairly/$$$	tiny	significant	minor			■		
High Flow CSO Storage	fairly/$$$	tiny	significant	minor			■		
High Flow CSO Treatment	fairly/$$$		significant	minor		■			
* Optimize the Existing Sewer System	yes/$		medium	tiny					■
Redirect Giddings Brook	no/$$$$	significant		minor			■		
Large New Stormwater Detention	difficult-no/$$	significant		minor			■		
Parallel Stormwater Culvert	difficult-no/$$$$	significant		medium			■		
Daylight Brook in University Circle	difficult/$$$-$$$$	medium		medium				■	
Daylight Brook in Gordon Park	difficult-no/$$$$	tiny		significant				■	
Enlarge University Circle Culvert	fairly/$$$	medium						■	
Keep University Circle Culvert Clear of Debris	yes/$$	medium							■
Enlarge Cedar Glen Sewer	fairly/$$$	medium						■	
Enlarge Rockefeller Park Channels	fairly/$$	medium		minor				■	
Enlarge Rockefeller Park Culverts	fairly/$$$	significant		tiny				■	
Small Projects:									
Revise City Codes to Require BMPs	yes/$	medium	medium	minor	❑	❑	❑		
Redesign MLK Detention Basin Outlet	yes/$	medium		tiny			■		
Stormwater Retrofits	yes–fairly/$-$$$	medium to signif.	significant	medium		❑	❑		
Stream Channel Restoration	fairly–difficult/$$-$$$	medium		significant			❑	❑	
* Channel Stabilization	fairly/$$-$$$		medium	medium				■	
* Stormwater Outfall Monitoring	yes/$		medium	minor					■
* Sanitary Sewer Maintenance	yes/$$		medium	minor					■
* Reinforce Dams Against Failure	yes–fairly/$$-$$$	significant	medium to negative	medium to negative		❑	❑		❑
* Lake Dredging	fairly/$$$	[17]	medium	medium	❑				❑
* Lake Aeration	yes/$		minor	medium		■			
Aquatic Plant Management	fairly/$		medium	minor		■			
Lake or Stream Biofiltration	yes–difficult/$-$$$		significant?	significant?		■			
Encourage Native Species and Discourage Invasive Exotics	fairly–difficult/$$			medium					■

17 Lake dredging will not increase the flood control capacity of the Shaker Lakes. See Chapter 7.

Table 8-5, continued	Summary of Doan Brook Restoration Techniques								
Measure	**Practical and Cost Effective?**	**Impact of Measure**			**Improvement Mechanism**				
		Hydrology	Water Quality	Habitat	Source Red.	Treatment	Flow Control	Chan. Improv.	Maintenance
Small Projects, continued:									
Species Reintroduction	fairly-difficult/$			medium					
Alternative Road Deicing	yes/$$		medium	medium	■				
Improve Golf Course Maintenance	yes/$-$$	minor	significant	medium	❑	❑	❑	❑	
Discourage Nuisance Waterfowl	yes–fairly/$		medium	minor	■				
Protect Riparian Corridor	yes/$		significant	significant					■
Increase Riparian Vegetation	yes/$		medium	medium		■			
* Street Litter and Debris Cleanup	yes/$		minor	minor		■			
Catch Basin Inspection and Cleaning	yes/$		minor	minor		■			
Erosion Control During Construction	yes/$		medium	minor	■				
Flow Augmentation	fairly/$$		tiny	minor			■		
Citizen Action:									
Downspout Disconnects	fairly-no/$	minor	minor	minor	❑		❑		
Rain Barrel Use	yes/$	minor	minor	minor	❑		❑		
Alternative Landscaping	fairly/$	minor	medium	minor	■				
* Proper Auto Waste Handling[10]	yes[18]/$		medium	minor		■			
Proper Car Wash Practices	yes[18]/$		medium	minor		■			
* Household Hazardous Waste Disposal[10]	yes[18]/$		minor	minor		■			
* Cleaning Pet Waste[10]	yes[18]/$		significant	minor		■			
Reduce Lawn Fertilizer, Pesticides and Herbicides	yes[18]/$		medium	minor	■				
* Proper Yard Waste Disposal[10]	yes/$		medium	minor		■			

Practicality: yes = highly practical – easy to implement; fairly = practical – not easily implemented; difficult = may be practical, but will be very difficult to implement; no = not practical.

Cost: $ = inexpensive; $$ = expensive; $$$ = very expensive; $$$$ = prohibitively expensive.

Area of Impact: Significant = measure has a significant impact on the problem; medium = measure helps the problem some; minor = measure helps the problem a little; tiny = measure has a very small but positive impact; negative = measure makes the problem worse.

Mechanism of Impact: ■ = sole mechanism; ❑ = one of several mechanisms.

18 A number of "citizen action" measures are quite easy to implement and have relatively small costs that are dispersed among the watershed's residents. Although some of these measures could have significant positive impact on the brook if they were widely embraced, obtaining compliance by a large number of people is difficult, at least over a short period of time. Very well run public education campaigns change the behavior of at most 20% of the targeted population. Time and persistent delivery of a consistent message may influence more people.

- Many of the measures that may benefit the brook involve small efforts spread over the watershed and over time. Because such dispersed efforts require fewer resources at any one time, they may be a more practical approach to Doan Brook restoration than a few large projects. However, successful execution of a long-term, dispersed effort will require not only close attention to a well-conceived watershed management plan, but also on-going monitoring to evaluate the success of each incremental effort.
- The gradual redesign of the urban Doan Brook watershed — the transformation of the way that water runs off from streets, parking lots, lawns, and rooftops — will require a combination of voluntary citizen action and modification of local building codes and ordinances. Some ordinances will need to be rewritten to allow less impervious construction; others will need to be rewritten to require changes in construction practices. The three watershed cities will need to cooperate to rewrite their ordinances to restore the health of the brook. In addition, the cities will need to be willing to explore new approaches to road construction, drainage design, bank stabilization, park maintenance, deicing, and other activities.
- Citizen education and participation will be essential.
- The combined efforts of the watershed cities, institutions, agencies, and citizens will be needed if we are to successfully restore the stream.

It should be obvious by now that the formation of a coherent watershed management plan is the first step in an on-going effort to restore Doan Brook. In 1998, NEORSD convened the Doan Brook Study Committee as part of their study of the Doan Brook watershed. The study committee was charged with creation of a watershed management plan, and the plan that they created (available through NEORSD and the Nature Center at Shaker Lakes) is an excellent starting point for restoration of the brook. The final chapter of this handbook outlines the steps that will make the plan a reality.

A garden club dedication in June 1968. Photograph by M.E. Croxton. From the Nature Center at Shaker Lakes collection.

At times we do fall back and become discouraged, but it is not that we are making no progress. Simply, this is the very nature of life — that it is a climb — and that the resolution of each issue in turn creates other issues, born of plights which are unimaginable today. The pursuit of happiness is never-ending; happiness lies in the pursuit.

— Saul D. Alinsky

Rules for Radicals

9 The Future of the Doan: The Need for Watershed Management

The first eight chapters of this handbook depict the past and present of Doan Brook and the options for its future. We must finally ask where we want to take the brook from here. Human beings are now the dominant species in the brook's watershed — its future depends entirely upon us. If we do not act to protect Doan Brook, the Shaker Lakes will gradually clog with overgrown vegetation, and Rockefeller Park will never again be a place to appreciate the beauty of the stream.

As previous chapters suggest, there is much interest in the brook, and there are many exciting plans for it. Our challenge now is to make these plans a reality and to do so as effectively as possible. Changes that are made one-by-one may be beneficial, but no single change will best help the stream, and an uncoordinated series of improvements will be a poor use of resources. To best restore the brook, we need a watershed management plan that sets forth a coordinated series of actions that can be taken over a period of time by many participants.

The process of creating and implementing a watershed management plan for Doan Brook is far along. The NEORSD study and its Doan Brook Study Committee assessed the stream's problems, set goals for restoration, evaluated options, and developed a conceptual plan for the watershed. The task of refining the conceptual plan, making it into a concrete blueprint for restoration, and carrying it forward will be spearheaded by the newly-created Doan Brook Watershed Partnership. This chapter describes the steps that are involved in creating and realizing a watershed management plan and discusses the process of making the plan for restoration of Doan Brook a reality.

9.1 Step Zero: The Commitment

Restoration of Doan Brook will stem from citizens' conviction that the brook and its parks are worth preserving and restoring. Such conviction was evident in the efforts of those who opposed the Clark and Lee freeways, who worked to stop dumping in the gorge, and who fought the construction of Site 14. It is again evident in the work that the Doan Brook Study Committee undertook to prepare the NEORSD watershed management plan. The watershed cities have supported their citizens by creating the new Doan Brook Watershed Partnership to move the watershed management plan forward. A continued commitment from both the cities and their citizens will be needed to fund and realize work for the benefit of the brook.

9.2 Step One: Gathering the Players

Doan Brook and its watershed span parts of Cleveland, Cleveland Heights, and Shaker Heights. The three cities have jurisdiction over some things that affect the brook — the streets, the building codes, the parks, and some of the sewers — while the Northeast Ohio Regional Sewer District (NEORSD) has jurisdiction over significant aspects of the sanitary sewer system. Ohio EPA has certain regulatory authority over water quality in the brook. The

Existing Meetings of the Players

Various efforts toward gathering the Doan Brook stakeholders have been made over the years. The Joint Committee on the Doan Brook Watershed is an ongoing effort by Cleveland, Cleveland Heights, and Shaker Heights to coordinate activities for the benefit of the brook. In addition, the NEORSD Doan Brook Study Committee brought more interested citizens and community groups together. The newly-formed Doan Brook Watershed Partnership, created in 2001 to further watershed management, includes members from the three cities, Holden Parks Trust, the Nature Center at Shaker Lakes, and NEORSD. In addition to standing groups, the Nature Center at Shaker Lakes, University Circle, Inc., and others have convened periodic gatherings in the interest of the brook.

U.S. Army Corps of Engineers may have authority over work in the watershed's wetlands. The Ohio Department of Natural Resources has responsibility for the safety of the Shaker Lake dams. The Nature Center at Shaker Lakes and the Shaker Historical Society are intimately concerned with different aspects of the upper watershed's environment and history. The Holden Parks Trust has similar interests in the lower watershed. The Cultural Gardens Association is involved in the upkeep and restoration of part of Rockefeller Park. University Circle, Inc., is interested in controlling flooding on the brook in University Circle, and perhaps also in restoring the brook there so that it can serve as the focus of the area. Case Western Reserve University (CWRU), the brook's neighbor and the chief victim of flooding, shares these interests. Scientists and engineers at CWRU, John Carroll University, Cleveland State University, and the Cleveland Museum of Natural History are interested in the brook's biology, geology, and hydrology. In addition to these and other organizations, many individual citizens are interested in the fate of the brook and willing to be active to influence its future.

The collective energies and resources of all of these organizations and individuals will be needed to plan and carry out a successful Doan Brook restoration. The political entities with primary responsibility and jurisdiction — the cities and NEORSD — must work together in all phases of planning to form the core of the restoration effort. Other agencies must be involved when they may have useful input to offer or when they have jurisdiction over an activity. Interested institutions should be included whenever their ideas and resources might make a contribution. Finally, all interested citizens should have an opportunity to take part in watershed planning.

In 2001, the Joint Committee on the Doan Brook Watershed formed the Doan Brook Watershed Partnership to provide a focal point for those interested in Doan Brook and to further Doan Brook watershed management. The Partnership's first task will be to bring all of the players together and use the existing efforts toward coordination and communication as a springboard to the future. The Partnership should seek to combine the resources and interests of all the parties for the benefit of the brook.

9.3 Step Two: Assessing the Problem

Once the players are gathered, the next step will be to assess Doan Brook's problems. We are fortunate here, because much or all of the necessary work has been done. NEORSD's Doan Brook Watershed Study has provided more information about Doan Brook than is generally available about any stream. This information and other data summarized in the earlier chapters of this handbook provide a clear picture of the brook's problems. It should be possible to review the data and move ahead with little or no additional data collection.

9.4 Step Three: Setting Goals

The next step, goal setting, will be more complicated than assessing the brook's problems. A variety of sometimes conflicting interests will need to be weighed. The goals should take into account a realistic assessment of the stream's condition and its watershed and should include an unsentimental evaluation of the best condi-

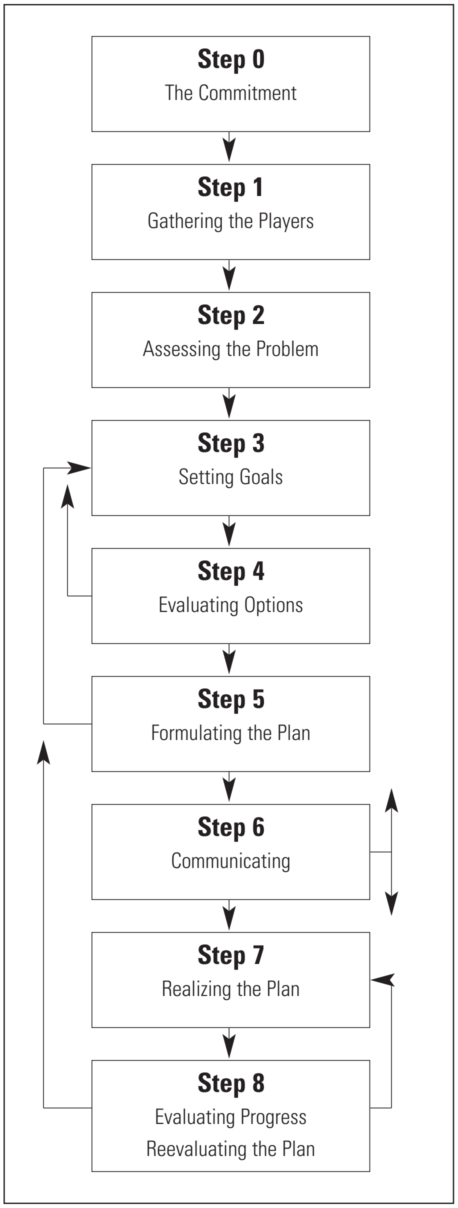

Figure 9-1 The Watershed Planning Process

tion that is achievable for the urban brook. Overall goals should be broken down into short and long term goals, and a mechanism for measuring progress toward the goals should be established. Again, the work done by NEORSD's Study Committee has gone far toward setting goals for restoration of Doan Brook.

9.5
Step Four: Evaluating Options

As goals for the watershed are set, consideration of options for achieving the goals will need to begin. Goal setting, at least for short term goals, and the evaluation of options should go hand-in-hand; goals that can be readily achieved using available measures deserve special consideration. As is discussed in Chapter 8, options for restoring Doan Brook will include large projects, small projects, and citizen action. No single approach will solve all of the stream's problems, and data about the effectiveness, feasibility, and cost of different options will be incomplete.

The task of evaluating the options will be somewhat daunting in the face of many possible approaches and incomplete information about the effectiveness and feasibility of each option. To make the evaluation more manageable, it should be broken down into several stages. One workable set of evaluation stages is as follows:

- Stage 1 — Information gathering to review previous planning efforts by the NEORSD Study Committee and others (chiefly for the Rockefeller Park area [by Holden Parks Trust] and the Shaker Lakes area). Also information gathering about legal and institutional issues that may have an impact on watershed management options.
- Stage 2 — General screening to eliminate options that clearly have little benefit or are infeasible for one reason or another.
- Stage 3 — Moderately detailed screening to gather information needed to determine the effectiveness and feasibility of the remaining options. This screening should include sufficient additional information gathering to indicate whether additional options are ineffective or infeasible.
- Stage 4 — Detailed screening of remaining options to allow a comparative evaluation of effectiveness, level of impact, feasibility, and approximate cost. This evaluation should be done in sufficient detail to allow remaining options to be combined into a watershed management plan.

The criteria and methods that are used for each evaluation should be clearly spelled out, and the results of the evaluations should be documented. Although the process of defining and documenting evaluations is cumbersome, it is essential. Otherwise, options that have been evaluated and discarded will continue to re-surface, and the work of the evaluation will be endlessly repeated.

The work done by the NEORSD Study Committee will again serve as the foundation for this step; however, it may be desirable to broaden the plan developed by the Study Committee to include some more ambitious projects (development of a Gordon Park wildlife sanctuary or creation of a park around a daylighted brook in University Circle, for example) that might be accomplished by coordinating a number of different interests.

9.6
Step Five: Formulating the Plan

Formulating the watershed management plan involves taking the options that emerge from the Step Four evaluation and combining them to meet watershed management goals. The final plan should include the following elements:

- A clear statement of the plan goals.
- The measures that are included to reach each of the goals and a statement of how each measure will help achieve each goal.
- A timeline for implementation of the plan.
- A statement of the priority attached to each measure included in the watershed management plan.
- Methods to monitor progress toward the goals and the effectiveness of each measure.
- A mechanism for regular reporting on the progress of the watershed management plan.
- A mechanism for keeping the general public informed about watershed management work.
- A provision for a periodic reevaluation of the plan and the progress that has been made.

In formulating the watershed management plan and the approach to monitoring the progress of the plan, it may be useful to break the watershed into subwatershed areas. This will make it easier to evaluate the impact of any given part of the plan.

While the watershed management plan prepared by the NEORSD Doan Brook Study Committee includes a good framework of goals and actions, it is largely a conceptual plan rather than a concrete plan of action. There is no timeline for implementation of the plan, and there are no specific mechanisms for monitoring progress or updating the plan over time. These elements will need to be part of the final watershed management plan in order for the plan to be implemented and in order for the long-term effort needed to restore the brook to be sustained.

9.7
Step Six: Communicating

The long-term success of watershed management will require that the general public be educated about the need for watershed restoration, the progress of watershed planning, and the progress of watershed management. Communication among the various "stakeholder" entities will also be important. The watershed management plan must therefore include a sustained emphasis on communication with the general public and among participating entities.

9.8
Step Seven: Realizing the Plan

This step moves the watershed management plan from paper to reality, and it is here that the commitment of the watershed's citizens and cities becomes critical. Although the effort required to create the plan is substantial, the effort that will be required to realize it is much greater. Restoring Doan Brook will require that the cities not only continue their own financial commitments, but also combine their interests with those of other institutions that surround the brook and procure additional funding from appropriate outside sources.

9.9
Step Eight: Evaluating Progress, Reevaluating the Plan

Once the watershed management plan is being implemented, its success and progress will need to be evaluated, and it will need periodic review and revision. The plan for each restoration measure should be accompanied by a means for its evaluation. As each measure is implemented, its success should be monitored, and its success or failure should be considered in a periodic reevaluation of the overall watershed management plan. Reevaluation should include assessments of whether plan implementation is on schedule, whether work has been more or less effective than expected, and whether the plan should be changed to reflect the successes or failures to date. The results of the evaluation should be communicated to watershed citizens and institutions.

American white pelican at the Lower Shaker Lake. Photograph by L. C. Gooch.

Epilogue

Doan Brook has much about it that is unique and uniquely interesting — its history and geology, its carefully planned and preserved parks, the museums that lie along it, and the fine neighborhoods of its watershed. At the same time, it is like many other small, urban streams that run almost unnoticed through our cities. We began the last century by taking these streams completely for granted and assuming that they could absorb whatever we dumped into them. Now, we view them as a resource that we need to protect. The impacts of our past negligence are visible whenever we look at a stream, river, or lake. The question is whether we will do what it takes to remedy old errors.

Our emphasis on urban stream restoration has grown out of an increasing awareness that small streams are ecologically important. They not only connect to larger streams and lakes, but they also provide significant habitats in their own right. As our cities have continued to expand, we have begun to realize that no stream is untouched by our presence. We have become aware that we must treat the watersheds we live in more carefully to save any remnant of natural stream habitat.

Growing awareness of our impact on the streams we live with is the continuation of a process that began almost a hundred years ago. Then, we realized that it mattered when we dumped sewage into a stream. Now, we realize that even the occasional overflow of a combined sewer is important, that stormwater runoff from paved landscape causes floods, and that the chemicals we leave on the ground make a difference. Just as we worked to stop direct sanitary sewage discharges in the early part of the twentieth century, we must now work to control the remaining sewage discharges and the damage caused by stormwater.

As we undertake this effort, we need to keep the reason for our labor in view. Walk the Doan Brook at any season. Look at the snow-covered trees in winter, listen to the red-winged blackbirds in spring, explore the Cultural Gardens in summer, and hike the gorge in the fall. Take advantage of the gift the philanthropists gave us in 1900. And make sure that their gift will still be here in another one hundred years.

Believe one who knows: you will find something more in woods than in books. Trees and stones will teach you that which you can never learn from masters.

— St. Bernard of Clairvaux

Epistles

Glossary

Words used in definitions that are themselves included in the glossary are shown in italics.

ague	A malarial fever with recurring chills and sweating fits.
anoxic	Lacking oxygen.
aquifer	A layer of soil or rock that is saturated and is capable of transmitting significant quantities of water. Some material, such as clay, can transmit very little water and will not generally be thought of as an aquifer. Other material, such as sand, gravel, or *sandstone*, can transmit significant quantities of water.
base flow	Flow in a stream during dry weather than is fed by *groundwater* seeping into the stream through its bed and banks.
B.C.E.	Before the Common Era. Equivalent to B.C. when used with dates.
bedrock	The layer of solid rock that underlies the surface soil. Bedrock in the *upper Doan Brook watershed* is *sedimentary rock* that lies a few feet below the surface. The sedimentary bedrock of the *lower watershed* lies several hundred feet below the surface.
biofiltration	The process of passing water through a concentrated colony of microorganisms that feed on contaminants found in the water. Biofiltration experiments on Doan Brook have used naturally occurring microbes to reduce the high concentrations of *nutrients* in the brook water.
BMP	Best Management Practice. BMPs for *watershed* management and development are the most effective and practical approaches to controlling *point* and *non-point source pollution* to levels that meet environmental quality goals.
C.E.	Common Era. Equivalent to A.D. when used with dates.
cfs	Cubic feet per second. Cfs is the unit typically used to report the rate at which water flows past a given point in a culvert or stream.
COE	United States Army Corps of Engineers.
combined sewer	A sewer line that carries both *stormwater runoff* and *sanitary sewage.*
confluence	The place where two streams meet.
CSO	Combined Sewer Overflow. Overflows of combined sewers to streams and lakes generally occur during wet weather, when the volume of *stormwater* is too large for the sewers to carry.

culvert — A pipe that carries a stream from one above-ground section to another above-ground section. For example, the pipe that carries a stream under a road is a culvert as is the long pipe that carries Doan Brook beneath University Circle.

CWRU — Case Western Reserve University.

daylighting — Restoring a section of a stream that has been confined in a culvert or storm sewer to an above-ground channel.

Design Flood — The flood that a dam or other structure must, by regulation, be designed to safely withstand. The Design Flood for Horseshoe Lake dam and the Lower Shaker Lake dam is one half of the *PMF*.

drainage area or drainage basin — See *watershed*.

dredge spoil — Soil material that is removed (dredged) from the bottom of a lake or stream and then must be disposed of.

DVI — Doan Valley Interceptor sewer. The DVI is a *combined sewer* that runs roughly parallel to Doan Brook in the *lower watershed*.

EPA — Environmental Protection Agency.

Escarpment — A long, cliff-like ridge of land or rock. In this handbook, the Escarpment (capitalized) refers specifically to the Portage Escarpment, the sharp fall in elevation that represents the westernmost edge of the Appalachian Plateau and separates the *lower* and *upper* Doan Brook *watersheds*.

eutrophic — Having high *nutrient* content and high biological activity. Refers specifically to lakes.

exotic species — Species of plants or animals that are not native to the area.

fissile — Geologic term referring to rock (generally *shale*) that breaks along parallel planes as it weathers, resulting in thin, plate-like fragments.

flood — See Appendix H for a discussion of flood return periods (that is, the definition of a 5-year flood, etc.).

gabions — Rock-filled wire baskets (generally square) that are stacked together to reinforce an eroding stream bank.

glacial till — A soil made up of jumbled clay, silt, sand, gravel, and sometimes larger particles, that was deposited in a relatively thin layer (generally less than a few tens of feet) by the glaciers as they retreated. Glacial till makes up much of the soil of the Doan Brook *watershed*.

groundwater — Water that soaks into the soil and then flows within the matrix of soil or rock particles. Many people picture groundwater as a series of streams flowing in caverns beneath the ground. This is only rarely the case. Most of the time, and certainly in the Doan Brook *watershed*, groundwater works its way through the soil and rock, winding tortuously among the soil or rock grains and seeping through cracks in rock. If you dig into an *aquifer* beneath the Doan Brook watershed, all you will find is wet soil or rock.

headwaters — The upstream-most sections of a stream; the area where a stream originates.

HHI — Heights/Hilltop Interceptor sewer. The HHI is a network of large-diameter *interceptor sewers* that is under construction in the *upper watershed*. When complete, it will divert much of the upper watershed's *sanitary sewage* away from the *Doan Valley Interceptor*.

hydrology — The science that deals with the circulation, distribution, and properties of the waters of the earth.

hypereutrophic — Having excessively high *nutrient* content and biological activity. Refers specifically to lakes. Hypereutrophic lakes (like all of the Shaker Lakes) are aesthetically unappealing at times due to odor, excessive plant and algae growth, and high turbidity. The dissolved oxygen content in the lakes is sometimes depleted by excessive plant growth, so that they support poor biologic communities.

impermeable — See *impervious*.

impervious — Allowing little or no water to *infiltrate*; water tight. Paved areas and building roofs are the primary *impervious* surfaces in most urban watersheds.

impoundment — A lake, reservoir, or detention basin.

infiltrate — To filter into or through. Groundwater infiltrates into *permeable* material (like soil), but does not infiltrate through *impervious* surfaces (like pavement or rooftops).

interceptor sewer — A large *sanitary* or *combined* sewer line that collects flow from a number of smaller sewers.

invasive exotic species — *Exotic species* that thrive in the local environment and grow excessively at the expense of native species. Purple loosestrife, Japanese knotweed, and many kinds of honeysuckle are examples of invasive exotics that are found in the Doan Brook *watershed*.

JCDBW — Joint Committee on Doan Brook Watershed.

lacustrine — Originating in lake water. Lacustrine sediments are those deposited on lake bottoms.

Lake Plain The relatively flat area adjacent to Lake Erie that once lay under the waters of the lake's ancestors. The Doan Brook *lower watershed* lies in the Lake Plain.

lower watershed The part of the watershed extending from Lake Erie to the sharp change in elevation (the *Escarpment*) just upstream (south and east) from University Circle.

macroinvertebrates Invertebrates (animals without backbones) large enough to be seen without a microscope. Macroinvertebrate species include aquatic insect larvae, crustaceans, aquatic worms, and shellfish, among others. The health of the macroinvertebrate population is an indicator of the water and habitat quality in a stream.

MLK Martin Luther King, Jr., Boulevard.

NCSL The Nature Center at Shaker Lakes.

NEORSD Northeast Ohio Regional Sewer District.

non-point source pollution Pollution that originates from the accumulation of low concentrations of pollutants collected over a large area. Most of the *nutrients* that are discharged to Doan Brook accumulate from lawns and golf courses that are spread over the entire *watershed*. Nutrient contamination in the brook is thus the result of non-point source pollution.

nutrients Essential chemicals needed by plants or animals for growth and health. In the context of water quality, "nutrients" refers primarily to nitrogen-containing compounds (ammonia, nitrates, nitrites, organic nitrogen) and phosphorus-containing compounds. Lack of these compounds (especially phosphorus) limits the growth of aquatic organisms. When nutrients are present in excessive quantities (as in Doan Brook), they promote excessive plant growth that creates *eutrophic* or *hypereutrophic* conditions.

ODNR Ohio Department of Natural Resources. ODNR is responsible for the safety of the Shaker Lakes dams and has authority or expertise in a number of other areas relevant to Doan Brook.

organic chemicals Chemicals containing carbon. Naturally occurring organic chemicals are the basis of life on earth. However, in the context of water quality, "organics" generally refers to manmade carbon containing compounds such as synthetic oils, *PCBs*, poly-aromatic hydrocarbons (PAHs), pesticides, and herbicides that are often toxic and that often remain toxic for a long time when they are released into the environment.

overtopping In the context of *hydrology,* overtopping refers to water flowing over the top of a dam or other water barrier, generally in a manner that the barrier is not intended to withstand. None of the Shaker Lakes dams is intended to withstand water flowing over its main earthen embankment.

PCBs	Polychlorinated biphenyls. A group of manmade, toxic *organic chemicals* that persist in the environment and have been linked to cancer, reproductive defects, and other health problems.
permeable	Allowing water to *infiltrate*.
Plateau	Generally refers to a level land area raised above the surrounding land. In this handbook, the Plateau (capitalized) refers to the Appalachian Plateau, the westernmost edge of which forms the *upper watershed* and terminates at the *Escarpment*.
PMF	*Probable Maximum Flood*.
point source pollution	Pollution that originates at a single location such as a factory waste discharge pipe.
Probable Maximum Flood	The Probable Maximum Flood, or *PMF*, is defined as "…the flood that can be expected from the most severe combination of critical meteorologic and hydrologic conditions that are reasonably possible…" in a given area (National Research Council, 1988). In other words, the worst flood that can be imagined if science is used to guide the imagination.
QHEI	Qualitative Habitat Evaluation Index. A physical habitat index designed to provide an empirical, quantified evaluation of the general stream microhabitat characteristics that are important to fish communities.
riparian	Having to do with the bank of a river. Used to refer generally to the area surrounding any natural body of water.
riparian corridor	The strip of land immediately adjacent to and including a stream. A riparian corridor that is left in its natural condition protects the stream's water quality and habitat.
riprap	Large rocks that are dumped or placed to prevent erosion. The downstream face of Horseshoe Lake dam has been armored by riprap.
runoff	Water that flows along the surface of the land.
sandstone	A *sedimentary rock* composed of sand particles cemented together.
sanitary sewage	Wastewater (sewage) collected from households and businesses.
sanitary sewer	A sewer that is designed to carry only sewage collected from household and business indoor drainage systems. Sanitary sewers are not intended to collect *stormwater runoff*.
sediment	Particulate material suspended in or settled to the bottom of a water body. Sediment may originate from natural sources such as natural soil erosion or from human activity such as construction, road grit, disturbed land, or agriculture. Increased flow in an urban stream like Doan Brook also increases the quantity of sediment eroded from the stream bed and banks.

sedimentary rock	A rock formed by the accumulation and cementation of mineral (sand, silt, clay, etc.) grains. Sedimentary rocks are generally formed when layers of material that were deposited over many years by wind or water are subsequently buried and compressed until they become rock.
sedimentation	Deposition of sediments in lakes or other areas of relatively still water. Over time, lake sedimentation degrades lake habitat and transforms lakes into marshes and eventually valleys. Lake sedimentation rarely changes a lake's ability to decrease downstream flooding (see Chapter 7).
sewershed	The area that drains into a *sanitary* or *combined sewer* system. The sewershed is generally related to the surface *watershed*, but it need not correspond exactly. The sewershed of the Doan Valley Interceptor Sewer (*DVI*) is currently much larger than the Doan Brook watershed. However, the completion of the Heights/Hilltop Interceptor Sewer (*HHI*) will make the DVI sewershed smaller than the Doan Brook watershed.
shale	A very fine-grained *sedimentary rock* composed of silt and clay. Shale tends to break apart along planes parallel to the plane in which the silt or clay was originally deposited. As a result, shale frequently weathers into thin plate-like fragments.
Site 14	The Corps of Engineers Diked Disposal Facility Site No. 14. The area of landfill over the mouth of Doan Brook at Lake Erie where the Corps of Engineers has disposed of material (*dredge spoil*) from the mouth of the Cuyahoga River and nearby Lake Erie navigation channels.
storm sewer	A sewer designed to carry *stormwater runoff* without any mixture of *sanitary sewage*.
stormwater	*Runoff* that flows from the surface of the *watershed* during a storm.
surface runoff	See *runoff*.
stormwater retrofit	Stormwater retrofits are new stormwater control structures (small or large) designed to reduce flooding or improve water quality. They are retrofit into already developed areas.
subwatershed	A small area of a larger *watershed* for which surface *runoff* drains to a particular point. The area that drains to Horseshoe Lake is an example of a subwatershed within the Doan Brook watershed. The area that drains to the Lower Shaker Lake is another subwatershed that contains the Horseshoe Lake subwatershed.
till	See *glacial till*.
uncontrolled drainage areas	Drainage areas (or *watersheds*) that do not include a lake or other structure that reduces flood peaks or slows storm *runoff*.

upper watershed The part of the Doan Brook *watershed* that lies on the higher elevation land east of the line of the *Escarpment*.

watershed A stream's watershed is the area of land over which water running along the ground surface (called *runoff* or *surface runoff*) will eventually flow into the stream. Also called a *drainage area* or *drainage basin*.

Annotated Bibliography

The following bibliography divides references into a number of categories (see the following list). A brief description of the content of the reference is given where useful, as is a notation of where the reference can be found.

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Biology and Ecology
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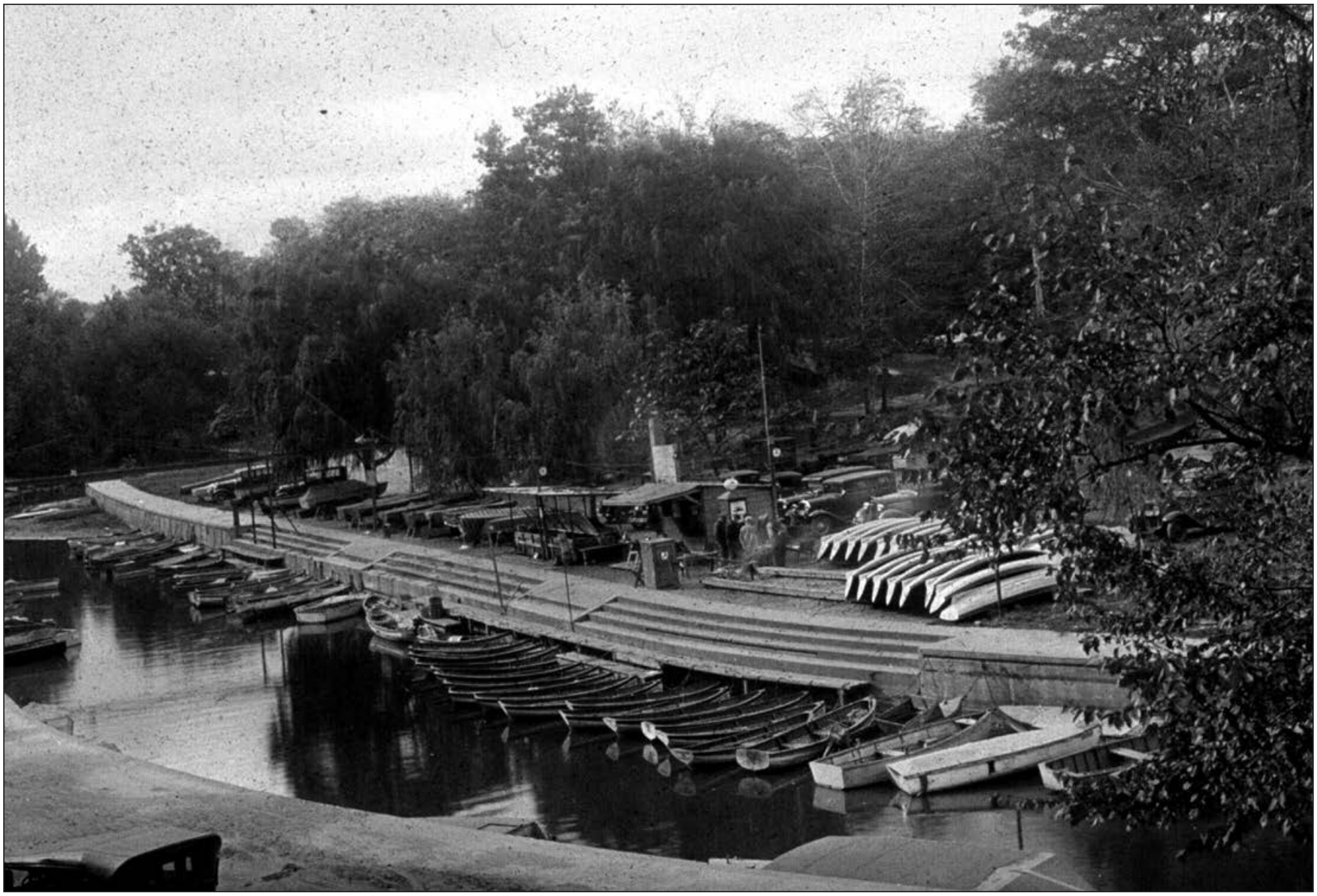


Gordon Park about 1930. Photographer unknown. From the Nature Center at Shaker Lakes collection.

Appendix A

The parks along Doan Brook offer a wealth of places to explore and opportunities for recreation. This general brook tour will give you an idea of some of the possibilities so that you can begin to explore on your own. If you are specifically interested in history or geology, see the tours in Appendices C and F. We begin at the mouth of the brook on Lake Erie and work our way upstream.

A.1
A Lake Erie Picnic: Gordon Park and the Brook Beneath

Doan Brook once ran through a beautiful landscape in Gordon Park and entered Lake Erie in the midst of a popular public bathing beach. The landscape of the park is less manicured now, and the brook is nowhere to be seen, having been buried in a culvert during the construction of I-90. Gordon Park is nonetheless a good spot for a picnic on the lake with a view of downtown Cleveland and for a bit of lakefront fishing. Public boat ramps are available if you want to venture out onto the lake.

When you've finished your picnic, walk east from the boat launch area and up the hill. The overgrown and fenced area on your left is the Corps of Engineer's Site 14 dredge spoil area. Doan Brook now flows into Lake Erie through a culvert buried deep beneath the fill. As you walk up the hill, you will see a large concrete vault on your left inside the dredge spoil area fence. This vault gives access to part of the culvert that contains the brook. Imagine how Gordon Park might be transformed if Doan Brook flowed in the open once more and the park and the dredge spoil area were landscaped around it! Bringing the stream to the surface may be too difficult, but Holden Parks Trust would still like to make Site 14 into a park. Others support the idea that the area should be maintained as a sanctuary for birds and other wildlife. Although it is closed to the public at present, it supports an extraordinary variety of migratory and nesting birds (see Appendix G).

If you follow the bike path to the top of the hill, you'll find another piece of Cleveland Lakefront State Park sitting on a bluff overlooking the boat launch and the dredge spoil area. This, too, is a good place for a picnic. There are an Ohio Department of Natural Resources Office, a few tables and grills, and some play equipment. You can also reach this area from Lakeshore Boulevard. Take the first driveway east of the Martin Luther King, Jr., Boulevard (MLK) interchange with I-90.

There is more of Gordon Park south of I-90, although this part of the park has not been as heavily used since the freeway severed it from the lake. The only automobile access to the park is from East 72nd Street. The abandoned Cleveland Aquarium building is here, as are a number of tennis courts and baseball fields. There is a good view of the lake as well. The footbridge across I-90 that connects the two pieces of Gordon Park is infrequently used and overgrown, and pedestrian access from one part of the park to the other is generally via the MLK underpass.

A.2
I-90 to East 105th: Rockefeller Park and the Cultural Gardens

Rockefeller Park Greenhouse

Tucked away on the east side of Doan Brook just south of I-90 is the City of Cleveland's Rockefeller Park Greenhouse. To get there, turn east from MLK just south of the Conrail tracks (the last of the historic stone bridges over MLK). The greenhouse, completed in 1905, was made possible by a donation from John D. Rockefeller. The 4-acre site includes indoor and outdoor gardens. There are a number of shows each year, including seasonal flower displays and flowering orchids. It's a great place to warm up in a bit of the tropics on a Cleveland winter afternoon!

As you walk around the outdoor Talking Garden for the blind and Japanese Garden, note the two large mill stones that are garden centerpieces. Although the history of these stones seems to have been lost, it is likely that they came from the Crawford sawmill that was once located on Doan Brook near Superior Avenue, or perhaps from the Cozad grist mill that was located near Wade Park Lagoon.

The Bike Path and the Cultural Gardens

A shaded bike path winds along Doan Brook through Rockefeller Park and the Cultural Gardens (between St. Clair Avenue and East 105th Street). The path is flat (it's in the Lake Plain!) and has few road crossings — an ideal place for a leisurely ride or stroll. You can stop along the way to explore the gardens adjacent to the path or detour up the hill to the east to see the gardens that face East Boulevard. Historic stone bridges designed by Charles Schweinfurth in the late 1800's span the path. Note the shape of Doan Brook's valley — a shallow, broad "U" cut into the surrounding landscape.

As the path crosses and re-crosses the brook you will see that the stream that once meandered back and forth to cut the valley is now confined in stone-walled rectangular channels. Near Superior Avenue, the stone channel walls have been replaced with steel sheetpiling. What would the park be like if the brook could be restored to a more natural channel? If you look at the stream valley just upstream from Superior, you will see that there is barely room here for the road and the existing channel. It would be very difficult to restore a more natural stream in the confined space available at this point. Other parts of the valley are wider and offer more possibilities for restoration.

As you move north, you will note a number of places where the stone retaining walls along the stream are damaged. Two good examples are north of Ansel Avenue on the west side of MLK and north of Wade Park Avenue on the east side of MLK. At the Wade Park Avenue site you can see that the brook has sometimes escaped from its banks and worn away at the bank behind the walls.

Near East 105th Street you will find a playground and public tennis courts, as well as the Rockefeller Park Lagoon. Notice that the brook detours around the lagoon, which is filled with treated water from the City of Cleveland.

If you continue upstream from East 105th, past the cancer survivor's monument all the way to the outlet from the University Circle culvert, you will come to one of the areas where the stream channel was stabilized and restored in 1999 using a "biorestoration" approach. You can also reach this area by parking on MLK along the west side of the Wade Park Lagoon and walking down hill (north) until you see the brook appear to the right. Beginning at the outlet of the culvert and continuing for about 100 yards downstream (to about the point where a chain link fence comes near the bank), a series of three pools has been created in the brook using natural stone. The pools and the riffles between them are intended to aerate the brook water as it emerges from the culvert and to create a natural environment where macroinvertebrates can thrive. The west bank here has been stabilized by embedding large tree trunks in the bank and by planting scrub willows and other native vegetation. New trees and bushes were also planted on the banks.

A.3
Wade Park and University Circle: Cultural Institutions and the Culvert

Although Doan Brook was once at the heart of Wade Park and University Circle, you'll be hard-pressed to find a trace of it there now. The University Circle culvert carries the brook underground between the Cleveland Museum of Art and the base of the main, steep hill of the Portage Escarpment. Keeping in mind that the brook is beneath your feet, you can stroll around the Wade Park Lagoon (the culvert runs just along the west side), play Frisbee on Wade Park Oval, visit the Cleveland Museum of Natural History, play in the Cleveland Botanical Gardens' playground, stroll through the herb and Japanese gardens, take in the art museum, explore history and the antique cars and planes at the Western Reserve Historical Society and Crawford Auto Aviation Museum, check out the Children's Museum of Cleveland — and much more.

As you enjoy Wade Park and University Circle, imagine how the area might look if an open brook once again formed the heart of the parks. A design sketch prepared in 2000 suggested that the brook might be brought above ground and might some day cascade into Wade Park Lagoon. Although this is an appealing idea, it would be very costly. It addition, it will be necessary to significantly improve water quality in the brook before it can be allowed to flow through Wade Park Lagoon. The lagoon is a clean and appealing lake now because it is filled with treated city water. With current water quality in Doan Brook, the brook's waters would leave Wade Park Lagoon choked with unsightly vegetation.

A.4
Up the Hill Through Ambler Park

Ambler Park carries the brook up the steepest part of the Portage Escarpment. As you walk through the park, it is clear that it was once a showpiece of the brook, complete with WPA-built stone paths and steps along the cascading stream. Ambler Park has suffered over the years, though. It has become isolated by heavy traffic on the adjacent roads (MLK and Fairhill Road), the lower part of the park has been filled in, and the upper part has been given over to the MLK detention basin. There is little parking nearby, and to reach the park on foot or by bicycle you must brave some difficult road crossings.

It is still interesting to explore the park, though. **Take a friend for safety (this area is isolated and often deserted) and wear sturdy shoes.** You can reach the park by bicycle or on foot from the path along Fairhill, or you can park on one of the side streets near the intersection of North Park Boulevard and MLK and walk down the hill.

Beginning at the lower end of the park, opposite the intersection of MLK and Ambleside, you will see an open field screened from the adjacent roads by trees. The brook used to flow here, until it was covered with fill material from the excavation of the Baldwin Filtration Plant reservoirs. Walk upstream (southeast) through the field and you will come to the entrance to the University Circle culvert. The inlet isn't too exciting most of the time, but it can be fairly interesting in a flood.

If you continue along the brook from the inlet, you will find yourself in a hidden valley surrounded by tall trees. Traffic on MLK and Fairhill rushes faintly by overhead, seeming far away. The brook is confined in a stone-walled channel here, but it has eroded under the wall in many places, and the wall has collapsed in a few.

It is difficult to walk up the brook through the park, now, because the stepping stones that once crossed the stream have crumbled. You can either continue along the south side as best you can or go back past the culvert inlet and then follow one of the roads up the hill. There is a paved path along Fairhill. From the top of the hill, where MLK crosses the stream, you can get a good look at the MLK detention basin. If you walk back down the hill toward the detention basin dam, notice the design of the basin: It has an outlet at the base to allow the stream to pass through during low flows and a large dam to back the stream up during floods. Unfortunately, the relatively large culvert at the base of the dam (6.5 feet high by 9 feet wide) will not detain sufficient water to have much impact on any but very large floods (see Chapter 7 for more discussion).

If you are adventurous, you can climb over the crest of the dam and explore the old WPA stone pathways on the northeast side of the brook below the dam. Some of the paths have crumbled away, and the steps lead nowhere, so proceed with caution.

A.5
MLK to Coventry: The Gorge and The Old Stone Grist Mill

Warning: Some parts of the Doan Brook gorge can be dangerous. In the steeper areas of the gorge, you can fall over 40 feet from the top of the slope straight to the stone floor below. A Shaker child was killed in such a fall in 1834. Slopes elsewhere are steep and slippery, and the rocks in the streambed can be slick with moss or ice. Rock walls overhang the stream in some places. Explore with caution.

The reach of Doan Brook between MLK and Coventry Road is hidden, but it is the most scenically dramatic part of the stream. In most places, walking or driving along the upper banks (on North Park or Fairhill) reveals little of the character of the gorge. You have to climb down to the stream to see the valley it has created. You can enjoy simply exploring the gorge, or you can go there to see what the brook has revealed about the geology that underlies the watershed or to explore the remains of the Shaker stone grist mill or one of several stone quarries. Tours of the brook's historic sites and geology are included in Appendices C and F. A few sites of particular interest are described below.

The Trash Rack and the Lower Gorge

If you climb down the slope immediately upstream (east) from MLK and North Park Boulevard you find yourself overlooking a wide spot in the brook channel. If the City of Cleveland had built the MLK detention basin according to their original proposal, you would now see a 40-foot tall, 20-foot diameter vertical concrete pipe sticking into the air in front of you, with its top almost as high as the top of the roadway embankment behind you. During a flood, water would have backed up until it overflowed the top of the vertical pipe, filling the gorge in front of you (about as high as the top of your head) with water. During normal flow, a small outlet at the bottom of the pipe would have allowed the brook to pass.

Since these plans for the detention basin were defeated by public opposition, what you see instead of an enormous vertical pipe is simply the brook crossed by an odd-looking concrete and steel structure. This structure, which looks like a giant set of concrete highway barricades with steel I-beam teeth sticking out of the top, is a *trash rack* that is intended to catch branches and debris that are carried by Doan Brook during floods and prevent them from clogging the culvert under MLK or the University Circle culvert farther downstream. During normal flow, the stream should pass through the gaps between the concrete sections. However, the brook frequently erodes a new channel around one end of the barricade (generally the south end), so that the main flow goes around, rather than through, the trash rack, rendering the structure much less effective for catching debris. Erosion along the downstream base of the trash rack indicates that considerable quantities of water have flowed over the rack at times, and debris caught on the upstream side shows that the rack is not completely ineffective.

Walking upstream from the trash rack quickly becomes difficult. If you persist, you pass through a wooded gorge where the stream has cut through sloping layers of shale and sandstone. However, this area of the gorge is more easily approached from the sandstone quarry farther up the brook.

Sandstone Quarry and Bank Reconstruction

If you walk up North Park Boulevard from MLK, you can follow the top of the gorge as far as Delaware Road. As you walk along, you may notice bronze medallions set in concrete at the bases of a number of the trees. Eight hundred and fifty of these markers and the adjacent oak trees were planted in 1919 to commemorate soldiers killed in World War I. The markers once extended all the way from Gordon Park to Horseshoe Lake. Several hundred remain, scattered along the original "Liberty Row."

At Delaware Road, a set of stone steps leads down toward the stream. If you pause at the bottom of the first set of steps, you will see vertical sandstone walls to your left, indicating that you are in one of the old sandstone quarries on Doan Brook. The Shakers and others quarried sandstone (some Berea Sandstone and some Euclid Bluestone) from this area and others along the brook.

More steps lead to the brook from the first quarry site, and you can explore the valley in both directions from here. Some of the more interesting geologic features and historic sites are nearby – see the tours in other appendices if you are interested.

Old Stone Grist Mill and the Berea Sandstone Falls

Still farther upstream from the sandstone quarry, just upstream from Roxboro Road, lie the scant remains of the Shaker stone grist mill, its flume and dam, and the quarry that replaced the mill. The mill was carefully located to take best advantage of the brook's descent over the edge of the tough Berea Sandstone, so the stream descends a 12 foot fall between the dam site and the mill. See Appendix C for a description of the mill and quarry remains and Appendix F for a description of the geology.

Looking across the gorge at the mill site, you can see a number of stone-filled wire baskets along the far bank of the stream. These *gabions* are part of the repair of the slope failure that threatened Fairhill Road in 1975. The gabions reinforce the toe of the slope. Compacted fill was placed on an even slope behind the gabions and vegetation was established. If you examine the south gorge slope from the mill site for about 300 feet downstream you may see signs of an unusually even slope and trees that are less than 25 years old.

A short distance upstream from the mill site, you will see a series of road piers crossing the gorge. Kemper Road once crossed the brook here. Notice that the stream channel under the piers is smooth stone. This is the cap of the hard Berea Sandstone. It formed the falls just downstream and created a desirable site for a mill. See the geology tour for more details.

The Mill Race and the Brook

Just a bit below the Lower Shaker Lake dam, between the intersections of Woodmere and Demington with North Park, you find the confluence of two brook channels: the northern one is almost dry, while the southern one carries the outflow from the Lower Shaker Lake. The northern channel was reportedly the original outlet of the lake, while the southern channel was built by the Shakers as the lake spillway. The northern channel was once the mill race for the Shaker sawmill just below the Lower Shaker Lake dam (see the next section). The channel and outlet through the dam were blocked after the mill was abandoned, so that the channel now carries little water.

A careful examination of the two channels does not reveal either of them to be obviously manmade, and the southern channel, supposedly dug by the Shakers, cuts a wide swath through the surrounding sandstone bedrock. Although this channel may be completely manmade, it seems more likely that it was an existing but disused channel that had been cut by the stream.

A.6
The Lower Shaker Lake and the Nature Center at Shaker Lakes

The Lower Shaker Lake and the Nature Center at Shaker Lakes are in the midst of popular, heavily-used parks, but they still hold some surprises even for the most frequent visitors. The Shaker sawmill site lies just downstream from the dam, southeast of the intersection of North Park Boulevard and Coventry Road. The mill site is described in Appendix C. Although the Shakers originally built a dam at this site in the 1820s and rebuilt the dam a number of times, few identifiable traces of the original dam remain on the surface. Some of the stone work that is visible near the north end of the downstream face might be Shaker work.

In the spring, forsythia, crab-apple, cherry, and other ornamental fruit trees bloom along the shores of the Lower Shaker Lake and Horseshoe Lake. Jack-in-the-pulpit, May apple, Virginia waterleaf, Solomon's seal and other wildflowers bloom downstream from the dam, and trout lily lines the lake shore. Many of these plants, both native and exotic, were planted and nurtured by area garden clubs.

A stroll around the lake and along the boardwalk at the Nature Center can reveal birds as well as wildflowers, particularly during migration season. Most casual visitors see only a small fraction of what is there to be seen, so you may want to take binoculars and allow time to look more closely. Muskrat swim in the brook and lake, and white-tailed deer frequent the Nature Center area, particularly in the spring, when you may see a fawn or two. Red-winged blackbirds dominate the marsh by the Nature Center, but keep your eyes open for song sparrow, red-tailed hawk, and others. The area along the south fork of the brook between the Nature Center and Shaker Boulevard provides a glimpse of the forest that was once typical of wet lowlands in the upper watershed (see Chapter 4). Visit the Nature Center itself to find out more about the area and about activities centered around the parks.

A.7
South Park Boulevard to Horseshoe Lake

Upstream from the Nature Center, the brook crosses South Park Boulevard. Between South Park and Horseshoe Lake, the stream runs through a protected wildlife area where use of trails along the stream is prohibited. You can still walk or bike on the path along North Park Boulevard and enjoy the shade of the woodlands along the stream. The trees here are some of the largest and oldest in the watershed, dating from the latter part of the 19th century. The deer that can sometimes be seen at the Nature Center spend much of their time in this area, as does other wildlife. The brook meanders through the trees in a relatively undisturbed state.

On the south side of the brook, upstream (east) from Lee Road, you will find the grave of Jacob Russell, Revolutionary War Veteran. Russell was the patriarch of the Russell family that settled in the upper watershed in 1812, just after the Warren family. His son, Ralph, founded the North Union Shaker community in 1822. The intersection of Lee and South Park was the center of the first Shaker community and later of the North Union Center family. You can find a memorial to the Shakers a bit to the south, at the northeast corner of Lee and Shaker Boulevard. More information about visible remains of the Shaker community is given in Appendix C.

Continuing around Horseshoe Lake, you can enjoy the flowering trees and other plantings that the garden clubs have maintained over the years. The marshes in the upstream arms of the lake provide good habitat for waterfowl, and red-headed woodpeckers sometime nest in the standing dead trees. With luck and persistence, you might even see a pileated woodpecker here.

Upstream from Horseshoe Lake, you can catch glimpses of the north and middle forks of the brook along Shelburne and South Park respectively. The above-ground portions of both forks now end in culverts at Warrensville Center Road. See Chapter 5 for maps showing where the brook ran before it was buried in the storm sewers.

A.8
The South Fork: The Nature Center to Green and Marshall Lakes

South of the Nature Center at Shaker Lakes, the south fork of Doan Brook flows through an area that has a relatively undisturbed channel and intact natural environment. There are fewer trees here than along the north fork above the Lower Shaker Lake, but the aquatic habitat is still relatively healthy, and the park land along the stream is a good place to wander. There is a good path and a fitness trail.

Much of the land around Green and Marshall Lakes is private property, where there are some beautiful mansions. The lakes themselves are, unfortunately, heavily impacted by poor water quality and sedimentation. There is extremely heavy algae and plant growth on the lakes during the summer (quite possibly because of unusually heavy fertilizer runoff from the surrounding houses and the upstream Shaker and Canterbury golf courses). The lakes are too shallow to allow a healthy lake environment. Mowed grass reaches to the water's edge, encouraging Canada geese and increasing water quality problems.

Upstream from Green Lake, the brook runs entirely through the Canterbury and Shaker golf courses. It is carried between the two courses in a culvert that actually passes under the Van Aken shopping center. The banks are eroded in some places on the Shaker Country Club course, and the grass is mowed all the way to the stream. The brook runs along one edge of the Canterbury course, and is generally buffered from the course by some un-manicured land. However, lawns from the adjacent houses immediately abut the brook in some places.

Appendix B

An Outline of Doan Brook History

Before 1640:	Native Americans of unknown origin occupy the Lake Erie shore in the vicinity of Doan Brook. In about 1640, their established settlements are deserted for unknown reasons.
1662:	King Charles II of England grants the Connecticut Colony the right of self government and a strip of land extending from the Colony's western border to the Pacific Ocean. This grant includes what was later to become the Connecticut Western Reserve.
Before 1796:	Native Americans traveling along Lake Erie cross Doan Brook at a ford near present-day Euclid Avenue and East 105th Street.
1786:	Connecticut reserves an area of northeast Ohio for her citizens in exchange for other western land that was included in King Charles' original grant. The Connecticut Western Reserve includes the Cleveland area and extends 120 miles west from the Pennsylvania border between Lake Erie and 41° north latitude (just south of Akron).
1795:	The Connecticut Land Company purchases title to most of the Connecticut Western Reserve, including the land in the Cleveland area.
1796:	Moses Cleaveland's surveying party comes to explore and map the area for the Connecticut Land Company. Cleaveland identifies the mouth of the Cuyahoga River as an ideal spot for the capital city of the Western Reserve. The surveyors in his party later name the spot Cleaveland. He negotiates a treaty with the Iroquois in which the Native Americans give up claim to all land east of the Cuyahoga River.
1797:	Nathaniel Doan (or Doane) comes to Cleaveland as the blacksmith for the second surveying party sent to the area by the Connecticut Land Company.
1798:	Nathaniel Doan returns to northeast Ohio with his wife, six children, and nephew. They initially settle near the Cuyahoga River on Superior Street.
1799:	The Doan family is forced from the area near the Cuyahoga River by fever, ague (malaria), and mosquitoes. They resettle at what is now Euclid Avenue between East 105th and 107th Streets. The nearest neighbors are Nathan Chapman at what is now Euclid and East 55th and a small group of settlers on the ridge to the south along what is now Woodhill Avenue.
Beginning in 1799:	The area around Nathaniel Doan's cabin, which comes to be known as "Doan's Corners," is the ford where travelers along the main east-west artery between Buffalo and Cleveland cross Doan Brook. Doan and other settlers eventually build a tavern, a store, a blacksmith shop, a church, a school, and a saleratus (baking soda) factory near the ford. Pioneers making their way west in wagons camp on the level ground east of Doan Brook (where Case Western Reserve University is later built) and frequent the tavern.
1808:	Daniel and Margaret Warren and their infant son come to Ohio. They eventually settle in Lot 42, Township 7, Range 11, which later becomes Warrensville Township.

1810:	In January, Daniel and Margaret Warren move into their newly completed log cabin near what is now the intersection of Lee and Kinsman Roads with their 2-year-old son and three-week-old baby. They are the first settlers in the upper Doan Brook watershed.
1811:	Revolutionary war veteran Jacob Russell purchases 475 acres of land in the upper Doan Brook watershed. Jacob's sons, Elijah and Ralph, travel from Connecticut to inspect the property and begin to clear land for a house and the beginning of a farm. They return the following year to build a cabin and plant the first crops.
1812:	Jacob Russell moves his family of 20 from Connecticut during the summer.
1816:	November 7 – The first election is held in Warrensville Township. Daniel Warren is elected Justice of the Peace. Jacob Russell, Elijah Russell, and Chester Risley are elected township trustees. Some references give this date as 1817.
1821:	Jacob Russell dies. His sons bury him near the present-day intersection of South Park and Lee Roads (north of South Park, east of Lee).
1822:	The North Union Shaker community is started by Ralph Russell, Jacob Russell's son, who had become a Shaker. The colony is established on the Russell property in the upper Doan Brook watershed, where it eventually acquires as many as 300 members (in 1850), land holdings of 1,366 acres, and 60 buildings. The Shaker community originally occupies the area along Lee Road between Shaker and South Park. Additional villages are built on Fontenay Road (south of Shaker and west of Eaton) and at Coventry and North Park.
1824:	By this date, the North Union Shakers are operating a sawmill near the current location of the Lower Shaker Lake dam. The first Shakers move to the Mill Family village site. It is not clear whether or not the brook is dammed to provide power for the first sawmill.
1829:	The Shakers build a wood frame grist mill a short distance downstream from the Lower Shaker Lake. A small dam is built of earth and timber near the location of the current Lower Shaker Lake dam to provide power for the mill.
1831:	The Shakers rebuild the dam for the Lower Shaker Lake.
1834 (or 1835):	The first railroad in Cleveland is built to carry stone from quarries in the Doan Brook gorge to downtown Cleveland.
1837:	The Shakers again rebuild the Lower Shaker Lake dam. They also rebuild the grist mill. The rebuilt lake reportedly covers about 20 acres, approximately the area of today's lake and the adjoining marsh.
1843:	The Shakers build a five-story stone grist mill in the Doan Brook gorge downstream from the previous grist mill location. The new mill lies on the north side of the brook just upstream from the current intersection of North Park and Roxboro.

1852: The North Union Shakers dam Doan Brook at Horseshoe Lake to provide power for their woolen mill.

1854: The North Union Shakers complete their woolen mill located at what is now the northeast quadrant of the intersection of Lee Road and South Park Boulevard. They raise Horseshoe Lake dam a few feet to better power the mill.

1870: Glenville is incorporated as a village on October 4.

1870: The Glenville Racetrack is built.

1872: Jeptha H. Wade begins to develop 63.5 acres of natural woodland in the Doan Brook valley north of Euclid Avenue as a public park (Wade Park).

1880s: John Lowe begins development of the upper watershed on 20 acres near the intersection of Cedar and Overlook. Most of the houses on this allotment are sold to Czech farm workers.

1880: Daniel Caswell opens the Blue Rock Spring House at the intersection of Cedar Road and Doan Brook (now the location of Emerson Gym on the CWRU campus), including a resort devoted to a water cure based on the sulfur-rich, blue-green spring water available at that location. The facility closes in 1908.

1880 (approximate)**:** William J. Gordon begins to develop a public park on his 122-acre lake-front estate at the mouth of Doan Brook (Gordon Park).

1882: Jeptha H. Wade presents Wade Park to the City of Cleveland.

1883: Western Reserve University moves its campus to University Circle.

1885: Case School of Applied Science moves from downtown Cleveland to University Circle.

1886: The Shakers lease the sandstone quarry on the north side of Doan Brook opposite the intersection of North Park and Roxboro to Charles Reader, who is not a Shaker. The stone grist mill, which stands on part of the quarry, is imploded with great fanfare on July 5.

1889: North Union Shakers, having declined to 27 members, dissolve their community. The remaining family members disperse to other Shaker communities.

1889: A zoological collection makes its home in Wade Park.

1892: North Union Shaker land is sold to a land development syndicate.

1893: The City of Cleveland receives the deed to Gordon Park as a gift from William J. Gordon.

1894:	The Ambler family donates 33 acres of land along Doan Brook between Cedar Avenue and Fairhill for use as park land. The new park is described as a wild area with white water, towering trees, thick underbrush, ferns, mosses, and wildflowers.
1894 – 95:	The City of Cleveland Park Commissioners acquire approximately 208 acres of land along Doan Brook, connecting Gordon Park and Wade Park. This area of virgin forest and rolling meadows was first referred to as "Doan Brook Parkway" and later as Rockefeller Park.
1895:	The City of Cleveland purchases 10.4 acres as an addition to Wade Park. Maintenance of the park system is financed by an annual half-mill tax levy.
1895 (approximate)**:**	Shaker Lake dams are rebuilt.
1896:	The City of Cleveland receives the deed to Shaker Heights Park from the Shaker Heights Land Company (headed by H.W. Gratwick). The park area covers almost 279 acres, and includes the Lower Shaker Lake and Horseshoe Lake, some mill runs, and natural woodlands. John D. Rockefeller donates an additional 22 acres for Ambler Park and 254 acres designated as Rockefeller Park. The 254 acre donation includes land along Doan Brook Parkway which has already been acquired by the City (for which Rockefeller now reimburses the City), and areas connecting Wade Park with Ambler Park and Ambler Park with Shaker Heights Park. On one Sunday in May, 43,715 people use East Boulevard (the High Level Drive) in carriages, on bicycles, and on foot.
1897:	Patrick Calhoun donates land along Cedar Glen to the City of Cleveland.
1898:	The Western Reserve Historical Society moves to University Circle. The society relocates to its current building in 1938–41.
1900 (or before)**:**	A street network is built to connect the continuous park area along Doan Brook between Lake Erie and Horseshoe Lake. Notable streets are MLK (originally Low Level Drive, then Liberty Boulevard), East Boulevard, North Park Drive, and Lakeshore Drive. Many of the bridges crossing the stream have been built. Shore protection, including three jetties and two piers, are installed at Gordon Park. Stone arch bridges are built to carry streetcar lines at Wade, St. Clair, and Superior.
1900 (approximate)**:**	Daniel Caswell and William Eglin Ambler begin a housing development in Ambler Heights (the area between Cedar Road, South Overlook, MLK, and North Park now known as Chestnut Hills).
1900 – 1918:	Residential areas around University Circle are built.
1901:	A flash flood roars down Cedar Hill and inundates entire neighborhoods.
1902 – 26:	Stone walls are built to line much of the Doan Brook channel downstream from MLK, and many culverts and bridges are built in Rockefeller Park.

1903:	Cleveland Heights is incorporated as a village.
1905:	Glenville is formally annexed into the City of Cleveland on June 19.
1905:	The Van Sweringen brothers begin to buy the North Union Shaker land. They complete their purchase of the land in 1906.
1908:	The Glenville Racetrack is abandoned.
1908 – 1950:	The Doan Brook culvert under University Circle is constructed in segments. The lower part of Ambler Park is filled with material excavated during the construction of the Baldwin fresh water reservoir. Doan Brook is diverted to a culvert beneath the fill, and the overlying area is made into a playground.
1911:	Shaker Heights is incorporated as a village.
1914:	The last of the Wade Park zoological garden animals is moved from Wade Park to Brookside Park on the west side of Cleveland.
1915:	Mrs. J.H. Rogers, Mrs. J. Ranney, Mrs. G.H. Gardner, and Mrs. H.J. Crawford organize the Shaker Lakes Garden Club to improve maintenance and preservation of the Shaker Lakes park land.
1916 – 39:	Areas along the brook between Lake Erie and Wade Park are set aside as cultural gardens and developed by various ethnic groups. The Shakespeare Garden is dedicated in 1916. After a second garden, the Hebrew Garden, is built in 1926, the idea for a series of cultural gardens is conceived. Then-existing gardens are dedicated as a group in 1939. WPA and City of Cleveland funding and labor do further work on the gardens during the depression. Work on existing gardens and occasional dedications of additions or new garden areas continue.
1916:	The Cleveland Museum of Art is built adjacent to Wade Park Lagoon.
1920:	The Van Sweringen brothers open the Shaker Rapid, providing transit service from two eastern termini (Van Aken at Lynnfield and Shaker at Warrensville Center) to Public Square. The two lines are later extended eastward to Van Aken at Warrensville Center (1929) and Shaker at Green (1937).
1921:	Cleveland Heights is incorporated as a city.
1922:	The Shaker Lakes Garden Club initiates development of the old Shaker sawmill site at the west end of the Lower Shaker Lake as a wildflower garden.
1925 – 50:	Green and Marshall Lakes are built on the south fork of Doan Brook.
1928:	The Epworth-Euclid United Methodist Church is constructed at East 107th and Chester.
1929:	In June, Doan Brook floods, overflowing its banks and washing out some sections of its retaining wall.

1930: The Garden Center of Greater Cleveland (now the Cleveland Botanical Garden) is located at the edge of the Wade Park Lagoon. The center moves to its current location during the 1960s.

1931: Shaker Heights is incorporated as a city.

1931: University Hospitals (then Lakeside Hospital) is dedicated on Adelbert Road in University Circle. Severance Hall is built.

1932: Modifications are made to the Doan Brook channel in Rockefeller Park to improve the channel hydraulics.

1935: The Shaker Lakes Garden Club and a number of other area garden clubs landscape and develop gardens on the point between the arms of Horseshoe Lake. Hemlocks are donated anonymously by the Van Sweringen Company.

1940: The Doan Brook channel in Rockefeller Park begins to show signs of being inadequate to convey flood flows, which have been increased by urbanization.

1947: The Shaker Historical Society is founded to preserve the history of the North Union Shakers, Warrensville Township, and Shaker Heights.

1958: The first building for the Cleveland Museum of Natural History is constructed at 1 Wade Park Oval.

1959: On June 1, 3 inches of rain fall on the Doan Brook watershed in 1 hour, resulting in a flood depth of 10 feet in low areas of University Circle. It is estimated that a storm of this or greater magnitude will occur once every 50 years. Horseshoe Lake dam overtops and partially fails. The south bank of the Doan Brook gorge near Kemper and Fairhill is severely eroded.

1959: The City of Cleveland arranges to have 50,000 cubic yards of material dumped along the south side of the Doan Brook gorge opposite the intersection of Fairhill and Kemper. Topsoil is later added and the area is seeded and planted with trees. The dumped material is intended to repair the slope failure caused by the June 1 flood.

1962: A rainfall of 1.5 inches on the Doan Brook watershed results in a flood depth of 3 to 4 feet in low areas of University Circle. It is estimated that a storm of this or greater magnitude will occur once every 10 years.

1962 (approximate)**:** A trash rack is installed immediately upstream from the entrance to the culvert that carries Doan Brook under MLK.

1964: The Cleveland VA Medical Center opens at its current location on East Boulevard.

1966: The Shaker Lakes Regional Nature Center (now the Nature Center at Shaker Lakes) is founded, primarily as part of an effort to stop the construction of the proposed Clark and Lee Freeways. Plans call for the freeways to run directly over the east end of the Lower Shaker Lake and all of Horseshoe Lake.

1968:	The Shaker Lakes Regional Nature Center leases 5.5 acres near the intersections of South Park, North Park and North Woodland on which to build the Nature Center building and associated trails. The leased land lies at the proposed location of the Clark and Lee freeway interchange.
1968:	A July 17 flood damages the 1959 repairs to the south wall of Doan Brook gorge near Kemper and Fairhill. The bank is eroded to within six feet of Fairhill Road.
1968:	In Glenville, a shootout between a black militant group and Cleveland Police on July 23 triggers five days of social unrest that leave 63 businesses damaged, with a total estimated cost of $2.6 million.
1969:	Frank Myers donates the home of his father, Louis Myers, to the Shaker Historical Society. The house at 16740 South Park Boulevard, which is located on land used by the North Union Shakers for part of their apple orchard, becomes the permanent home and museum for the society.
1969:	The City of Cleveland allows contractors to dump material excavated from University Circle construction in the Doan Brook gorge opposite the intersection of Kemper and Fairhill. The dumped material is intended to repair the slope failure caused by the July 17, 1968, flood.
1971:	The U.S. National Park Service names the Nature Center at Shaker Lakes a National Environmental Education Landmark.
1972:	Approval for construction of the proposed Clark and Lee Freeways is withdrawn.
1975:	A rainfall of 6 inches results in a flood depth of 11 feet in low areas of University Circle. The storm causes severe flood damage, and is followed by a second storm and flood of nearly equal magnitude 4 days later. The storm also causes severe erosion to previous repairs to the south bank of the gorge near Kemper and Fairhill. It is estimated that a storm of this or greater magnitude will occur once every 50 years.
1975:	A velocity breaker and trash rack are built near the railroad bridge at MLK. The structure is intended to protect University Circle during floods which overflow the culvert. The University Circle culvert is cleaned, and between 3,000 and 5,000 tons of debris are removed.
1976:	A durable repair is made to erosion damage along the south side of the Doan Brook gorge near Kemper and Fairhill.
1977:	The Doan Brook culvert under MLK is reported to be eroding badly and in danger of at least partial collapse. The channel downstream from MLK is also reported to be eroding badly, particularly adjacent to Fairhill Road. Debris is reported to have accumulated in the culvert under University Circle, worsening flooding problems.

1977:	The Corps of Engineers begins filling in the Site 14 dredge spoil area at the mouth of Doan Brook. The culvert that already carries the brook under I-90 is extended under the dredge spoil area.
1985:	The Cleveland Botanical Garden relocates to its current location over Wade Park ravine.
1987:	In December, Baldwin Filtration Plant stops discharging filter backwash wastes to Doan Brook. NEORSD begins systematic monitoring of Doan Brook water quality.
1995:	Improvements are made to the Horseshoe Lake dam crest and downstream area to reduce the risk of dam failure during overtopping.
1996:	A blocked sanitary sewer regulator is repaired. Before repair, the blockage was resulting in the discharge of approximately 100,000 gallons per day of untreated sewage to Doan Brook in the University Circle culvert.
1997:	A new impoundment is built in the Doan Brook ravine downstream from MLK in an attempt to reduce flooding in University Circle.
1999:	The Lower Shaker Lake is drained and a low water outlet is installed. Work is done to strengthen the structure.
2001:	The NEORSD study of the Doan Brook watershed is complete.
2001:	The Doan Brook Watershed Partnership is formed.
2001:	On August 31, heavy rains flood Doan Brook. The Lower Shaker Lake Dam overtops, flooding North Park Boulevard.

Appendix B – An Outline of Doan Brook History

Appendix C

Doan Brook History: A Watershed History Tour

At a casual glance, the Doan Brook watershed seems a model of modern suburbia, filled with houses, streets, and shops. Some of the houses are "old" — built in the late 19th or early 20th century — but there seem to be few traces of life here before the city arrived. If you take a little time to look carefully, though, you can find signs of the early settlement of the watershed and of the parks that were built at the end of the 19th century. This appendix gives a tour of some of the signs of the past that you can find in the watershed.

C.1 The Lower Watershed

Early settlement in the lower watershed centered first around the village at Doan's Corners and the associated farms and later around the parks that were developed along the brook. There are only a few signs of the first settlement left, but much that was built in the late 19th and early 20th centuries is still part of the life of the lower watershed. This tour points out a few of the historic sites that are most closely tied to Doan Brook.

C.1.1 The Rockefeller Park Greenhouse and the Old Mill Stones

The City of Cleveland's Rockefeller Park Greenhouse, built in 1905, was made possible by a donation from John D. Rockefeller. The original brick buildings form the core of today's greenhouse. Two mill stones in the outdoor gardens (one in the Japanese Garden and one in the Betty Ott Talking Garden) suggest the previous life of the lower watershed. Although no one seems to know exactly where the mill stones came from, it is likely that they were once part of the Crawford sawmill that was located on Doan Brook near Superior Avenue in the mid-nineteenth century.

To reach the Rockefeller Park Greenhouse, take Martin Luther King, Jr., Boulevard (MLK) north almost to Lake Erie. Turn east (right) from MLK just before you get to the Conrail tracks (the last of the historic stone bridges over MLK). The greenhouse will be at the top of the hill directly in front of you. Follow the road around to the right. The parking lot is on your right past the main buildings.

C.1.2 Cultural Gardens

Cleveland's Cultural Gardens line the Doan Brook valley between Superior and St. Clair Avenues. The first garden, built in 1916, was the Shakespeare Garden. In 1926, Leo Weidenthal led the establishment of the Cultural Garden League, an organization founded with the purpose of establishing a series of gardens to honor each of the city's national communities. The Hebrew Garden, the first garden completed with this purpose in mind, was installed next to the Shakespeare (or British) Garden in 1926. The city set aside land for a series of gardens in 1927, and many more communities built gardens between 1927 and 1939, when the Cultural Gardens were formally dedicated. Additional gardens honoring newer Cleveland communities have been built since.

The gardens lie both on the Doan Brook flood plain and on the upper part of the east side of the brook valley between Superior and St. Clair. Some are most easily accessible from East

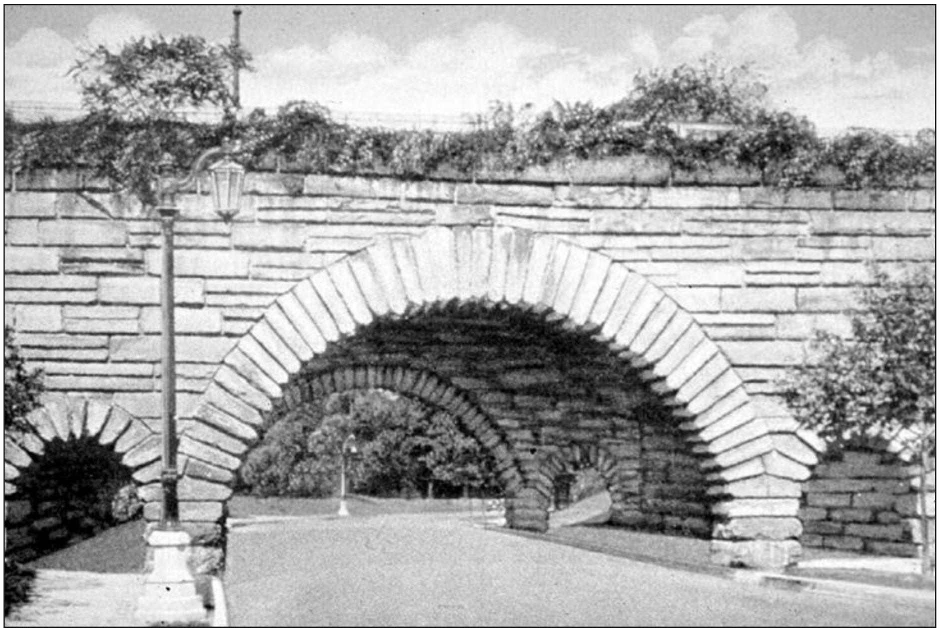


Figure C-1 Superior Road bridge over Martin Luther King, Jr., Boulevard. Designed by Charles Schweinfurth. From the Nature Center at Shaker Lakes collection.

Boulevard, others from the bike paths along MLK. The gardens fell into disrepair and suffered from vandalism in the 1960s and 1970s. Fountains were turned off and some statuary was removed for safety. However, an effort has been made to maintain and restore the area in recent years, and the community has taken more interest in the gardens again. Restoration and maintenance efforts are led by the Cultural Gardens Association, the Holden Parks Trust, and the City of Cleveland. Although they have not yet regained their past stature, the gardens are nonetheless a pleasant place to stroll and marvel at what area communities built to honor their diverse cultures in the heart of the Great Depression.

C.1.3
Schweinfurth Bridges

When the Doan Brook park lands were first set aside in the late 1800s, park planners designed a boulevard along the brook (now Martin Luther King, Jr., Boulevard) and one along the top of the valley on the east side (East Boulevard). Streetcar lines were extended so that city dwellers could get from downtown Cleveland to the new parks. To insure that the bridges that carried the streetcars across the Doan Brook valley would enhance the new park rather than detract from it, the park planners commissioned bridge designs from well-known Cleveland architect Charles Schweinfurth. Schweinfurth — designer of many houses on Euclid Avenue's "Millionaire's Row," Trinity Cathedral, the Union Club, and Harkness Chapel, among others — designed the stone bridges that carry the CSX railroad and Superior, St. Clair, and Wade Park Avenues across the brook valley. Note the ornamental stone and tile work, the brick arches overhead as you pass under the bridges, and the curving stairways that provide pedestrian access between the park and the roadways.

C.1.4
Wade Park: Mills, Springs, and Bear Dens

Wade Park has been the home of some of Cleveland's key cultural institutions since the Cleveland Museum of Art was established there in 1916. There is still a little bit of evidence of the uses of this land before the museum came.

The current location of the Wade Park Lagoon must have been a natural place for a reservoir, since Samuel Cozad built a dam and grist mill there in the early nineteenth century. The mill pond reverted to a marsh overrun by cattle after the mill was no longer in use, only to be later converted into a landscaped pond to provide a vista for the art museum.

Both Charles Asa Post and Earl Gurney Mead report that a spring in the ravine behind the Cleveland Botanical Garden was an important source of high quality drinking water for early settlers. This same ravine, now part of the Botanical Garden's Japanese Garden, was used as a bear den when the Cleveland Zoological Society housed its animal collection in Wade Park (from 1889 to 1914).

C.1.5
Western Reserve Historical Society

The Western Reserve Historical Society (at 10825 East Boulevard, adjacent to Wade Park) houses extensive collections about the history of the Cleveland area, an exceptional collection of cars and aircraft, and an outstanding research library. It is well worth a visit if you are curious about the history of any part of the Connecticut Western Reserve.

C.1.6
Doan's 100 Acres

Nathaniel Doan's original 100 acres extended from East 105th Street to Severance Hall and from Carnegie Avenue to the south side of the Cleveland Museum of Art (see Figure 2-1 in Chapter 2). None of the original buildings is left, but the Ronald McDonald House, which sits on the corner of East 105th and Euclid where Doan's tavern once stood, sometimes has exhibits about the history of Doan's Corners.

C.1.7
Ambler Park

Ambler Park, which lies on the edge of the Escarpment between MLK and Fairhill (between the point where MLK crosses the brook and the rapid transit and railroad tracks), was part of the original park system that extended along Doan Brook from Lake Erie to Horseshoe Lake. Although the park has fallen into disrepair, you can still see evidence of the paths and stairways that were built in the park as part of the depression era public works projects. Explore the area between the inlet to the University Circle culvert and the MLK detention basin.

C.2
The Upper Watershed

Most of the upper watershed is as developed as the lower watershed, and signs of its early history are few. However, much of the Shaker settlement of the area was inside the band of parks along the brook. Although the Shaker buildings were demolished by the Van Sweringens, their remains have been somewhat protected because they are inside the parks, and careful exploration can reveal a number of remnants of the Shaker communities.

C.2.1
The Shaker Stone Grist Mill and Dam

The Shakers' five-story stone grist mill, built in 1843, was surely one of the most spectacular structures in the early upper watershed (see Figure 2-7), and the colorful story of its destruction (see Chapter 2) adds to curiosity about what may remain. As you walk along the north edge of the Doan Brook gorge today, it is surprising to see how few traces of the once-impressive mill and dam can be found.

About 0.44 mile downstream from the Lower Shaker Lake dam, between the point where the bridge piers for the former Kemper Road bridge cross the brook and the intersection of Roxboro Road and North Park Boulevard, there is a notch in the top of the cliff on the north side that allows you to step down a few feet below the lip of the gorge. This is the narrowest spot in the gorge. Just downstream, the brook begins to descend rapidly over a series of sandstone ledges. Peering across the gorge from the notch, you can see signs of workmanship in the rock on the far side. Similar traces are faintly visible in the bank where you are standing.

Turning back to face North Park, you will notice that you crossed over a stone slab with a hollow under it as you stepped down into the notch. This was once the inlet to the stone flume that carried water from the dam to the grist mill. The flume was a rectangular channel, deeper than it was wide, that was carved into the rock along the edge of the gorge and then covered with flat stone slabs like the one in front of you. The flume took water from the top of the reservoir behind the dam and carried it to the grist mill, where it was dropped down a penstock to power the mill.

When you climb back out of the notch to the top of the cliff, you can follow the line suggested by the stone slab through the underbrush, and see the partially buried remains of the stone flume running west along the edge of the gorge. Surprisingly, the flume ends abruptly at the cliff edge about thirty feet west (downstream) from the notch. You can see the end of the flume by walking about fifty feet downstream and looking back to where the cliff curves toward the brook. Descriptions of the grist mill say that it was located one-twelfth of a mile downstream from the dam, much farther than the current end of the flume. If you continue downstream along the edge of the gorge to a point about one-twelfth of a mile (about 440 feet) from the dam, you will note a semicircular notch in the lip of the gorge with definite signs of workmanship. This is the point where the grist mill is reported to have been, although exploration of the top of the gorge at this point reveals few, if any, signs of the building that once stood here. The stone that held the rest of the flume, between the current flume end and the grist mill site, was removed by the quarry that replaced the grist mill in 1886.

If you continue downstream for a short distance, you can descend to the stream and make your way back up toward the grist mill site. Great caution and some scrambling are required to reach the site. Be careful of the overhanging cliff and the slick rocks under foot. At the base of the cliff below the semicircular notch where the grist mill stood, you can see numerous chisel marks in the stone. These continue up the cliff below the notch. Some distance away from the base of the cliff, there is a straight row of large stones that looks as if it may have been laid as part of the foundation for the grist mill. A considerable distance upstream, the rectangular cut of the flume sits mysteriously near the top of the cliff.

Aside from some puzzling triangular notches in the stone of the stream bed opposite the end of the flume, and some stones and threaded metal rods downstream from the mill site on the lip of the gorge, few other traces of the mill remain.

C.2.2
The Lower Shaker Lake and the Sawmill

The Shakers' original sawmill lay just downstream from the Lower Shaker Lake near the north end of the current dam. The sawmill sat in what is now a depression between the road along the dam and Coventry Road. Water that flowed across the mill wheel continued downstream from the mill in a channel (the mill race) that is now blocked by Coventry Road. You can find the remnant of the channel (almost dry now that it is cut off from the lake) by crossing Coventry and exploring the area between Fairmount and North Park. The abandoned mill race channel rejoins the channel

Figure C-2 Shaker sawmill ruin and site of later wildflower garden. Just downstream from the Lower Shaker Lake dam – May 1966. Photograph by M. E. Croxton? From the Nature Center at Shaker Lakes collection.

from the Lower Shaker Lake spillway a bit downstream (between the intersections of Demington and Woodmere with North Park).

There is still considerable stone work amongst the brush in the depression where the sawmill stood, but it is difficult to separate what may have been part of the Shaker mill from what was built as part of a wildflower garden established there by the Garden Club of Cleveland and the Shaker Lakes Garden Club in April 1923. The foundations of the Shaker mill reportedly remain. The foundation of an ice house that once lay south of the mill was buried when fill was placed to strengthen the dam.

The Shaker sawmill site is the focus of much interest from local historians, from those who would like to restore the former wildflower gardens, from area archeologists who would like to explore what remains in more detail, and from the Ohio Department of Natural Resources, which is concerned with the safety of the Lower Shaker Lake dam and sees the depression behind the dam as a threat to the integrity of the dam embankment.

C.2.3
Jacob Russell's Grave

When Revolutionary War veteran Jacob Russell died in 1821, his family buried him on the Ohio land he had purchased for them. Russell bought the land ten years before and brought his family there the following year to become the second group of settlers in the upper watershed. His son, Ralph, established the North Union Shakers' Center Family on that land a year after Jacob's death, and the Shakers' Center Family Village grew up near the grave. Because it was protected by the establishment of the Doan Brook parks, Jacob Russell's grave has never been moved. The fenced grave and large stone marker lie just northeast of the intersection of Lee Road and South Park Boulevard.

C.2.4
The Woolen Mill and Its Flume

The corner of the Shakers' 1852 woolen mill lay at the edge of the Center Family Village, a few feet north of Jacob Russell's grave. The mill was built to facilitate the production of wool, brooms, and iron goods, all of which were important parts of Shaker industry in the early 1850s. James Prescott (1880) described the woolen mill this way:

> *In 1852 a building was erected for a woolen factory, twenty four, by fifty feet, three stories high, on the south side, and on the north, four stories, including the basement. The upper story is occupied by a spinning jack of one hundred and sixty spindles, two power looms, for weaving cloth, a twister — the next story below is occupied with the carding machines, etc. they manufacture the most of their wool into stocking yarn, as there is a great demand for it just now, 1870.*

Figure C-3 Remains of the earth channel that once carried a wooden flume along the south side of Doan Brook between Horseshoe Lake and the Shaker woolen mill near South Park Boulevard and Lee Road. Photograph by L. C. Gooch.

> *The next story below is an iron lathe for turning iron, and another lathe for turning broom handles, etc. And in the basement story is hung a large grind-stone, and a buz-saw [sic], for sawing stove wood, for fuel, to keep forty or fifty fires going through the winter. The whole machinery is carried by water power by an Overshot wheel — with water drawn from the upper pond.*

Few if any remains of the mill are visible, but the flume that carried water along the south side of the Doan Brook valley between Horseshoe Lake (called the "upper pond" by Prescott) and the woolen mill is still clearly visible. You can reach it by scrambling through the bushes directly north of Russell's grave, but it is easier to find and get to if you walk back upstream, following the edge of the grass lawn. As you go upstream, you will come to a point where you can see an open, dry ditch on the side of the hill that leads toward the brook, just inside of the trees and bushes that fringe the mowed grass. The ditch, five or six feet deep and perhaps ten or fifteen feet wide, is separated from the brook valley proper by another embankment. If you scramble down into the ditch, you will find a trail that follows the line of the ditch in some places and runs along the top of the north embankment in others. This ditch held the wooden flume that conveyed water from Horseshoe Lake to the woolen mill. You can follow the ditch upstream almost to the Horseshoe Lake dam, but the brook has eroded away a section about 100 yards downstream from the dam, and changes to the dam itself have obscured the outlet that originally fed water to the flume.

C.2.5
Horseshoe Lake Dam

The Horseshoe Lake dam that was built to power the woolen mill was an impressive structure in its day. A visitor who viewed the dam under construction in 1852 wrote the following:

> *The dam is built of dirt. It is twenty rods [330 feet] or more in length and upwards of twenty feet high, a stone drain at the bottom to carry off the waste water, a stone penstock which connects at the upper end of the drain. This penstock is built around about ten feet in diameter of black stone. The water pours over the top all around, the bottom is flat stone laid in water cement. This is the best and most durable floor I ever saw of the kind. It is not finished for they calculate to raise the dam four feet higher and have a cast iron curb around the top of the floom [sic] to prevent the frost getting hold of the top stone* (quoted from Klyver, 1992).

The design and core of the Shakers' original dam are still in place, although the dam has been strengthened and modified a number of times. The spillway (referred to as a penstock in the quote above) retains its original shape, and there is still reportedly a Shaker-built stone face on the upstream side of the dam, although it is normally below the water level and therefore not visible. Some of the original stonework can be seen immediately around the downstream end of the outlet, though. You can see the original stonework by walking down the grass "peninsula" on the south side of the brook downstream from the dam. Looking back at the outlet, you see a rectangular opening beneath the dam. The stonework immediately around the opening does not match the rest of the stone, and appears to be original Shaker work — precisely cut stone with very tight joins between the individual blocks. The surrounding work and much of the other stone work now visible on the dam was done as part of Depression-era works projects in the 1940s. The large stone riprap that sits on the downstream face of the dam was placed in 1995 to prevent the dam from failing in the event that water flows over the crest.

C.2.6
The Shaker Historical Society and Museum

The Shaker Historical Society and Museum, located adjacent to the south side of Horseshoe Lake at 16740 South Park Boulevard, houses a permanent collection of items relating to the North Union Shakers and to Shaker life in general and hosts changing exhibits about both Shaker history and other local history. The Society's Elizabeth B. Nord Library houses a good collection of books and archival materials about the Shakers, early Warrensville history, and the development of Shaker Heights.

Appendix D

Doan Brook Watershed Cultural Institutions

Over the years, the ribbon of parks along Doan Brook has attracted a number of cultural institutions in search of appealing locations. Some, such as the Nature Center at Shaker Lakes and the Shaker Historical Society, have a purpose that ties them directly to the brook. Others, such as the Cleveland Museum of Art, simply chose the banks of the brook as an attractive place to make their home. Still others were brought to the brook or the watershed by the proximity of other cultural institutions. Some of the many cultural resources to be found along the Doan Brook are listed below.

Ambler Park
Between Fairhill and Martin Luther King, Jr., Boulevards west of Martin Luther King, Jr., Blvd.

Case Western Reserve University
10900 Euclid Avenue
216-368-2000

Children's Museum of Cleveland
10730 Euclid Avenue
216-791-7114

Cleveland Botanical Garden
11030 East Boulevard

Cleveland Cultural Gardens
Rockefeller Park (see below)

Cleveland Institute of Art
11141 East Boulevard
216-421-7000

Cleveland Institute of Music
11021 East Boulevard
216-791-5000

Cleveland Museum of Art
11150 East Boulevard
216-421-7340

Cleveland Museum of Natural History
1 Wade Oval Drive
216-231-4600

Cleveland Music School Settlement
11125 Magnolia Drive
216-421-5806

Dittrick Museum of Historical Medicine
11000 Euclid Avenue
216-368-2000

Fine Arts Garden and Lagoon
Between Euclid Avenue and the Cleveland Museum of Art

Gordon Park
Martin Luther King, Jr., Boulevard at Lake Erie

Horseshoe Lake Park
On the upstream side of Horseshoe Lake, between South Park and North Park Boulevards and Lee Road

Nature Center at Shaker Lakes
2600 South Park Boulevard
216-321-5935

Rockefeller Park
Along Martin Luther King, Jr., Boulevard between I-90 and East 105th

Rockefeller Park Greenhouse
750 East 88th Street
216-664-3103

Sculpture Center
12206 Euclid Avenue
216-229-6527

Severance Hall
11001 Euclid Avenue
216-231-1111

Shaker Historical Society and Museum
16740 South Park Boulevard
216-921-1201

Wade Park
University Circle

Western Reserve Historical Society and Crawford Auto-Aviation Museum
10825 East Boulevard
216-721-5722

Appendix E

Doan Brook Geology and Soils

E.1 Geologic History of the Doan Brook Watershed

The Doan Brook watershed is a small part of a much larger area that was shaped by a series of geologic events that began in Precambrian times, over a billion years ago. This appendix describes the processes that shaped the larger area and the place of Doan Brook in the overall geologic picture.

E.1.1 The Shaping of Northeast Ohio

A billion years ago, a great mountain chain — the Grenville orogenic belt — stood over much of North America, including the area that became northeast Ohio. Over time, the geologic activity that built these mountains ceased, and wind and rain began to wear them down. By about 600 million years ago (the beginning of the Paleozoic Era), the once-enormous mountains had been reduced to a flat plain made up of the granite and gneiss that had originally been the mountains' roots. This plain became warped, and in Ohio it was pushed far below sea level. This granite "basement," on which subsequent rock layers were built, now lies approximately 5,000 feet below sea level in the Cleveland area.

As the granite plain warped downward, the sea advanced, covering northeast Ohio and much of the North American continent. The sea that first flooded the area as much as 600 million years ago persisted for millions of years, sometimes advancing, sometimes retreating. To the east, the ancestors of the Appalachian Mountains rose and eroded, and the sea floor was covered with many hundreds of feet of mud and sand carried down from the mountains. Buried mud and sand deposits compressed into rock — shale and sandstone, respectively — beneath the weight of the overlying material. Each time the sea retreated, some of the rock that was exposed eroded away; each time the waters advanced once again, new layers of sand and mud came to rest on the eroded rock surface.

The sea withdrew from Ohio for the final time about 300 million years ago. As the land rose above the sea, the surface of the rock was again eroded by wind and rain. Erosion continued until about 2 million years ago. Then, the ice ages began and glaciers scraped over the ground, carving out the basins of the Great Lakes. East of the lake basins, the ice encountered the edge of the Appalachian Mountains (the Appalachian Plateau). The glaciers advanced across northeast Ohio four times over a period of almost 2 million years, retreating for the last time about 15,000 years ago.

When the ice finally left northeast Ohio, it left a thin layer of jumbled clay, silt, sand, and gravel soil called glacial till on the surface of the bedrock. The ancestors of the current Great Lakes were trapped between the edge of receding glaciers to the north and the land surface along the edge of the scraped out lake basins to the south. The lakes, filled with water from the melting glaciers, had considerably higher water levels than the current lakes, and their shores were typically the edge of the Appalachian Plateau. The cliffs they carved in the edge of the Plateau can now be seen many feet above Lake Erie, and the silts, sands, and clays that were deposited in their waters form the soil that lies along the current lake shore.

Doan Brook and other streams flowing north toward the lakes from the Plateau carved narrow valleys through the lifted layers of bedrock to meet the falling lake levels. Over time, lake levels declined to their current elevations, leaving a series of carved shorelines and beaches in their wake. Forests advanced from the south to blanket the newly exposed land, and northeast Ohio began to resemble the land that Moses Cleaveland found when he arrived here in 1796.

E.1.2
The Geology of the Doan Brook Watershed

The forces that shaped all of northeast Ohio left us the Doan Brook of today. The upper reaches of the watershed lie in the glacial tills that thinly coat the sedimentary bedrock of the western margin of the Appalachian Plateau. Here, the soil is a thin layer of the glacial till that was left behind when the glaciers retreated to the north. A few feet beneath the surface lie the sedimentary Meadville Shale, Sharpsville Sandstone, and Orangeville Shale that were laid down beneath the ancient sea about 330 million years ago. These bedrock units underlie much of the upper watershed. The brook flows gently across the gradually sloped surface of the bedrock, meandering and bending across a shallow valley.

Toward the western part of the upper watershed (downstream from the Lower Shaker Lake), the land becomes steeper as it approaches the Escarpment that forms the edge of the Appalachian Plateau. Here, the flow of the water quickens, and the course of the brook straightens. The slope of the land gives the water enough strength to cut a deep channel into the underlying rock, and the brook has created a narrow gorge that is as much as 50 feet deep in some places. In the gorge, the older rock units that lie beneath the shales and conglomerate of the upper watershed are exposed.

Following the brook down the gorge between the Lower Shaker Lake and the intersection of Martin Luther King, Jr., Boulevard (MLK) and Ambleside, one can see layer beneath layer of the sedimentary bedrock that formed beneath the ancient seas. Orangeville Shale, Berea Sandstone, Bedford Shale (including the well-known Euclid Bluestone sandstone), Cleveland Shale, and Chagrin Shale are all exposed as Doan Brook rushes down toward Lake Erie. Bedrock outcrops along the brook are described in detail in the tour of brook geology in Appendix F.

The steep hill traversed by MLK, Fairhill, Cedar Glen, and Edgehill Roads is the main slope of the western edge of the Appalachian Plateau. The waves of one of Lake Erie's ancestral lakes once lapped at this cliff, and Doan Brook's waters flowed directly into the lake here. The soil below the Escarpment changes from the glacial silty clay till to layered silts, clays, sands, and gravels that were deposited at the bottom of the ancient lakes. The total thickness of these deposits in the lower watershed varies from a few feet to possibly as much as 600 feet near the mouth of the brook, where it crosses the buried valley of the ancient Cuyahoga River. In the buried river valley, the lake-deposited soils are layered with the jumbled till left behind by glaciers, demonstrating that glacial advances were interspersed with warmer periods during which the lower watershed was inundated by the ancient lakes. The level of Lake Erie decreased over the centuries, leaving ridges to mark the locations of a series of lake shores.

The bottom of the ancient lake became flat as soil was deposited, and the slope between the edge of the Escarpment and the current Lake Erie shore became very gradual. As the brook flows across this flat plain, it begins to meander once more, as long as it is not confined within retaining walls. Over many years, the stream's meanderings across this broad plain created the relatively wide valley that now accommodates both the confined brook and MLK.

E.2
Doan Brook Watershed Soils

Soils found in the upper Doan Brook watershed consist almost entirely of glacial tills. In the lower watershed, soils are primarily made up of intermixed layers of lacustrine[1] silts, clays, and fine sands deposited by the ancient glacial lakes. Some layers of till are intermingled with the lacustrine materials in the lower watershed, indicating that the lakes periodically retreated and were replaced by glaciers. Table E-1 describes the watershed soils in some detail. More information about the watershed's soils, including maps that show the locations of different soil units and tables that give technical data about the soil, can be found in the U.S. Soil Conservations Service's *Soil Survey of Cuyahoga County.*

1 Lacustrine is used to indicate soil materials that are deposited by lake waters.

Table E-1	Significant Soils in the Doan Brook Watershed[2]	
Location	**Soil Type**	**Description**
Lower Watershed: General	UeA – Urban land-Elnora complex	Mixture of urban land and a deep, moderately well-drained Elnora loamy fine sand with slopes ranging from 0-3%. Soil is typically very dark grayish brown, very friable loamy fine sand. Soil has moderate permeability and slow runoff (Hydrologic Soil Group B[3]). Area is about 70% urban land, 30% Elnora soil.
Lower Watershed: Brook Valley Sides	OsF – Oshtemo sandy loam	Deep, very friable sandy loam on steep or very steep Doan Brook valley sides. Permeability is moderately rapid and runoff is rapid (Hydrologic Soil Group B, with 25–55% slopes).
Lower Watershed: Brook Valley Bottom	Tg – Tioga loam, frequently flooded	Deep, nearly level, well drained soil with slope 0–2%. Dark brown, very friable loam with surface soil about 8 inches thick. Permeability is moderate to moderately rapid, and runoff is slow (Hydrologic Soil Group B).
Escarpment: Lower Area	Ub – Urban land	More than 80% of the area (University Circle) is covered by buildings and pavement.
Escarpment: South of Norfolk and Western/RTA Tracks	LuC – Loudonville-Urban land complex	Mixed urban land (50%), Loudonville silt loam (35%) and Ellsworth soils (15%). Loudonville surface soil is dark grayish brown, friable silt loam about 6 inches thick. Deeper strata are friable silt loam, silty clay loam and friable channery silt loam. Bedrock lies at a depth of about 25 inches (Hydrologic Soil Group C).
Upper Watershed: General	LuC – Loudonville-Urban land complex	See above. There is a moderately large area of this soil in the western part of the upper watershed.
Upper Watershed: General	UnB – Urban land-Mitiwanga complex	Mixture of urban land (70%) and moderately deep, somewhat poorly drained, undulating Mitiwanga silt loam (20%) (other soils 10%). Mitiwanga surface soil is dark grayish brown, friable silt loam about 11 inches thick. Deeper strata are friable flaggy loam, with sandstone bedrock at a depth of about 30 inches. Permeability is moderate and soil may be strongly acid (Hydrologic Soil Group C). Large areas of this soil are mixed with smaller areas of LuC in the western part of the upper watershed.
Upper Watershed: General	UmB – Urban land-Mahoning complex	Mixture of urban land (70%) and deep, somewhat poorly drained Mahoning silt loam (20%) (other soils 10%). Mahoning surface soil is dark grayish brown, friable soil loam about 7 inches thick. Deeper strata are silty clay loam and clay loam. Permeability is slow to very slow, and soil may be strongly acid. Runoff is slow or medium (Hydrologic Soil Group D). This soil forms most of the general watershed soil in the eastern part of the upper watershed.
Upper Watershed: Brook	Tg – Tioga Loam, frequently flooded LuC – Loudonville-Urban land complex EsC – Ellsworth-Urban land complex ElB, C, D– Ellsworth silt loam	See above for descriptions of Tg and LuC. Ellsworth-Urban land complex consists of a mixture of urban land (30%) and Ellsworth silt loam (55%) (other soils 15%). Ellsworth soil has a dark brown, friable silt loam surface layer about 7 inches thick. Permeability is slow or very slow, and runoff is rapid or very rapid (Hydrologic Soil Group C). Near the headwaters of Doan Brook, some land becomes exclusively Ellsworth silt loam with slow or very slow permeability and moderate to rapid runoff.

2 Data on soils are from United States Department of Agriculture Soil Conservation Service. Undated. *Soil Survey of Cuyahoga County*.

3 Hydrologic Soil Groups are designations used by hydrologists to indicate the tendency of rainfall to run off from or infiltrate into a particular soil. Hydrologic Soil Group designations are as follows (after Bras 1990): A — Low runoff potential. Soils such as drained sands and gravels with high infiltration rates; B — Moderate runoff potential. Soils such as fine sands and silts with moderately fine to moderately coarse textures and moderate rates of infiltration and water transmission; C — Moderately high runoff potential. Soils such as fine silts and moderate clays with moderately fine to fine texture and slow infiltration rates and rates of water transmission; D — High runoff potential. Clay soils with permanently high water table and very slow infiltration rates and rates of water transmission.

Appendix F

A Geologic Doan Brook Tour

Warning: The Doan Brook gorge is beautiful and well worth visiting. However, you should keep in mind that some parts of the gorge are steep, with dangerous cliffs and overhanging rocks. Exercise appropriate caution here as you would in any natural area. Some parts of the gorge are also somewhat isolated and infrequently visited. You may wish to take a friend along for safety. Finally, the water in the brook may contain high concentrations of bacteria, particularly after a rain. While contact with the water is unlikely to make you sick, you should be aware that it may have high levels of bacteria and either avoid contact or wash carefully when you return home. Children should always be accompanied by an adult.

The Doan Brook gorge offers excellent opportunities for an amateur geologist to identify and examine some of the sedimentary rocks of northeast Ohio. Puzzling out the locations of the different formations and finding them along the stream can be both fun and challenging. Even though the rocks exposed along Doan Brook are sedimentary deposits that were laid down in relatively regular layers, the formations don't always appear quite as you would expect.

The tour offered here is intended to give the amateur geologist or interested layman a starting point — to point out where the different rock types can be seen and what they look like along Doan Brook. Some of the more interesting features of the rocks are also described. The descriptions should help you identify the different formations even if you don't know much about geology when you start. See Appendix E for an account of how the rocks got where they are.

Geologic descriptions in the tour and in Table F-2 are based on the work of a number of geologists (see the bibliography) and on the author's own exploration of brook geology. The true enthusiast may want to look at some of the references for more detailed descriptions of Doan Brook rocks. There is more to be seen and understood than is described here, so you may want to make your own explorations. If you find something really interesting, let the Nature Center at Shaker Lakes know so that they can pass it on to others.

The tour begins with the lowest (and oldest) rocks that are exposed along the brook and works its way upstream into the younger formations in the upper part of the watershed. Figure F-1 shows a schematic cross-section of the bedrock in the Doan Brook watershed. Figures F-2 and F-3 show the locations of most of the formations that are described in the text. Table F-1 summarizes the stops and sidetracks on the tour. Because the text is organized by geologic formations instead of by stops, formations that you can see at a single stop are sometimes discussed in more than one text section. The text is keyed to the stops shown in Table F-1, but it may be helpful to read ahead a bit. You will also want to refer to Table F-2 for more detailed descriptions of the rocks than are included in the text.

Table F-1 Summary of the Geologic Tour

Stop #	Location	Formations	Text Section/ Notes	Suggested Parking[1]
1	North of Wade Park Lagoon	Chagrin Shale	F.1	MLK along W. side of Wade Park Lagoon
2	Lower Ambler Park	Chagrin Shale	F.1	University Circle, Chestnut Hills at North Park, or Baldwin Rd. near Fairhill
		Cleveland Shale	F.2	
3	East Side of MLK between North Park and Ambleside	Cleveland Shale	F.2	
		Lower Bedford Sandstone	F.2	
Sidetrack 1	South Side of Fairhill East of Baldwin Road	Cleveland Shale	F.2	Baldwin Road, or go on foot from Ambler Park
		Lower Bedford Sandstone	F.2	
4	MLK Detention Basin	Cleveland Shale	F.2/look for fossils	Chestnut Hills at North Park, or go on foot from Ambler Park
		Bedford Gray Shale	F.2	
		Lower Bedford Sandstone	F.2	
5	Brook opposite North Park and Harcourt	Euclid Bluestone	F.3	South Overlook (or another side street) and North Park
6	Brook near North Park and Delaware	Bedford Formation Shale	F.3	
		Berea Sandstone	F.4	
7	Top of gorge at North Park and Grandview	Berea Sandstone	F.4/cross-bedding and thin bedding	
8	Gorge between North Park at Roxboro and Woodmere	Berea Sandstone	F.4/gorge and falls	
Sidetrack 2	South side of Brook opposite Kemper and Fairhill	Berea Sandstone	F.4/massive, thin bedding, cross-bedding	Kemper at Fairhill, or on foot from the Lower Shaker Lake dam
9	Fairhill at bridge between North Moreland and Coventry	Berea Sandstone	F.4/thin bedding	Lower Shaker Lake dam, or the Nature Center at Shaker Lakes
10	Brook from Lower Shaker Lake dam to Coventry	Orangeville Shale	F.5	
11	South branch of Brook at Nature Center at Shaker Lakes	Orangeville Shale	F.5	
12	Lower Shaker Lake	Glacial erratics	F.6	

1 If you are more energetic, the best way to take most of the geology tour is to pick a single parking spot on one of the side streets off of North Park between Coventry and MLK and explore Stops 2 through 10 from there.

F.1
Chagrin Shale: The Base of the Escarpment

The oldest rock that is exposed in the Doan Brook watershed, or anywhere in the Cleveland area, is the almost 400 million year old Chagrin Shale. The Chagrin Shale extends from several hundred feet below Lake Erie's current surface to approximately 175 feet above the lake level (see Figure F-1). In Doan Brook's lower watershed, the shale was generally eroded or scraped away by glaciers, and it is covered by as much as 600 feet of newer sediment. As a result, the shale can first be seen at the toe of the Escarpment, just below University Circle. The appearance of the Chagrin Shale in the Doan Brook streambed is one of the first signs that you are approaching the edge of the Escarpment, where Lake Erie's ancestors lapped at their highest shorelines.

You can find good exposures of Chagrin Shale in two reasonably accessible places:

- **STOP 1** Chagrin Shale: Just downstream from the University Circle culvert outlet — Take the sidewalk down hill (northwest) along the west side of the Wade Park Lagoon until you see the culvert outlet and brook about 50 yards away to your right. The Chagrin Shale outcrops in a number of places along the banks, with a particularly good exposure on the west (left if you are facing downstream) bank about 50 feet downstream from the culvert outlet. The appearance of the shale here is quite characteristic of the Chagrin Shale – it is gray with some weathering to a reddish tan and breaks into irregular fragments rather than consistently flaking into thin sheets. The shale bank is so soft that it turns to mud if you rub your boot across it. When there is not too much vegetation, you can see another Chagrin Shale outcrop if you continue downstream to the far side of the fenced maintenance building and look across the brook at the cliff on the far side (just below the Cleveland Museum of Art parking garage).
- **STOP 2** Chagrin Shale: Lower Ambler Park upstream from the University Circle culvert inlet — Ambler Park is a bit difficult to get to, but the surprising beauty and peace of this park surrounded by busy streets make the effort worthwhile. You can park on one of the side streets off of North Park Boulevard (Chestnut Hills Drive, for example) and walk down the hill, you can park in University Circle and walk up, or you can park on Baldwin Road at Fairhill. In any case, you should enter the park roughly opposite the intersection of Ambleside and MLK. Walk up the center of the park (southeast) until you find the culvert inlet. Continue upstream, following the brook, looking for areas where the brook has eroded away the bottom of its retaining walls as you go. Where the retaining walls are eaten away, you will see a dark shale below them. This is the Chagrin Shale. You can get a somewhat better look at the rock if you continue for about 100 yards until you reach a small, perhaps artificial, waterfall. The shale is well exposed in the face of the falls.

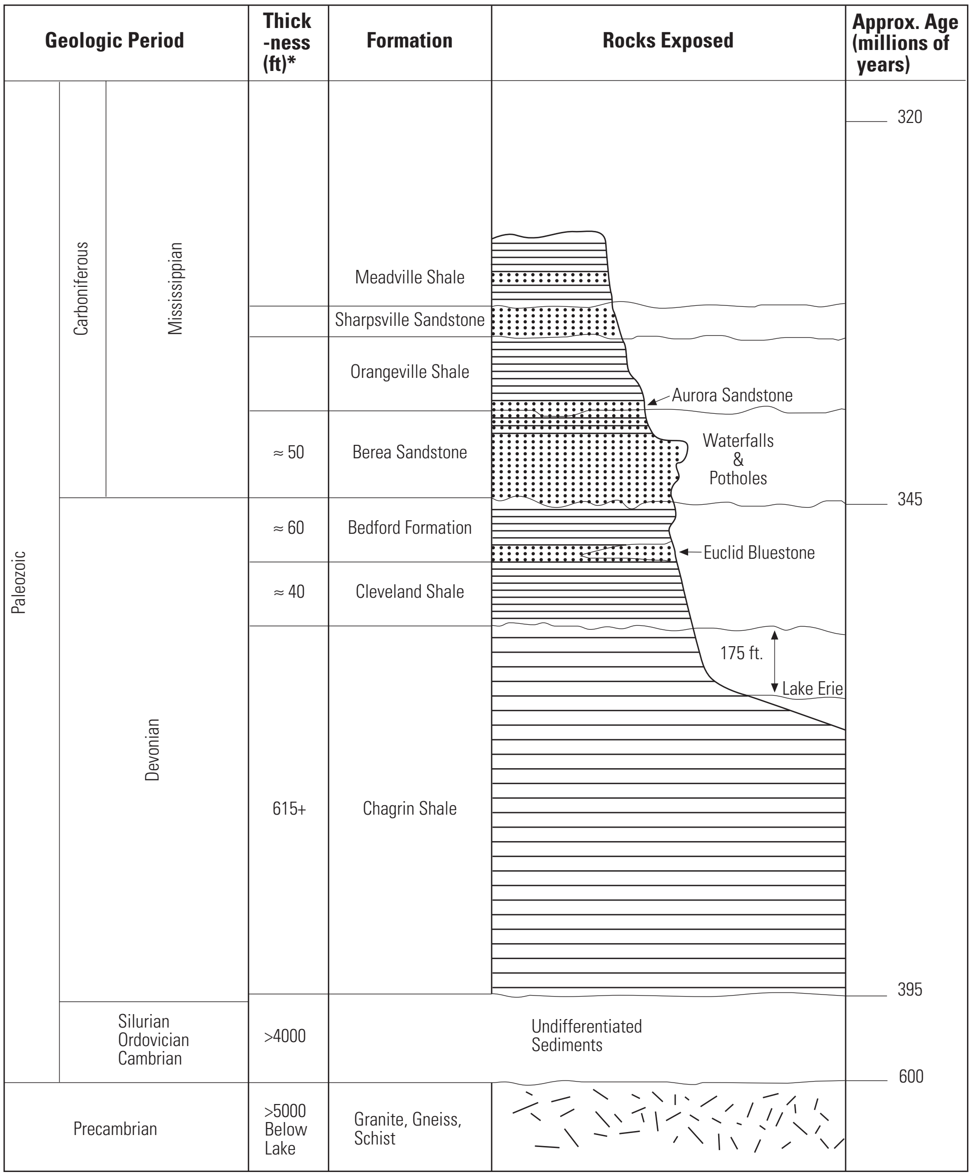
  The Chagrin Shale that is visible in this part of Ambler Park is all within the streambed and it is generally wet. It looks very dark gray here, with some areas stained to a deep reddish brown. The visible areas have weathered into moderately thin but somewhat blocky fragments. If you venture into the stream channel (this is somewhat difficult — be careful and remember that the brook's water is not entirely clean) you will find that the shale is soft and breaks easily between your fingers. The thin (one to two inch thick) very fine sandstone (or siltstone) layers that are characteristically interbedded with the Chagrin Shale are clearly visible here. They are the lighter colored stone that projects from the shale in the face of the waterfall and in many other places.

  See Section F.2 for a description of the exposure of the Cleveland Shale that lies near the waterfall in Ambler Park.

F.2
The Cleveland Shale and the Lower Bedford Formation: The Edge of the Escarpment and the MLK Detention Basin

The Cleveland Shale lies immediately above the Chagrin Shale. The top of the Chagrin Shale shows evidence of weathering, indicating that the land surface emerged from the water and was eroded between the time that Chagrin Shale deposition ended and Cleveland Shale deposition began. Although the Chagrin rock and the Cleveland rock are both shales, the difference in the two materials is quite obvious. The Cleveland Shale is a hard, brittle shale that generally weathers into thin, sharp-edged sheets. The shale is black when it is first broken, but it appears dark gray or deep red when weathered. The thin edges may appear tan in a cliff face where they have been coated by eroded material from above. The Cleveland Shale does not weather to a soft mud as the Chagrin Shale does.

The Cleveland Shale is exposed in the middle part of the steep part of the Escarpment.



*Thickness is approximate thickness along Doan Brook. Units may have different thickness elsewhere.

Figure F-1 Doan Brook Bedrock Cross-Section

Where it appears along Doan Brook, it is generally capped with a clearly visible sandstone layer from the lower part of the Bedford Formation. Like the Chagrin Shale exposures in Ambler Park, the Cleveland Shale cliffs along Doan Brook lie in Ambler Park and along busy MLK and Fairhill and are a bit difficult to reach. They are readily identifiable once you reach the spot, though. Good exposures can be found in the following places:

- **STOP 2** As you stand by the waterfall in Ambler Park that is described at Stop 2 in Section F.1, you can see that a flaky shale forms the steep slope to your right (as you face upstream — spectacular tree roots wrap the top of the shale mound). This is the hard, brittle Cleveland Shale. If you break a piece, you'll see that the freshly broken surface is dark, reddish black.
- **STOP 3** Cleveland Shale and Bedford Formation Sandstone: East side of MLK between North Park and Ambleside — As you curve down the steep hill of the Escarpment on MLK, you see a steep cliff on the right (northeast) side of the road. This cliff is made of Cleveland Shale capped by the sandstone at the base of the Bedford Formation. You must walk along the sidewalk (up from Ambleside or down from North Park) to see the rock. On foot, you will see that the lower part of the cliff is made up of a sharp-edged, thinly bedded shale that appears to be a dirty tan color. Fragments of the shale that you can pick up from the piles that collect along the base of the retaining wall show that the shale is actually black (look at the edge of a freshly broken piece) but weathers to gray and deep red. The tan appearance of the shale on the cliff seems to be the result of coating by material washed down from above. The shale is hard and brittle, breaking cleanly between your fingers.

  Toward the top of the cliff, massive layers of tan sandstone replace the shale. Some of the sandstone layers (maybe rocks that have fallen from above) project from the cliff and give platforms for overhanging trees. The sandstone is the basal (bottom) rock unit of the Bedford Formation that overlies the Cleveland Shale.
- **SIDETRACK 1** Cleveland Shale and Bedford Formation Sandstone: South of Fairhill between Baldwin Filtration Plant and Baldwin Road — As you drive up the Escarpment on Fairhill Road, you will see a cliff on your right just after you pass the open water reservoirs and the intersection with Baldwin Road. This cliff shows an exposure of Cleveland Shale and overlying Bedford Formation Sandstone very similar to the one on MLK directly across the brook. The only significant difference is that the sandstone seems to be absent or to form only a thin layer at the top of the cliff.
- **STOP 4** Cleveland Shale and Bedford Formation Shale and Sandstone: Doan Brook Streambed between MLK and the MLK Detention Basin Dam — As you walk west from MLK toward the MLK detention basin dam you descend into the Doan Brook valley. The Cleveland Shale is visible in the streambed and in the lower part of the cliff on the north side of the stream. A manmade retaining wall tops the Cleveland Shale. Above the wall is a layer (perhaps 20-30 feet thick) of gray shale that belongs to the Bedford Formation. Above the gray Bedford Shale, the basal sandstone of the Bedford Formation appears once again. Some fossils have been found in the upper part of the Cleveland Shale just below the Bedford Formation in this area.

F.3
The Bedford Formation: Red Shale and Euclid Bluestone

Tracing the location and character of the Bedford Formation presents one of the more challenging geologic puzzles along Doan Brook. The formation is generally described as consisting of a very soft red or blue shale interbedded with sandstone layers. However, a stroll along Doan Brook where the Bedford formation is exposed (between MLK and a bit downstream from Roxboro) might lead you to the conclusion that the Bedford Formation is entirely dark blue-gray sandstone. In fact, the lower part of the formation along Doan Brook consists of massive sandstone that appears tan in some places and dark gray or blue in others. This layer appears to be more than 25 feet thick along Doan Brook, and additional layers of dark blue sandstone appear to be interbedded with the shale above this basal layer. This massive, hard, fine-grained sandstone is the Euclid Bluestone that was a greatly valued building material and was quarried not only along Doan Brook but also farther north, where you now find Bluestone Road and Quarry Park. A layer of dark red, very soft shale overlies the sandstone, but the shale is so soft that it is easy to miss — there are no obvious cliffs of the red Bedford Shale. In fact, you can stand on a bank of the red shale and notice only that the mud is stained deep red. The blue (or gray) Bedford Shale seems to be scarce along Doan Brook, only appearing obviously at Stop 4, as is mentioned in Section F.2.

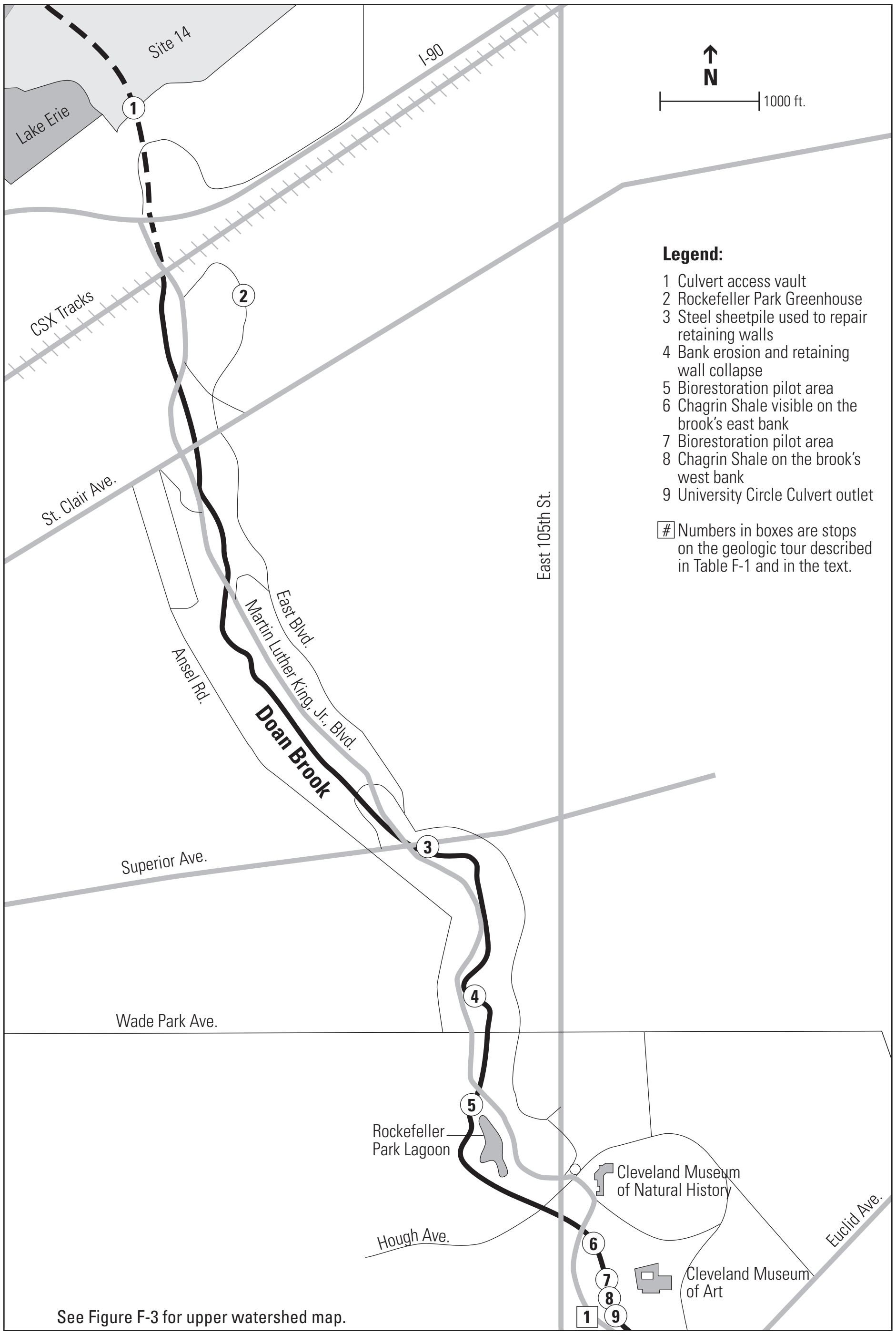


Figure F-2 Doan Brook Geology Tour Map: Lower Watershed

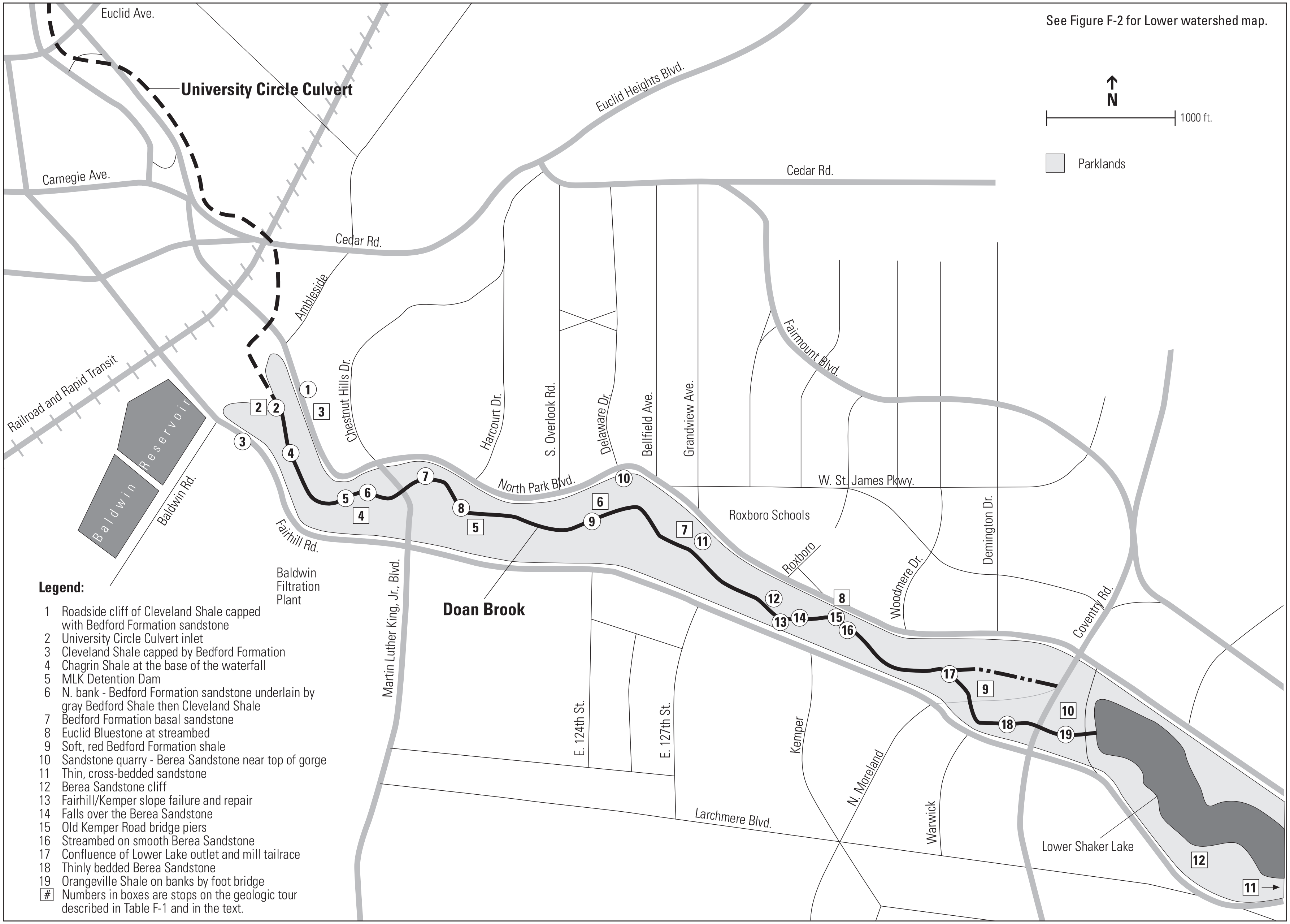


Figure F-3 Doan Brook Geology Tour Map: Upper Watershed

You can see the very bottom of the Bedford Formation sandstone where it intersects with the underlying Cleveland Shale in the locations described in Section F.2. In addition, the Bedford formation extends from the top to the bottom of the Doan Brook gorge between MLK and South Overlook — almost any rock that you see in the gorge in this area is from the Bedford Formation, unless it was carried there from outside. Particularly good exposures of both the Euclid Bluestone and the red Bedford Shale can be seen in the following locations:

- **STOP 5** Euclid Bluestone: The Brook Opposite Harcourt — The Euclid Bluestone is visible in the Doan Brook gorge in many places between MLK and Delaware.[2] The most spectacular place to see the Bluestone, though, is in the streambed about opposite the intersection of North Park and Harcourt. To get to this point, you must descend into the gorge opposite South Overlook and walk back downstream. If you work your way down toward the brook, you will eventually reach a point where the streambed is formed of dark, smooth rock rather than of mud or cobbles. The banks here are dark, greenish sandstone that juts into the brook in a horizontal stair-step pattern, with regular blocks that almost look manmade (the retaining walls on the south side of the stream *are* manmade). If you break a piece of this stone, the broken surface will be a lighter bluish gray, and the sandstone will appear dense and fine-grained. This is the classical exposure of the Euclid Bluestone. If you look carefully at the chunks of sandstone along the banks and in the gorge, you will see some examples of cross-bedding, or places where the layers of sandstone are at angles to each other. You may also find ripple marks in the stone — places where you can see evidence of wave action on the sand that was later compressed to make the stone.

  Although the classic Euclid Bluestone is best found at this location, the same name was used generally to refer to all of the dense, fine-grained sandstone that was found in the Bedford Formation. Some of this stone (like the material that is visible at Stop 4) is tan, without the slightest hint of blue.

- **STOP 6** Bedford Formation Shale: Downstream from North Park at Delaware — The best place to find the elusive Bedford Formation red shale is on the banks of the brook downstream from Delaware Road. Opposite the intersection of North Park and Delaware, there is a set of stone steps that lead from North Park into the gorge. Take the steps down, and continue toward the brook and downstream. When you reach the stream bank, look down at the mud under your feet. If you are on a Bedford Shale bank, the mud will be stained red. If the bank where you are standing isn't reddish, walk up or downstream and dig around a bit along the stream bank until you find a spot where it is. When you find a reddish bank, examine it closely until you find small bits of projecting, brick red, soft rock. This red shale, which looks more like small chunks of solid red mud than anything else, is the red Bedford Shale.

  As you continue a bit farther downstream along the bank (no farther than South Overlook), you will see that the far (south) bank of the stream looks quite red. If you venture across the brook (the rocks are slippery and the water is dirty) you will find a clear exposure of the red Bedford Shale on the far bank. You can also reach this bank by taking the path that leads toward the brook from Fairhill Road just east of the condominiums at Fairhill and East 126th Street.

F.4
Berea Sandstone: The Lower Shaker Lake to the Grist Mill

The Berea Sandstone's resistance to erosion led to the formation of the deepest, steepest part of the Doan Brook gorge and created the waterfall that the Shakers used to help power their five-story stone grist mill. The formation consists of light colored gray or tan pure quartz sandstone that is relatively coarse compared to the Bedford Formation sandstones. The individual sand grains are loosely cemented together, so that the rock can hold a great deal of water. Because of this, the Berea Sandstone is one of the most important aquifers in the area. The bottom part of the formation is massive — that is, it has few layers — while the upper parts are thinly bedded, with many clearly visible layers that may be less than an inch thick. The lower, massive part of the formation is also very erosion resistant, so that many streams, including Doan Brook, form waterfalls over the lip of this level of the Berea Sandstone.

The interface between the Berea Sandstone and the underlying Bedford Formation is irregular. It is evident that the seas receded after the Bedford Formation rocks were deposited, so that the surface of the formation was eroded before the seas returned to deposit the sand that was to become the Berea Sandstone.

The Berea Sandstone is hard to miss along Doan Brook. It extends from the top of the gorge to the streambed from below Coventry Road to below Roxboro Road. It forms the walls of the most spectacular part of the Doan Brook gorge, as well as the stream's stone bottom.

2 Caution – The stone at the top of the gorge beginning slightly downstream from Delaware and extending upstream is Berea Sandstone, not Euclid Bluestone.

Figure F-4 Berea Sandstone in the Doan Brook gorge, showing massive bedding along the brook and thin, cross-bedded layers above. Photograph by L. C. Gooch.

Some particularly interesting spots to examine the sandstone are as follows:

- **STOP 6** Berea Sandstone: North Park at Delaware — At the bottom of the first flight of the stone steps that lead down into the gorge at the intersection of North Park and Delaware you find yourself in an open area with heavily-grafittied sandstone walls to the left and straight ahead. This is the first appearance of the Berea Sandstone at the top of the gorge, and it is one of many areas along the brook where sandstone was quarried. There is often water seeping from the rock, showing that the Berea Sandstone does indeed carry water. If you follow the steps down and around the rocks that lie straight ahead, you will see evidence of cross-bedding on the back of the sandstone.
- **STOP 7** Berea Sandstone with cross-bedding and thin bedding: North Park and Grandview — Just upstream from the intersection of North Park and Grandview, you can take a path that leads down into the gorge and upstream. A few feet down the path, you will see layers of exposed dark sandstone on your left. This rock is very thinly bedded, looking almost like sidewalk stones that have been cut and stacked. The formation has excellent examples of cross-bedding. That is, some layers of the rock have been turned aslant, only to be topped by still other layers that remain horizontal.
- **STOP 8** Berea Sandstone in the gorge and the falls: North Park from Roxboro Road to Woodmere Road — If you follow along the north side of the top of the gorge between Roxboro Road and Woodmere Drive, you can see the point where the brook cuts most steeply through the sandstone. The gorge walls here are nearly vertical, and the stream bottom is smooth sandstone. The brook plunges about twelve feet over a waterfall, although the falls are difficult to see from the top of the gorge. Some of the stone has been quarried out, particularly near the downstream end of this stretch. This was the site of the Shakers' stone grist mill and the dam that provided its power (see Appendix C and Chapter 2). Just a bit downstream from Woodmere, you will see the footings of an abandoned bridge in the streambed. This is the point where Kemper Road once crossed the brook.
- **SIDETRACK 2** Berea Sandstone bedding and cross-bedding: Fairhill at Kemper Road — You can see an exposure of about thirty feet of the Berea Sandstone from the bottom of the south side of the gorge opposite the intersection of Fairhill and Kemper. Follow the remains of the abandoned Kemper Road Bridge down into the gorge until you find yourself standing just above the sandstone floor of the gorge across the stream from a vertical sandstone cliff. The lower part of the cliff is massive sandstone with little or no evidence of layering, while the upper part is composed of many fairly thin layers. The layers of one section are aslant from another (cross-bedded), showing that some sections of the stone were tilted after they were deposited. Doan Brook's twelve foot falls over the massive section of the Berea Sandstone lie a short distance to the left (downstream).
- **STOP 9** Berea Sandstone thin bedding: Fairhill Road Bridge over the Brook between North Moreland and Coventry — The thinly-bedded upper part of the Berea Sandstone is visible in the bed and banks of the brook between Woodmere and Coventry Roads. You can get a good look at the shelving layers of the streambed from either side of the Fairhill bridge over the brook or by walking along the south side of the stream between Fairhill and Coventry.

F.5
Orangeville Shale: Coventry Road and Farther Upstream

The varied rocks of the Cuyahoga Formation overlie the Berea Sandstone in the upper parts of the Doan Brook watershed. Only the lowest layer — the Orangeville Shale — is visible along the brook. The next two layers — the Sharpsville Sandstone and the Meadville Shale — are buried beneath the upper watershed's glacial till. Still younger layers of the Cuyahoga Formation are found at higher elevations outside of the Doan Brook watershed.

The Orangeville Shale is a soft, blue-black shale that weathers very quickly where it is exposed.

Table F-2	Bedrock Outcrops in the Doan Brook Watershed – Highest Formation to Lowest[3]	
Formation	**Description**	**Location**
Cuyahoga Formation	Orangeville Shale, Sharpsville Sandstone, and Meadville Shale underlie the Doan Brook watershed. Only the Orangeville Shale is exposed. The main body of the Orangeville Shale is a soft blue-black clay shale. Some beds are fissile,[4] others more solid, but all are weak and yield rapidly to the weather. The exposures along Doan Brook below the Lower Shaker Lake appear very flaky and weather to reddish rusty brown and gray. The edges of the fragments are tan, but the flat sides are reddish brown or gray. The shale is so fragile and the fragments so thin that the exposed edge of the formation looks almost like a dry pile of decaying leaves.	Orangeville Shale appears on the banks of the brook between the Lower Shaker Lake dam and Coventry Road. It is also sometimes visible along the south fork of the brook just upstream from the Lily Pond marsh at the Nature Center at Shaker Lakes.
Berea Sandstone	Light gray to yellowish brown, medium to fine grained clay-bonded quartz sandstone. May be ripple marked or cross-bedded. The formation is massive at its base and thinly bedded in its upper parts. This unit is highly erosion-resistant, leading to the formation of deep, steep-walled channels.	The Berea Sandstone forms the banks and channel of Doan Brook between Coventry and Roxboro Roads and is present at the top of the gorge as far downstream as the quarry opposite Delaware Road. The sandstone forms the erosion-resistant layer in the stream bed that creates the falls at the Shaker grist mill site, opposite the intersection of North Park and Roxboro.
Bedford Formation: Shale and Euclid Sandstone Member	Soft clayey shale ranging in color from blue gray to maroon or black, with thin interbeds of fine-grained blue-gray sandstone. Contains hard dark-gray concretions. Thicker sandstone interbeds form the Euclid Sandstone Member. Sandstone may be ripple-marked; shale layers may be tilted. The base of this unit is frequently a rather thick sandstone layer.	The basal sandstone of the Bedford Formation can be seen capping the Cleveland Shale in the cliffs up the hill from the intersection of MLK and Ambleside and up hill from the intersection of Fairhill and Baldwin Roads. Euclid Bluestone (part of the sandstone) can be seen in the stream bed opposite the intersection of North Park and Harcourt and along the gorge walls between MLK and South Overlook. The red Bedford Formation Shale can be seen on the north and south banks of the brook between Delaware and South Overlook. The grey Bedford Formation Shale can be seen in the middle part of the cliff on the north side of the brook just upstream from the MLK detention basin.
Cleveland Shale	Dark gray to black, weathering into thin, sharp-edged, slaty fragments which are stained reddish-brown. Pyrite and marcasite concretions may be found. A thin film of pyrite (<2" thick) is present along the base of this formation in some areas. A few fossils have been found in the upper part of the Cleveland Shale along Doan Brook.	Cleveland shale can be seen along the east side of MLK down the hill from Chestnut Hills Drive (going down the hill after the intersection of MLK with North Park). The lower part of the cliff here is composed of Cleveland Shale, as are the piles of shale fragments along the retaining wall at the base of the cliff. Cleveland shale can also be found in the lower part of the cliff on the southwest side of Fairhill Road below Baldwin Filtration Plant (between the plant and Baldwin Road), in the streambed and lower part of the cliff on the north side of the MLK detention basin, and on the southwest slope above the brook at the waterfall in Ambler Park.
Chagrin Shale	Soft clay shale, blue-gray, which weathers to sticky, soft clay. Interbedded with thin (one to two inch) sandstone layers.	Chagrin shale can be seen on the banks of Doan Brook just downstream from the University Circle culvert outlet. It can also be seen in the Doan Brook channel upstream from the University Circle culvert inlet in Ambler Park, where the brook has eroded the bottoms of the retaining walls. Thin sandstone layers that project from the surrounding shale are clearly visible here.

3 Geologic data are from a variety of sources. See the bibliography.

4 Fissile is a geologic term that indicates that a rock unit tends to break along parallel planes, resulting in thin, plate-like fragments.

Some parts flake readily into thin sheets, while others do not. The Aurora Sandstone, a fine-grained blue gray sandstone that weathers to yellowish brown, lies between the main body of the shale and the Berea Sandstone in some areas. Along Doan Brook, this layer is either absent or difficult to distinguish.

- **STOP 10** The easiest place to find the Orangeville Shale is along Doan Brook's banks between the Lower Shaker Lake dam and Coventry Road. Here, the shale appears rusty reddish brown and gray with tan edges. It breaks into very thin, weak flakes, so that the bank looks almost like a pile of dry, decaying leaves.

  There is an interesting contrast between the materials of the streambed and banks upstream and downstream of the Coventry Road bridge. Upstream from the bridge, the banks are purely soft, flaky Orangeville Shale — no hint of sandstone here. Downstream from the bridge, by contrast, you will find only the thinly bedded sandstone of the upper Berea Sandstone, with no sign of any shale. The interface between the two formations seems to occur entirely beneath the Coventry Road bridge.

- **STOP 11** The Orangeville Shale is sometimes exposed along the south branch of Doan Brook adjacent to the trails at the Nature Center at Shaker Lakes. As you walk along the trails, examine the steep banks that the stream has cut, looking for places where there is fresh erosion. You should be able to pick out some shale layers. Where there is no recent erosion, the shale weathers and is covered with soil from above, so that no clear rock layers are visible.

F.6
Glacial Erratics: Where Did *That* Rock Come From?

- **STOP 12** As you walk along Doan Brook you will occasionally see a large boulder that is quite unlike the sedimentary rocks that form the area bedrock. These boulders — usually granite but sometimes limestone or other rock — that don't seem to belong here are a legacy of the ice sheets that once covered the area. As the glaciers scraped across the land to the north, they pulled the rock apart and absorbed the resulting debris. Most of the material that the glaciers carried was in the form of the small particles — mixed clay, silt, sand, and gravel — that was left to become glacial till soil when the glaciers departed. Sometimes, though, the glaciers picked up large boulders and carried them hundreds of miles, only to drop them again as they receded. These boulders, scattered in a seemingly random pattern, are called glacial erratics. You can find a number of them in the Doan Brook watershed; some can be found easily along the shores of the Lower Shaker Lake.

Appendix G

The efforts of many people over the years have created a rich database about the flora and fauna of Doan Brook. The results of a number of these past studies were considered during the preparation of the main *Handbook* text. This appendix includes tables that summarize some of the background data on the brook's biology.[1]

List of Biological Data Tables

1 Every effort has been made to present the data in a logical and consistent way. Data users should nonetheless keep in mind that data collected by different investigators at different times and using different methods may not be directly comparable. Original data sources should be consulted where appropriate.

Table G-1: Trees of the Doan Brook[1]

Common Name	Scientific Name	Before 1790	1964	1966A	1979	1981	1994	1997
Apple	*Pyrus malus*							p
Ash, black	*Fraxinus nigra*	S						
Ash, green	*Fraxinus pennsylvanica*					l	R	p
Ash, mountain	*Pyrus decora*		p			l		p*
Ash, white	*Fraxinus americana*	vp	p	p	p	l		
Basswood	*Tilia americana*	rvs	p	p	p	l	r	p
Beech	*Fagus grandifolia*	rVP	p	p	P	l	e	p
Beech, European	*Fagus sylvatica*					l*		
Beech, European white	*Fagus sp.*					l*		
Birch, black	*Betula lenta*	r	p	p				
Birch, gray	*Betula populifolia*		p					
Birch, paper	*Betula papyrifera*					l		
Birch, river	*Betula nigra*					l		p*
Birch, yellow	*Betula lutea*	r	p	p			r	
Bladdernut	*Staphylea trifoliata*						r	
Buckeye, Ohio	*Aesculus glabra*		p					p
Butternut	*Juglans cinerea*	p	p	p				
Catalpa, northern	*Catalpa speciosa*		p				r*	
Cherry, choke	*Prunus virginiana*		p	p				
Cherry, cornelian	*Cornus mas*					l		
Cherry, flowering	*Prunus serrulata ?*					l*		
Cherry, Japanese	*Prunus serrulata?*		p					
Cherry, sweet	*Prunus avium*		p				Re	
Cherry, wild	*Prunus sp.*					l		
Cherry, wild black	*Prunus serotina*		p	p	p		Re	p
Chestnut	*Castanea dentata*	eb		e				
Cottonwood	*Populus deltoides*	s	p	p	r	l	R	p
Crabapple	*Pyrus coronaria sp.*					l		
Crabapple, American	*Malus coronaria*		p					
Crabapple, flowering	*Malus sp.*		p					
Cucumber-Tree	*Magnolia acuminata*	evp	p	p		l	r	
Cypress, bald	*Taxodium distichum*					l		
Dogwood, Chinese						l		
Dogwood, flowering	*Cornus florida*	p	p	p				p
Dogwood, gray	*Cornus foemina*						R	p
Dogwood, pink	*Cornus sp.*					l		
Dogwood, red osier	*Cornus stolonifera*		p					
Dogwood, red twig	*Cornus sp.*					l		
Dogwood, silky	*Cornus amomum*						e	
Dogwood, white	*Cornus sp.*					l		
Dogwood, yellow twig	*Cornus sp.*					l		
Elder, box	*Acer negundo*					l		
Elm, American	*Ulmus americana*	S	p	p		l	r	p
Elm, Chinese	*Ulmus parvifolia*					l		
Elm, English	*Ulmus prŏcera*					l*		
Elm, red (slippery)	*Ulmus rubra*		p				re	
Elm, scotch	*Ulmus sp.?*					l		
Elm, Siberian	*Ulmus pumila*						r	
Fringe tree	*Chionanthus virginicus ?*					l		
Ginkgo	*Ginkgo biloba*					l*		
Golden rain tree	*Koelreuteria paniculata*					l*		

Table G-1: Trees of the Doan Brook[1]

Common Name	Scientific Name	Before 1790	1964	1966A	1979	1981	1994	1997
Hackberry	*Celtis occidentalis*						e	
Halesia	*Halesia sp.*					l		
Hawthorn	*Crataegus sp.*		p	p		l		p
Hawthorn, blushing	*Crataegus pruinosa*						e	
Hawthorn, English	*Crataegus monogyna*						r*	
Hemlock	*Tsuga canadensis*	R	p	p	r			
Hickory	*Carya sp.*					l		
Hickory, bitternut	*Carya cordiformis*	s	p	p			e	p*
Hickory, pignut	*Carya glabra*	e			p			
Hickory, shagbark	*Carya ovata*	e	p	p	rp		e	
Hophornbeam	*Ostrya virginiana*	p	p	p		l	R	
Hornbeam, American	*Carpinus caroliniana*	ps	p	p	p	l	e	p
Juniper	*Juniperus sp.*					l		
Larch	*Larix laricina*		p					
Linden, European	*Tilia eropea?*					l*		
Linden, silver	*Tilia sp.?*					l		
Locust, black	*Robinia pseudoacacia*		p			l	e*	
Locust, honey	*Gleditsia triacanthos*					l		
Magnolia	*Magnolia sp.*					l		
Maple, black	*Acer nigrum*					l		
Maple, hedge	*Acer campestre*					l*		
Maple, Japanese	*Acer palmatum*		p			l*		
Maple, mountain	*Acer spicatum*	r						
Maple, Norway	*Acer platanoides*		p			l		p*
Maple, red	*Acer rubrum*	rpS	p	p	p	l	re	p
Maple, silver	*Acer saccharinum*		p	p	rp			p
Maple, sugar	*Acer saccharum*	VP	p	p	P	l	Re	
Maple, sycamore	*Acer pseudoplatanus*					l		
Mulberry	*Morus sp.*					l		
Mulberry, red	*Morus rubra*						e	
Mulberry, white	*Morus alba*		p					
Oak, black	*Quercus velutina*	rb			p		E	p
Oak, bur	*Quercus macrocarpa*		p	p				
Oak, chestnut	*Quercus montana*	e	p	p		l	E	
Oak, pin	*Quercus palustris*		p	p	r	l	e	p
Oak, red	*Quercus maxima*	eb	p	p	FP	l	rE	p
Oak, scarlet	*Quercus coccinea*	eb		p		l		
Oak, shingle	*Quercus embricaria*					l		
Oak, swamp white	*Quercus bicolor*	s	p	p				
Oak, white	*Quercus alba*	Eb	p	p	r	l	E	p
Oak, willow	*Quercus phellos*					l		
Olive, Russian	*Olea sp.*					l		
Pawpaw	*Asimina triloba*	f	p	p				
Pine, Austrian	*Pinus nigra*					l		
Pine, scotch	*Pinus sylvestris*					l		
Pine, white	*Pinus strobus*	r	p	p		l		p
Pine, yellow	*Pinus echinata*		p					
Plum, wild	*Prunus americana*	f					e	
Redbud	*Cercis canadensis*		p			l		
Redwood, dawn	*??*					l		
Rubber tree, hardy	*??*					l		
Saphora	*??*					l		
Sassafras	*Sassafras variifolium*	e	p	p		l		p
Shadbush	*Amelanchier canadensis*	p	p			l		
Spruce	*Picea sp.*					l		

Table G-1: Trees of the Doan Brook[1]

Common Name	Scientific Name	Before 1790	1964	1966A	1979	1981	1994	1997
Spruce, blue	*Picea sp.*		p					
Spruce, white	*Picea glauca*		p					
Sumac	*Rhus sp.*							
Sweetgum	*Liquidambar stryraciflua*					l		
Sycamore	*Platanus occidentalis*		p	p			R	p
Sycamore, American	*Platanus occidentalis*							
Tree-of-heaven	*Ailanthus altissima*					l	r*	
Tuliptree	*Liriodendron tulipifera*	rvbp	p	p	p		r	
Tupelo	*Nyssa sylvatica*	vp	p	p		l		p
Walnut, black	*Juglans nigra*		p	p				
Willow, basket	*Salix purpurea*		p					
Willow, black	*Salix nigra*	s	p	p			r	p
Willow, crack	*Salix fragilis*						e	
Willow, heart leaved	*Salix cordata*	s	p	p				
Willow, pussy	*Salix discolor*	s						
Willow, shining	*Salix lucida*		p	p				

[1] Not all surveys covered the entire watershed. This list should therefore be taken as a list of what was present at the time of the survey, not of what was absent.

Key to species locations:

p = Plateau
s = swampy areeas on Plateau
e = Escarpment edge
r = stream ravines
v = valley sides in Lake Plain
l = Lake Plain
u = understory
b = sand banks in Lake Plain
f = valley bottom in Lake Plain

Capital letters indicate dominant species. * Indicates a non-native species (not all exotics are so marked).

Data Sources:

Before 1790: Williams, Arthur B. January 1949. Also from Arthur Williams 1950. Some input from naturalists at the Nature Center at Shaker Lakes.
1964: List in files at the Nature Center at Shaker Lakes. Probably compiled by Harold Wallins.
1966A: National Audubon Society, Nature Center Division. 1971.
1979: Institute for Environmental Education. 1979.
1981: Behnke and Associates. 1981.
1994: URS Consultants. March 16, 1994.
1997: Davey Resource Group. June 1997.

Table G-2: Shrubs of the Doan Brook[1]							
Common Name	**Scientific Name**	**Before 1790**	**1964**	**1966A**	**1981**	**1994**	**1997**
Alder, black	*Alnus glutinosa*					e	
Alder, speckled	*Alnus rugosa*						p
Aralia	*Aralia sp.*				l		
Arborvitae	*Aborvitae sp.*				l		
Arrow wood, northern	*Viburnum recognitum*					re	p
Azalea	*Rhododendron sp.*				l		
Barberry, Japanese	*Berberis thunbergii*					r*	
Blackberry, allegheny	*Rubus allegheniensis*					e	p
Buckthorn, common	*Rhamnus cathartica*					e*	p*
Buckthorn, European	*Rhamnus frangula*					re*	p*
Burning bush	*Euonymus europaeus*				l	e	
Buttonbush	*Cephalanthus occidentalis*						p
Cockspur thorn	*Crategus crus-galli*					re	
Cotoneaster	*Cotoneaster pyracantha*				l		
Cranberry, European	*Viburnum opulus*						p*
Cranberry, high bush	*Viburnum opulus*					r*	
Deutzia	*??*				l		
Dewberry	*Rubus flagellaris*						p
Elder(berry), common	*Sambucus canadensis*		p			e	p
Elder, red berried	*Sambucus racemosa*	p	p				
Euonymous alatus	*Euonymous alatus*		p				
Forsythia	*Forsythia sp.*				l		
Gooseberry, wild	*Ribes cynosbati*						p
Grape, riverbank	*Vitis riparia*					r	
Hercules club	*Aralia spinosa*		p				
Holly	*Ilex sp.*				l		
Honeysuckle, European fly	*Lonicera xylosteum*				l		p*
Honeysuckle, Japanese	*Lonicera japonica*					re*	
Honeysuckle, Maack's	*Lonicera maackii*					re*	
Honeysuckle, Morrow's	*Lonicera morrowii*					re*	
Jetbead	*??*				l		
Lilac	*Syringa sp.*				l		
Orange, mock	*??*				l		
Orange, osage	*Maclura pomifera*						p*
Poison ivy	*Rhus radicans*	s				r	p
Privet	*Ligustrum vulgare*				l	r*	p*
Raspberry, black	*Rubus occidentalis*					e	
Raspberry, purple flowering	*Rubus odoratus*	p	p				
Raspberry, red	*Rubus idaeus*					e*	
Rhododendron	*Rhododendron sp.*				l		
Rose, multiflora	*Rosa multiflora*					e*	p*
Serviceberry, downy	*Amelancier arborea*			p		r	p

Table G-2: Shrubs of the Doan Brook[1]							
Common Name	**Scientific Name**	**Before 1790**	**1964**	**1966A**	**1981**	**1994**	**1997**
Spicebush	*Benzoin aestivale*	ps				e	
Spirea	*Spirea sp.*				l		
Sumac	*Rhus, sp.*				l		
Sumac, smooth	*Rhus glabra*						p
Sumac, staghorn	*Rhus typhina*		p	p		e	
Taxus	*Taxus sp.*				l		
Viburnum, maple-leaved	*Viburnum acerifolium*	p	p	p	l	e	p
Wayfaring tree, European	*Viburnum lantana*						p*
Weigelia	*??*		p		l		
Witchhazel	*Hamamelis virginiana*	p				e	p
Withe-rod	*Viburnum cassinoides*					r	

[1] Not all surveys covered the entire watershed. This list should therefore be taken as a list of what was present at the time of the survey, not of what was absent.

Key to species locations:
p = Plateau
s = swampy areeas on Plateau
e = Escarpment edge
r = stream ravines
l = Lake Plain

Capital letters indicate dominant species. * Indicates a non-native species (not all exotics are so marked).

Data Sources:
Before 1790: Williams, Arthur B. January 1949. Also from Arthur Williams 1950. Some input from naturalists at the Nature Center at Shaker Lakes.
1964: List in files at the Nature Center at Shaker Lakes. Probably compiled by Harold Wallins.
1966A: National Audubon Society, Nature Center Division. 1971.
1981: Behnke and Associates. 1981.
1994: URS Consultants. March 16, 1994.
1997: Davey Resource Group. June 1997.

Table G-3: Herbaceous Plants of the Doan Brook[1]							
Common Name	**Scientific Name**	**Before1790**	**1966B**	**1979**	**1981**	**1994**	**1997**
Anemone, rue	*Anemonella thalictroides*		p				
Arrowhead	*Alisma sp.*		s				
Aster	*Aster sp.*					re	p
Avens	*Geum canadense*					r	
Baneberry	*Actaea sp.*		p				
Bedstraw, rough	*Gallium asprellum*		p				
Beggar ticks	*Bidens frondosa*					r	
Bellwort, sessile-leaved	*Uvularia sessilifolia*		p				
Bindweed	*Polygonum sp.*		p				
Bloodroot	*Sanguinaria canadensis*		p	p			
Buckwheat, false	*Polygonum scandens*					e	
Bugle	*Ajuga reptans*						p*
Burdock	*Arctium minus*						p
Buttercup, early	*Ranunculus fascicularis*		p				
Buttercup, spotted	*Ranunculus sp.*		p				
Buttercup, swamp	*Ranunculus septentrionalis*		s				
Carrot, wild	*Daucus carota*					e*	
Cattail	*Typha sp.*		s	s			p
Cinquefoil, old field	*Potentilla simplex*		p				p
Clover, white	*Trifolium repens*						p*
Coltsfoot	*Tussilago farfara*		p*				
Columbine, European	*Aquilegia vulgaris*		p*				
Creeper, Virginia	*Parthenocissus quinquefolia*						p
Cress, purple	*Cardamine douglassii*		s				
Cress, spring	*Cardamine bulbosa*		p				
Cress, toothed rock	*Arabis lyrata?*		p				
Crowfoot, small flowered	*Ranunculus abortivus*		p				
Cuckoo flower	*Cardamine pratensis*		p				p
Daisy, white	*??*		p				
Dandelion	*Taraxacum officinale*					r*	p*
Daylily	*Hemerocallus fulva*						p*
Dock, curly	*Rumex crispus*					e*	p*
Dock, water	*Rumex obtusifolius*					e*	
Dock, whorled swamp	*Rumex verticuillatus*					r	
Fairy bells	*Disporum lanuginosum*		p				
Fern, Christmas	*Polysticum acrostichoides*						p
Fern, sensitive	*Onoclea sensibilis*	s					p
Figwort, hare	*Scrophularia lanceolata*		p				
Figwort, Maryland	*Scrophularia marilandica*		p				
Fleabane, daisy	*Erigeron annuus*		p				
Garlic, wild	*Allium vineale*						p
Geranium, wild	*Geranium maculatum*		p	p			
Goldenrod, blue stem	*Solidago caesia*	pre				e	
Goldenrod, field	*Solidago canadensis*	pre				e	
Grape, summer	*Vitis aestivalis*	p					p
Grass, autumn bent	*Agrostis perennans*					e	
Grass, blue-eyed	*Sisyrinchium sp.*		p				
Grass, cord	*Spartina pectinata?*			s			
Grass, creeping bent	*Agrostis stolonifera*					e	
Grass, fowl manna	*Glyceria striata*					e	
Grass, Kentucky blue	*Poa pratensis*					e	

Table G-3: Herbaceous Plants of the Doan Brook[1]							
Common Name	**Scientific Name**	**Before1790**	**1966B**	**1979**	**1981**	**1994**	**1997**
Grass, orchard	*Dactylis glomerata*						p
Grass, sweet vernal	*Anthoxanthum odoratum*						p
Greenbriar, common	*Smilax rotundifolia*					e	
Groovebur	*Agrimonia sp.*						p
Hawkweed	*Hieracium pratense*					e*	
Hepatica	*Hepatica acutiloba*	p					
Honewort	*Cryptotaenia canadensis*		p				
Horsetail	*Equisetum arvense*						p
Iris, blue flag	*Iris sp.*		p				
Iris, yellow	*Iris psuedacorus*		p*				p*
Ivy, English	*Hedera helix*				l		p*
Jack-in-the-pulpit	*Arisaema sp.*	p	p				p
Jewelweed	*Impatiens sp.*	s		s		r	p
Jumpseed	*Polygonum virginianum*					re	
Knotweed, Japanese	*Polygonum cuspidatum*					e*	p*
Knotweed, Virginia	*Polygonum virginianum*						p
Lady's thumb	*Polygonum persicaria*					e*	
Leek, wild	*Allium tricoccum*		p				
Lily of the Valley	*Convallaria majalis*		p*				p*
Lily, spatterdock	*Nuphar variegatum*		s				
Lily, trout	*Erythronium americanum*	p	p	p			p
Lily, white trout	*Erythronium albidum*		p				p
Loosestrife, fringedleaf	*Lysimachia ciliata*			s			
Matrimony vine	*??*				l		
Mayapple	*Podophyllum peltatum*		p	p			p
Mertensia	*Mertensia sp.*		p				
Milfoil, European water	*Myriophyllum spicatum*						p
Moneywort	*Lysimachia nummularia*						p
Mustard, garlic	*Alliaria petiolata*		p*			re*	p*
Myrtle	*Vinca minor*				l		p
Nightshade, bittersweet (deadly)	*Solanum dulcamara*		p			r*	p*
Nightshade, enchanter's	*Circaea quadrisulcata*			s		r	
Nightshade, southern broad-leaved enchanter's	*Circaea lutetiana*						p
Pachysandra	*??*				l		
Phlox, wild blue	*Phlox divaricata*		p				
Plantain, common	*Plantago major*						p*
Pokeweed	*Phytolacca americana*					e	
Pondweed	*Potamogeton crispus*						p
Pussytoes	*Antennaria sp.*		p				
Richweed	*Collinsonia canadensis*					e	
Rocket, yellow	*Barbarea vulgaris*						p*
Rose, early wild	*Rosa sp.*		p				
Rue, early meadow	*Thalictrum dioicum*			p			
Rue, waxy meadow	*Thalictrum revolutum*		p				
Rush, spike	*Eleocharis sp.*						p
Rush, wood	*Luzula sp.*						p
Rye, river wild	*Elymus riparius*					r	
Sarsaparilla, wild	*Aralia nudicaulis*		p				
Sedge, wetlands	*Carex sp.*						p
Skunk cabbage	*Symplocarpus foetidus*		p				p
Smartweed, water	*Polygonum peritanorum*					r	
Smartweed, water	*Polygonum punctatm*					r	
Snakeroot, wild	*Eupatorium rugosum*					r	
Solomon's seal	*Polygonatum sp.*		p				p
Spring beauty	*Claytonia virginica*	p	p				

Table G-3: Herbaceous Plants of the Doan Brook[1]

Common Name	Scientific Name	Before1790	1966B	1979	1981	1994	1997
Star of Bethlehm	*Ornithogalum umbellatum*		p*				
Stick tight	*Bidens cernua*					r	
Sweetflag	*Acorus calamus*						p
Toothwort, cut-leaved	*Dentaria laciniata*		p	p			
Toothwort, two-leaved	*Dentaria diphylla ?*		p				
Trillium, great white	*Trillium grandiflorum*	p	p				
Violet, blue	*Viola sp.*		p				
Violet, common blue	*Viola papilionacea*						p
Violet, Holland leaved	*Viola sp.*		p				
Violet, pale early	*Viola affinis*		p				
Violet, Selkirk's	*Viola selkirkii*		p				
Violet, yellow	*Viola rotundifolia?*		p				
Water-pepper, mild	*Polygonum hydropiperoides*					e	
Willow herb, hairy	*Epilobium hirsutum*			s			

[1] Not all surveys covered the entire watershed. This list should therefore be taken as a list of what was present at the time of the survey, not of what was absent.

Key to species locations:

p = Plateau
s = swampy areeas on Plateau
e = Escarpment edge
r = stream ravines
l = Lake Plain

Capital letters indicate dominant species. * Indicates a non-native species (not all exotics are so marked).

Data Sources:

Before 1790: Williams, Arthur B. January 1949. Also from Arthur Williams 1950. Some input from naturalists at the Nature Center at Shaker Lakes.
1966B: List titled "Wild Flowers Found in the Shaker Heights District" made by Harold Wallins in about 1966.
1979: Institute for Environmental Education. 1979.
1981: Behnke and Associates. 1981.
1994: URS Consultants. March 16, 1994.
1997: Davey Resource Group. June 1997.

Table G-4: Fungi of the Shaker Lakes Area	
Common Name	**Scientific Name**
Bird's nest fungi	*Crucibulum levis*
Boletus merulioides	*Boletus merulioides*
Boleus alboater	*Boletus alboater*
Chanterelle	*Craterellus cantharellus*
Clitopilus albogriseus	*Clitopilus albogriseus*
Dead Men's Fingers	*Xylaria polymorpha*
Emetic russula	*Russula emetica*
Fawn colored mushroom	*Pluteus cervinus*
Fly mushroom	*Amanita muscaria*
Haymaker's mushroom	*Panaeolus foenisecii*
Horse mushroom	*Agaricus arvensis*
Leccinum subglabripes	*Leccinum subglabripes*
Lepiota cristata	*Lepiota cristata*
Lepiota naucina	*Lepiota naucina*
Lycoperdon marginatum	*Lycoperdon marginatum*
Mary's Russula	*Russula Mariae*
Meadow mushroom	*Agaricus campestris*
Mica ink mushroom	*Coprinus micaceus*
Naucoria sp.	*Naucoria sp.*
Polyporus Berkelyii	*Polyperus Berkelyii*
Polystictus sp.	*Polystictus sp.*
Psilocybe foenceii	*Psilocybe foenceii*
Red and yellow pore mushroom	*Boletus bicolor*
Sheathed mushroom	*Amanitopsis vaginata*
Skunk fungus	*Russula foetens*
Slippery jack	*Suillus luteus*
Turquoise mushroom	*Russula virescens*
Winter mushroom	*Flammulina collybia velutipes*

Data are from Cibula, William. Undated (ca. 1965?). *A Partial Survey of the Higher Fungi Found in the Shaker Lakes Area* .

Table G-5: Birds of the Doan Brook						
Common Name	Scientific Name	Shaker Lakes Area				Site 14
		1966	1973-79	1979 BBC	1997-99	1980-2000
Loon, common	*Gavia immer*	x			u	x
Grebe, horned	*Podiceps auritus*	x	x			x
Grebe, eared	*Podiceps nigricollis*					x
Grebe, pied-billed	*Podilymbus podiceps*	x	c		c	x
Grebe, red-necked	*Podiceps grisegena*					x
Pelican, American white	*Pelecanus erythrorhynchos*				r	x
Cormorant, double-crested	*Phalacrocorax auritus*				u	x
Bittern, least	*Ixobrychus exilis*		r			x
Bittern, American	*Botaurus lentiginosus*		r		r	x
Heron, black-crowned night	*Nyticorax nyticorax*	x	x	x	m	x
Heron, yellow-crowned night	*Nyctanassa violacea*		r			
Heron, green	*Butorides virescens*	x	c	b	b	x
Heron, tricolored	*Egretta tricolor*					x
Heron, little blue	*Egretta caerulea*	x				x
Egret, cattle	*Bubulcus ibis*					x
Egret, snowy	*Egretta thula*					x
Egret, great	*Ardea alba*	x	r		u	x
Heron, great blue	*Ardea herodias*	x	c		c	x
Swan, tundra	*Cygnus columbianus*		x			x
Swan, mute	*Cygnus olor*					x
Goose, snow	*Chen caerulescens*		r			x
Goose, Canada	*Branta canadensis*	x	c	x	b	x
Brant	*Branta bernicla*					x
Duck, wood	*Aix sponsa*	x	c	n	b	x
Mallard	*Anas platyrhynchos*	x	c	n	b	x
Duck, American black	*Anas rubripes*	x	c		u	x
Gadwall	*Anas strepera*		x		m	x
Teal, green-winged	*Anas crecca*		x		m	x
Wigeon, American	*Anas americana*	x	c		m	x
Wigeon, Eurasian	*Anas penelope*	x	r			x
Pintail, northern	*Anas acuta*	x	r			x
Shoveler, northern	*Anas clypeata*	x	x		m	x
Teal, blue-winged	*Anas discors*	x	c		m	x
Canvasback	*Aythya valisineria*		x			x
Redhead	*Aythya americana*		x		r	x
Duck, ring-necked	*Aythya collaris*	x	x		m	x
Scaup, greater	*Aythya marila*		c		m	x
Scaup, lesser	*Aythya affinis*	x	c			x
Scoter, black	*Melanitta nigra*					x
Scoter, white-winged	*Melanitta fusca*					x
Scoter, surf	*Melanitta perspicillata*					x

Table G-5: Birds of the Doan Brook

Common Name	Scientific Name	Shaker Lakes Area				Site 14
		1966	1973-79	1979 BBC	1997-99	1980-2000
Duck, harlequin	*Histrionicus histrionicus*					x
Long-tailed duck	*Clangula hyemalis*		r			x
Goldeneye, common	*Bucephala clangula*	x	c		u	x
Bufflehead	*Bucephala albeola*	x	x	m	m	x
Merganser, common	*Mergus merganser*	x	x		r	x
Merganser, red-breasted	*Mergus serrator*	x	c		m	x
Merganser, hooded	*Lophodytes cucullatus*	x	r		m	x
Duck, ruddy	*Oxyura jamaicensis*	x	x		m	x
Vulture, turkey	*Cathartes aura*		x		u	x
Osprey	*Pandion haliaetus*	x	r		u	x
Harrier, northern	*Circus cyaneus*		x			x
Eagle, bald	*Haliaeetus leucocephalus*				r	x
Hawk, sharp shinned	*Accipiter striatus*		r		u	x
Hawk, cooper's	*Accipiter cooperii*	x	x		u	x
Goshawk, northern	*Accipitier gentilis*		r			x
Hawk, broad-winged	*Buteo platypterus*	x	x			x
Hawk, red shouldered	*Buteo lineatus*		x		r	x
Hawk, red-tailed	*Buteo jamaicensis*	x	c		b	x
Hawk, rough legged	*Buteo lagopus*		r			x
Kestrel, American	*Falco sparverius*	x	c			x
Merlin	*Falco columbarius*		r		r	x
Falcon, peregrine	*Falco peregrinus*					x
Pheasant, ring-necked	*Phasianus colchicis*		r			x
Turkey, wild	*Malleagris gallopavo*				r	
Rail, king	*Railus elegans*					x
Rail, Virginia	*Rallus limicola*		r			x
Rail, yellow	*Coturnicops noveboracensis*					x
Rail, sora	*Porzana carolina*	x	r		u	x
Moorhen, common	*Gallinula chloropus*					x
Coot, American	*Fulica americana*	x	x		m	x
Crane, sandhill	*Grus canadensis*					x
Plover, black-bellied	*Pluvialis squatarola*					x
Plover, American golden-	*Pluvialis dominica*					x
Plover, piping	*Charadrius melodus*					x
Plover, semipalmated	*Charadrius semipalmatus*					x
Killdeer	*Charadrius vociferus*	x	c	b	b	x
Avocet, American	*Recurvirostra americana*					x
Willet	*Catoptrophorus semipalmatus*					x
Yellowlegs, greater	*Tringa melanoleuca*	x	x		m	x
Yellowlegs, lesser	*Tringa flavipes*	x	x		m	x
Sandpiper, solitary	*Tringa solitaria*	x	x		c	x

Table G-5: Birds of the Doan Brook

Common Name	Scientific Name	Shaker Lakes Area				Site 14
		1966	1973-79	1979 BBC	1997-99	1980-2000
Sandpiper, spotted	*Actitis macularia*	x	c	b	c	x
Whimbrel	*Numinius phaeopus*					x
Godwit, marbled	*Limosa fedoa*					x
Godwit, hudsonian	*Limosa haemastica*					x
Turnstone, ruddy	*Arenaria interpres*					x
Sandpiper, purple	*Calidris maritima*					x
Knot, red	*Calidris canutus*					x
Sanderling	*Calidris alba*					x
Dunlin	*Calidris alpina*					x
Sandpiper, curlew	*Calidris ferruginea*					x
Sandpiper, semipalmated	*Calidris pusilla*					x
Sandpiper, western	*Calidris mauri*					x
Sandpiper, least	*Calidris minutilla*		x		r	x
Sandpiper, white-rumped	*Calidris fuscicollis*					x
Sandpiper, Baird's	*Calidris bairdii*					x
Sandpiper, pectoral	*Calidris malanotos*		x			x
Sandpiper, sharp-tailed	*Calidris acuminata*					x
Sandpiper, upland	*Bartramia longicauda*					x
Sandpiper, buff-breasted	*Tryngites subruficollis*					x
Ruff	*Philomachus pugnax*					x
Dowitcher, short-billed	*Limnodromus griseus*					x
Dowitcher, long-billed	*Limnodromus scolopaceus*					x
Sandpiper, stilt	*Calidris himantopus*					x
Snipe, common	*Gallinago galinago*		x		u	x
Woodcock, American	*Scolopax minor*	x	x		u	x
Phalarope, Wilson's	*Phaloropus tricolor*		r			x
Phalarope, red-necked	*Phalaropus lobatus*					x
Phalarope, red	*Phalaropus fulicaria*					x
Jaeger, pomarine	*Stercorarius pomarinus*					x
Jaeger, parasitic	*Stercorarius parasiticus*					x
Gull, Franklin's	*Larus pipixcan*					x
Gull, laughing	*Larus atricilla*					x
Gull, Bonaparte's	*Larus philadelphia*		x			x
Gull, black-headed	*Larus ridibundus*					x
Gull, little	*Larus minutus*					x
Gull, ring-billed	*Larus delawarensis*	x	c		c	x
Gull, California	*Larus californicus*					x
Gull, herring	*Larus argentatus*	x	c	x	c	x
Gull, glaucous	*Larus hyperboreus*					x
Gull, Iceland	*Larus glaucoides*					x
Gull, Thayer's	*Larus thayeri*					x

Table G-5: Birds of the Doan Brook

Common Name	Scientific Name	Shaker Lakes Area				Site 14
		1966	1973-79	1979 BBC	1997-99	1980-2000
Gull, lesser black-backed	*Larus fuscus*					x
Gull, great black-backed	*Larus marinus*					x
Kittiwake, black-legged	*Rissa tridactyla*					x
Tern, Caspian	*Sterna caspia*		r		u	x
Tern, Forster's	*Sterna fosteri*					x
Tern, common	*Sterna hirundo*		r			x
Tern, least	*Sterna antillarum*					x
Tern, black	*Chlidonias niger*	x	r			x
Guillemot, black	*Cepphus grylle*					x
Dove, rock	*Columba livia*	x	c	n	c	x
Dove, mourning	*Zenaida macroura*	x	c	n	c	x
Cuckoo, yellow-billed	*Coccyzua americanus*	x	x	b?	u	x
Cuckoo, black-billed	*Coccyzus erythropthalmus*		x	m?		x
Owl, barn	*Tyto alba*					x
Owl, short eared	*Asio flammeus*		x			x
Owl, great horned	*Bubo virginianis*		x			x
Owl, barred	*Strix varia*	x	r			
Owl, snowy	*Nyctea scandiaca*		r			x
Owl, eastern screech	*Otus asio*		x			
Owl, northern saw-whet	*Aegolius acadicus*					x
Nighthawk, common	*Chordeiles minor*	x	c	x	c	x
Whip-poor-will	*Caprimulgus vociferus*		x			
Swift, chimney	*Chaetura pelagica*	x	c	x	c	x
Hummingbird, ruby throated	*Archilochus colubris*	x	x	b	c	x
Kingfisher, belted	*Megaceryle alcyon*	x	c	x	b	x
Woodpecker, red-headed	*Melanerpes erythrocephalus*	x	c	n	u	x
Woodpecker, red-bellied	*Melanerpes carolinus*		x		b	x
Flicker, northern	*Colaptes auratus*	x	c	n	b	x
Sapsucker, yellow-bellied	*Sphyrapicus varius*	x	x	m	m	x
Woodpecker, downy	*Picoides pubescens*	x	c	n	b	x
Woodpecker, hairy	*Picoides villosus*	x	c	b	b	x
Flycatcher, olive-sided	*Contopus borealis*		r		u	
Peewee, eastern wood	*Contopus virens*	x	x	b	b	x
Flycatcher, acadian	*Empidonax virescens*		x			x
Flycatcher, yellow bellied	*Empidonax flaviventris*		x			
Flycatcher, alder	*Empidonax alnorum*	x				x
Flycatcher, willow	*Empidonax traillii*		x			x
Flycatcher, least	*Empidonax minimus*	x	x		u	x
Phoebe, eastern	*Sayornis phoebe*	x	c	b	b	x
Flycatcher, great crested	*Myiarchus crinitus*	x	c	b	b	x
Kingbird, eastern	*Tyrannus tyrannus*	x	x		u	x

Table G-5: Birds of the Doan Brook						
Common Name	**Scientific Name**	**Shaker Lakes Area**				**Site 14**
		1966	**1973-79**	**1979 BBC**	**1997-99**	**1980-2000**
Shrike, loggerhead	*Lanius lodovicianus*		r			x
Shrike, northern	*Lanius excubitor*	x	r			x
Vireo, white-eyed	*Vireo griseus*	x	r			x
Vireo, yellow-throated	*Vireo flavifrons*	x	x		u	
Vireo, blue-headed	*Vireo solitarius*	x	x		m	x
Vireo, red-eyed	*Vireo olivaceus*	x	c	n	b	x
Vireo, Philadelphia	*Vireo philadelphicus*	x	x		m	x
Vireo, warbling	*Vireo gilvus*	x	x		m	x
Jay, blue	*Cyanocitta cristata*	x	c	n	b	x
Crow, American	*Corvus brachyrhynchos*	x		b	b	x
Lark, horned	*Eremophila alpestris*		r			x
Swallow, tree	*Tachycineta bicolor*	x	c		x	x
Martin, purple	*Progne subis*	x	x	x	x	x
Swallow, bank	*Riparia riparia*	x	x	x	x	x
Swallow, cliff	*Petrochelidon pyrrhonota*		r		x	x
Swallow, northern rough-winged	*Stelgidopteryx serripennis*	x	c	x	b	x
Swallow, barn	*Hirondo rustica*	x	c		m	x
Titmouse, tufted	*Parus bicolor*	x	c	b	b	x
Chickadee, black-capped	*Parus atricapilus*	x	c	n	b	x
Creeper, brown	*Certhia americana*	x	x		c	x
Nuthatch, white-breasted	*Sitta carolinensis*	x	c	b	b	x
Nuthatch, red-breasted	*Sitta canadensis*	x	x	n	u	x
Wren, house	*Troglodytes aedon*	x	c	b	b	x
Wren, winter	*Troglodytes troglodytes*	x	x		u	x
Wren, Carolina	*Thryothorus ludovicianus*	x	x		b	x
Wren, marsh	*Cistothous palustris*		r		r	x
Wren, sedge	*Cistothorus platensis*		r			x
Kinglet, golden-crowned	*Regulus satrapa*	x	x		m	x
Kinglet, ruby-crowned	*Regulus calendula*	x	r		m	x
Gnatcatcher, blue-gray	*Polioptila caerulea*	x	x	b	m	x
Bluebird, eastern	*Sialia sialis*		r			
Thrush, wood	*Hylocichla mustelina*	x	c	n	m	x
Veery	*Catharus fuscescens*	x	x		m	x
Thrush, gray-cheeked	*Catharis minimus*	x	x		u	x
Thrush, Swainson's	*Catharus ustulatus*	x	x	m	m	x
Thrush, hermit	*Catharus guttatus*	x	x		m	x
Robin, American	*Turdus migratorius*	x	c	n	b	x
Catbird, gray	*Dumetella carolinensis*	x	c	n	b	x
Mockingbird, northern	*Mimus polyglottus*		r			x
Thrasher, brown	*Toxostoma rufum*	x	c	b	m	x
Starling, European	*Sturnus vulgaris*	x	c	n	b	x

Table G-5: Birds of the Doan Brook						
Common Name	Scientific Name	Shaker Lakes Area				Site 14
		1966	1973-79	1979 BBC	1997-99	1980-2000
Pipit, American	*Anthus rubescens*					x
Pipit, Sprague's	*Anthus spragueii*					x
Waxwing, cedar	*Bombycilla cedrorum*	x	c	b	c	x
Warbler, prothonotary	*Protonotaria citrea*	x	x		u	
Warbler, blue-winged	*Virmivora pinus*	x	c		m	
Warbler, golden-winged	*Vermivora chrysoptera*	x	x		m	
Warbler, Tennessee	*Vermivora peregrina*	x	c		m	x
Warbler, orange-crowned	*Vermivora celata*	x	x		m	x
Warbler, Nashville	*Vermivora ruficapilla*	x	c		m	x
Parula, northern	*Parula americana*	x	x		m	x
Warbler, chestnut-sided	*Dendroica pensylvanica*	x	x		m	x
Warbler, Cape May	*Dendroica tigrina*	x	c		m	x
Warbler, magnolia	*Dendroica magnolia*	x	c		m	x
Warbler, yellow-rumped	*Dendroica coronata*	x	c	m	m	x
Warbler, black and white	*Mniotilta varia*	x	c	m	m	x
Warbler, black-throated blue	*Dendroica caerulescens*	x	x		m	x
Warbler, cerulean	*Dendroica cerulea*	x	x		m	
Warbler, blackburnian	*Dendroica fusca*	x	x		m	x
Warbler, black-throated green	*Dendroica virens*	x	c	m	m	x
Warbler, yellow-throated	*Dendroica dominica*	x	r		r	
Warbler, prairie	*Dendroica discolor*	x	r		u	
Warbler, bay-breasted	*Dendroica castenea*	x	c		m	x
Warbler, blackpoll	*Dendroica striata*	x	x		m	x
Warbler, pine	*Dendroica pinus*	x	r		u	x
Warbler, palm	*Dendroica palmarum*	x	c		m	x
Warbler, yellow	*Dendroica petechia*	x	c	b?	m	x
Warbler, mourning	*Oporornis philadelphia*	x	x		r	x
Warbler, Connecticut	*Oporornis agilis*	x	r			x
Warbler, Kentucky	*Oporornis formosus*	x	r			
Warbler, Canada	*Wilsonia canadensis*	x	c		m	x
Warbler, Wilson's	*Wilsonia pusilla*	x	c		m	x
Warbler, hooded	*Wilsonia citrina*	x	x		m	
Warbler, worm-eating	*Helmitheros vermivorus*	x	r			
Ovenbird	*Seiurus aurocapillus*	x	c		m	x
Waterthrush, Louisiana	*Seiurus motocilla*	x	x		m	
Waterthrush, northern	*Seiurus noveboracensis*	x	x		m	x
Yellowthroat, common	*Geothlypis trichas*	x	x	b?	m	x
Chat, yellow-breasted	*Icteria virens*	x				x
Redstart, American	*Setophaga ruticilla*	x	c	b?	m	x
Tanager, summer	*Piranga rubra*		r?		r	x
Tanager, scarlet	*Piranga olivacea*	x	c	b?	m	x

Table G-5: Birds of the Doan Brook

Common Name	Scientific Name	Shaker Lakes Area				Site 14
		1966	1973-79	1979 BBC	1997-99	1980-2000
Towhee, eastern	*Pipilo erythrophthalmus*	x	c		m	x
Sparrow, American tree	*Spizella arborea*	x	c		m	x
Sparrow, field	*Spizella pusilla*	x	c		m	x
Sparrow, chipping	*Spizella passerina*	x	c	b	m	x
Sparrow, clay colored	*Spizella pallida*		r			x
Sparrow, grasshopper	*Ammodramus savannarum*					x
Sparrow, Henslow's	*Ammodramus henslowii*		x			x
Sparrow, Le Conte's	*Ammodramus leconteii*					x
Sparrow, Nelson's sharp-tailed	*Ammodramus nelsoni*					x
Sparrow, fox	*Passerella iliaca*	x	x		u	x
Sparrow, Savannah	*Passerculus sandwichensis*	x	x			x
Sparrow, Lincoln's	*Melospiza lincolnii*		x		m	x
Sparrow, song	*Melospiza melodia*	x	c	b	m	x
Sparrow, vesper	*Pooeceter gramineus*	x	x			x
Sparrow, swamp	*Melospiza georgiana*		x		u	x
Sparrow, white-throated	*Zonotrichia albicollis*	x	c		m	x
Sparrow, white-crowned	*Zonotrichia leucophrys*	x	x		m	x
Junco, dark-eyed	*Junco hyemalis*	x	c		m	x
Longspur, Smith's	*Calcarius pictus*					x
Longspur, Lapland	*Calcarius lapponicus*					x
Bunting, snow	*Plectrophenax nivalis*		x			x
Grosbeak, rose-breasted	*Pheucticus ludovicianus*	x	c		m	x
Cardinal, northern	*Cardinalis cardinalis*	x	c	n	b	x
Dickcissel	*Spiza americana*					x
Bunting, indigo	*Passerina cyanea*	x	c		u	x
Bobolink	*Dolichonyz oryzivorus*					x
Meadowlark, eastern	*Sturnella magna*	x	x			x
Blackbird, yellow-headed	*Xanthocephalus xanthocephalus*				r	x
Blackbird, red-winged	*Agelaius phoeniceus*	x	c	n	b	x
Grackle, common	*Quiscalus quiscula*	x	c	n	b	x
Blackbird, rusty	*Euphagus carolinus*	x	x			
Cowbird, brown-headed	*Moluthrus ater*	x	c	b	b	x
Oriole, orchard	*Icterus spurius*		r		r	x
Oriole, Baltimore	*Icterus galbula*	x	c	b	m	x
Finch, purple	*Carpodacus purpureus*	x	r		u	
Finch, house	*Carpodacus mexicanus*		r	b	b	x
Crossbill, red	*Loxia curvirostra*	x	r			x
Crossbill, white-winged	*Loxia leucoptera*	x	r?			
Siskin, pine	*Carduelis pinus*	x	x			x
Goldfinch, American	*Carduelis tristis*	x	c	b	b	x
Redpoll, common	*Carduelis flammea*	x	x		u	x

Table G-5: Birds of the Doan Brook						
Common Name	Scientific Name	Shaker Lakes Area				Site 14
		1966	1973-79	1979 BBC	1997-99	1980-2000
Grosbeak, evening	*Coccothraustes verspertinus*	x	r			
Sparrow, house	*Passer domesticus*	x	c	n	b	x
Bishop, Orange	*Euplectes franciscanus*					exotic
Waxbill, black-rumped	*Estrilda troglodytes*					exotic

x = species is present
c = species is a common resident
m = species is a regular migrant
u = species is unusual
r = species is rare
b = species is breeding in the area
n = there is direct evidence of species nesting in the area (1979 BBC only)
exotic = a non-native bird that is assumed to be an escaped cage bird

Different surveyors used different notations and criteria in their surveys, so that a species labeled present in the 1966 survey or the Site 14 survey may be indicated as common, unusual, or rare in another survey, etc.
Site 14 refers to the Corps of Engineers Site 14 Diked Disposal Area on Lake Erie at the mouth of Doan Brook.

Data Sources:
Shaker Lakes 1966: List compiled by Perry Peskin 1966.
Shaker Lakes 1973-79 and 1979 BBC: Institute for Environmental Education 1979.
Shaker Lakes 1997-99: Compiled from the records of Laura Gooch and Leo Deininger.
Site 14 1980-2000: Sean T. Zadar.

Table G-6: Mammals Along the Doan Brook			
Common Name	**Scientific Name**	**1979**	**1994**
Opossum	*Didelphis virginiana*	u	p
Shrew, short-tailed	*Blarina breicauda*	x	p
Raccoon	*Procyon lotor*	c	p
Skunk	*Mephistis mephisis*	u	p
Woodchuck	*Marmota monax*	x	p
Chipmunk, eastern	*Tamias striatus*	c	p
Squirrel, fox	*Sciurus niger*	c	p
Squirrel, flying	*Glaucomys volans*	r	
Mouse, white-footed	*Peromyscus leucopus*	c	p
Vole, meadow	*Microtus pennsylvanicus*	u	
Muskrat	*Ondatra zibethica*	c	
Rat, Norway	*Rattus norvegicus*	u	
Mouse, house	*Mus musculus*	u	
Rabbit, eastern cottontail	*Sylvilagus floridans*	c	p
Mole, common	*Scalopus aquaticus*	p	
Mole, hairy-tailed	*Parascalops breweri*	l	
Mole, star-nosed	*Condylura cristata*	p	
Shrew, masked	*Sorex cinereus*	p	
Bat, big brown	*Eptesicus fuscus*	x	
Bat, little brown	*Myotis lucifugus*	x	
Bat, red	*Lasiurus borealis*	x	
Weasel, New York	*Mustela frenata novaboracensis*	p	
Fox, red	*Vulpes fulva*	p	
Squirrel, red	*Tamiasciurus hudsonicus*	p	
Squirrel, gray	*Sciurus carolinensis*		p
Mouse, deer	*Peromyscus maniculatus bairdii*	p	p
Mouse, meadow jumping	*Zapua hudsonius*	p	
Deer, white-tailed	*Dama virginiana*	x	p

x = present u = uncommon r = rare p = possible (not observed)
l = likely (not observed)

Data Sources: 1979: Institute for Environmental Education. 1979.
1994: URS Consultants. 1994.

Table G-7: Reptiles and Amphibians of the Doan Brook				
Type	**Common Name**	**Scientific Name**	**1968**	**1979**
Frogs and Toads				
	American toad	*Bufo americanus*		small numbers
	Bullfrog	*Rana catesbeiana*		release; reproduction doubtful
	Green frog	*Rana clamitans*	present	release; reproduction doubtful
	Leopard frog	*Rana pipiens*	1 present	possible
	Spring peeper[1]	*Hyla crucifer*		
Salamanders				
	Dusky salamander	*Desmognathus fuscus*	present	absent - should be present
	Red-backed salamander	*Plethodon cinereus*	present	rare
	Slimy salamander	*Plethodon glutinosis*	present	
	Spotted newt	*Diemictylus viridescens*	released	absent - should be present
	Two-lined salamander	*Eurycea bislineata*		rare
Snakes				
	Black rat snake	*Elaphae obsoleta*		release
	Brown or Dekay snake	*Storeria dekayi*		probably present in small numbers
	Common water snake	*Natrix sipedon*		absent - should be present
	Eastern garter snake	*Thamnophis sirtalis*		probably present in small numbers
	Milk snake	*Lampropeltis doliata*	present	
	Red-bellied snake	?	present	
Turtles				
	Blanding's turtle	*Emydoidea blandingi*	present	present
	Box turtle	*Terrapene carolina*	present	release
	Map turtle	*Graptemys geographica*		probable
	Midland painted turtle	*Chrysemys picta marginata*	present	present
	Red-eared turtle	*Pseudemys scripta elegans*		release
	Snapping turtle	*Chelydra serpentina*	present	present
	Spotted turtle	*Clemmys guttata*		release
	Stinkpot	*Sternotharus odoratus*		present
	Wood turtle	*Clemmys insculpata*		release

[1] Reported "present or expected" by URS 1994.

Table G-8: Fish in the Doan Brook			
Common Name	**Scientific Name**	**1979**	**1994**
Common carp	*Cyprinus carpio*		b
Shiner	*Notropis sp.*		b
Green sunfish	*Lepomis cyanellus*	uplh	
Fathead minnow	*Pimephales promelas*	uplh	
Goldfish	*Carassius auratus*	uplh	

Fish Location Key:
u = brook u/s from Lower Shaker Lake p = lily pond l = Lower Shaker Lake h = Horseshoe Lake
m = Marshall Lake g = Green Lake b = brook d/s from Lower Shaker Lake

Data Sources for Tables G-7 and G-8:
1968: Wolfe, Ronald. 1968.
1979: The Institute for Environmental Education. 1979.
1994: URS Consultants. 1994.

Table G-9: Fish Expected in the Doan Brook			
Common Name	**Scientific Name**	**1979**	**1994**
Mudminnow, central	*Umbra limi*	p	
Pickerel, redfin	*Esox americanus vermicularis*	lp	
Sucker, hog	*Hypentilium nigricans*	b	
Sucker, white	*Catostomus c. commersoni*	bl	b
Sucker, spotted	*Minytrema melanops*	l	
Carp, common	*Cyprinus carpio*	lp	b
Goldfish	*Carassius auratus*	blp	b
Shiner, golden	*Notemigonus crysoleueas*	blp	b
Dace, blacknose	*Rhinichthyes atratulus*	b	
Dace, redbelly	*Phoxinus erythrogaster*	b	
Dace, redside	*Clinostomus elongatus*		
Chub, creek	*Semotilus atromaculatus*	b	
Shiner, central striped	*Notropis chrysocephalus*	b	b
Shiner, emerald	*Notropis atherinoides*		b
Shiner, spotfin	*Notropis cornutus*	bl	b
Shiner, spottail	*Notropis hudsonius*		b
Minnow, silverjaw	*Ericymba buccata*	b	
Minnow, fathead	*Pimephales p. promelas*	blp	
Minnow, bluntnose	*Pimephales notatus*	bl	b
Minnow, stoneroller	*Campostoma anomalum*	b	
Catfish, channel	*Ictatalurus punctatus*	l	
Bullhead, black	*Ictalurus melos*	blp	b
Bullhead, brown	*Ictalurus nebulosus*	lp	
Bullhead, yellow	*Ictalurus natalis*		b
Silverside, brook	*Labidesthes sicculus*	bl	
Crappie, white	*Pomoxis annularis*	l	
Bass, largemouth black	*Micropterus s. salmoides*	blp	
Sunfish, green	*Lepomis cyanellus*	blp	
Sunfish, bluegill	*Lepomis m. macrochirus*	blp	
Sunfish, pumpkinseed	*Lepomis gibbosus*	blp	b
Sunfish, warmouth	*Lepomis gulosus*	lp	
Darter, Johnny	*Etheostoma n. nigrum*	b	
Darter, rainbow	*Etheostoma caeruleum*	b	
Darter, faintail	*Etheostoma f. flabellare*	b	
Stickleback, brook	*Cualea inconstanus*	p	

Fish Location Key:

u = brook u/s from Lower Shaker Lake
p = lily pond
l = Lower Shaker Lake
h = Horseshoe Lake
m = Marshall Lake
g = Green Lake
b = brook d/s from Lower Shaker Lake

Data Sources:
1979: The Institute for Environmental Education. 1979.
1994: URS Consultants. 1994.

Table G-10: Macroinvertebrates in the Shaker Lakes

Common Name	Scientific Name	1973	1974	1979	1998
	Corethrella	l			
	Einfeldia	l			
Aquatic Worms	*Oligochaeta*	l			hl
	Lumbricidae		l		
	Lumbriculus sp.		hl		
	Lumbriculus inconstans			hl	
	Aulodrilus piqueti	l			
	Aulodrilus pluriseta	l			
	Branchiura sp.		l		
	Branchiura sowerbyi	l		l	
	Orphodinais serpentina	l			
	Nais sp.	l			
	Tubificidae		l		
	Tubifex sp.		l		
	Tubifex tubifex	l		hl	
	Enchytraeus sp.		l	l	
	Dero sp.	l			
	Limnodrilus sp.		hl	hl	
	Limnodrilus hoffmeisteri	l			
	Limnodrilus cervix	l			
	Limnodrilus spirallis	l			
	Limnodrilus maumeensis	l			
	Peloscolex sp.		l	l	
	Aleosoma sp.			h	
Bivalves	*Spaerium sp.*		l		
Dragonflies	Ishnura sp.		l	hl	
	Dibullula sp.			hl	
	Gomphus sp.			l	
Flatworms	*Dugesia sp.*		l		
Flies	*Ceratopogonidae*				h
	Pentaneura sp.		hl	hl	
	Chironomus sp.	l	hl	hl	hl
	Harnischia	l			
	Chironomus chironomus			hl	
	Cryptochironomus	l			
	Glyptotendipes lobiferus	l			
	Polypedilum sp.		l	l	
	Cricotopus sp.	l	h		

Table G-10: Macroinvertebrates in the Shaker Lakes					
Common Name	**Scientific Name**	**1973**	**1974**	**1979**	**1998**
	Orthocladius sp.		l		
	Simulium sp.		l		
Leeches	*Erpobdella sp.*		l		
	Erpobdella punctata			hl	
	Helobdella stagnalis			hl	
	Dina sp.	?	l	l	
	Placobdella sp.		h		
Moss Animals	*Plumatella sp.*			h	
Nematodes	*Nematoda*	l			
Snails	*Gastropoda*				h
	Physa sp.		hl	hl	
	Lymaea sp.			hl	
	Viviparus sp.		hl	hl	
	Viviparus georgianus	l			
	Gyraulus sp.		l		
Sponges	*Hydra*	l			
Watermite	*Hydracarina*		l		

Location Key: l = Lower Shaker Lake h = Horseshoe Lake

Data Sources:
1973: Bill, Steven. 1973.
1974: Water Quality Program: Cleveland Department of Public Utilities. 1976.
1979: Institute for Environmental Education. 1979.
1998: Montgomery Watson. October 1999.

Table G-11: Macroinvertebrates in the Doan Brook						
Common Name	**Scientific Name**	**1974**	**1987**	**1989**	**1990**	**1998**
Aquatic Worms	*Oligochaeta*		nc		nc	launecs
	Lumbricidae	n				
	Haplotaxis sp.	n				
	Naidium sp.	n				
	Tubificidae		l			
Bivalves	*Anadonta grandis*					uc
	Fusconaja flava					c
Caddisflies	*Cheumatopsyche sp.*					la
	Hydropsyche betteni			l		laun
	Hydropsyche simulans					laun
	Hydroptilia sp.					l
	Hydroptilis cansmilis					l
Crustaceans	*Grammarus sp.*					laucs
	Crangonyx gracilis			l		
	Caecidotea sp.					a
	Pelecypods		nc			
Dragonflies	*Calopteryx sp.*					lau
	Enallagma sp.			nc	nc	laucs
	Erythemis sp.					u
	Hetaerina sp.					n
	Argia sp.			nc	n	n
	Somatochlora sp.					n
Flatworms	*Platyhelminthes*		c	nc	nc	acs
Flies	*Tipula sp.*					lus
	Psychodidae sp.			l		
	Simulium sp.	n		lnc	c	launes
	Chironimidae		lnc			
	Natarsia sp.				c	
	Ablablesmyia sp.				c	c
	Thienemannimyia sp.			c		
	Conchapelopia sp.					launcs
	Penteneura sp.	n	l			
	Paratanytarsus sp.					lun
	Rheotanytarsus distinctissimus					lu
	Rheotanytarsus exiguus					laun
	Tanytarsus glabrescens					luns

Table G-11: Macroinvertebrates in the Doan Brook						
Common Name	**Scientific Name**	**1974**	**1987**	**1989**	**1990**	**1998**
	Tanytarsus guerlus					launc
	Chironomus sp.	n		l		
	Chironomus riparius					l
	Dicrotendipes sp.				c	
	Dicrotendipes modestus					lune
	Dicrotendipes neomodestus					aes
	Dicrotendipes nervosus					lunecs
	Dicrotendipes simpsoni					ec
	Endochironomus nigricans					lun
	Endochironomus subtendens					luc
	Glyptotendipes sp.	n		l		laun
	Paratendipes sp.					launecs
	Phaenospectra dyari (?)					au
	Phaenospectra flavipes					lanes
	Polypedilum sp.				c	
Flies, *continued*	*Polypedilum convictum*					lune
	Polypedilum illenoense					lune
	Polypedilum scalaenum					nes
	Stenochironomus sp.					a
	Tribelos sp.					s
	Cardiocladius obscurus					l
	Cricotopus sp.	n		l	c	
	Cricotopus bicinctus					lue
	Cricotopus vierriensis					l
	Nanocladius crassicornus					luec
	Synorthocladius sp.					lau
	Nanocladius minimus					l
	Empididae					lue
	Hemerodromia sp.					ln
	Larsia sp.					s
	Odontomyia sp.					u
Leeches	*Hirudineans*		nc			
	Erpobdella parva					u
	Erpobdella puntata					launcs
	Erpobdella sp.			nc		
	Moorebdella microstoma					l
	Moorebdella tetragon					c

Table G-11: Macroinvertebrates in the Doan Brook

Common Name	Scientific Name	1974	1987	1989	1990	1998
	Moorebdella sp.				c	
	Alboglossiphonia heteroclita					lac
	Gloiobdella elongata					lncs
	Helobdella fusca					lac
	Helobdella stagnalis					l
Mayflies	*Baetis sp.*		c	nc		launcs
	Centroptilium sp.					u
Snails	*Gastropods*		nc			
	Physa sp.	n				
	Physa vernalis					l
	Physella sp.			lc	c	
	Planorbella trivolvus sp.					l
	Marstonia decepta					u
	Fossaria parva					c
	Amnicola limnosa			nc	nc	c
	Sphaerium sp.			n	nc	
	Gyraulus circumstriatus				n	
	Gyraulus parvus				c	
	Helisoma anceps				c	
Sponges	*Spongillidae*					ac
True Bugs	*Ramphocorixa sp.*					l
	Merragata sp.					l
	Gerridae					s

Location Key:

l = lower watershed (Rockefeller Park)
n = between Horseshoe and Lower Shaker Lake
c = u/s from Lower Shaker Lake, S. Branch
a = Ambler Park
u = d/s from Lower Shaker Lake
e = u/s from Horseshoe Lake, N. Branch
s = d/s Shaker Golf Cours, S. Branch

Data Sources: 1974: Institute for Environmental Education. 1979.
1987-1998: NEORSD. Additional data may be available from NEORSD.

Appendix G – Doan Brook Biology Data

Appendix H

This appendix includes a discussion of the meaning and calculation of flood return periods (Section H.1), a summary of basic background information about the hydrology of Doan Brook (Section H.2), and a list of the references that were used to compile hydrologic information (Section H.3).

Hydrologic data are summarized in the following tables:

H-1 Summary of Doan Brook Hydrologic Information

H-2 Summary of Information About Major Doan Brook Culverts

H-3 Doan Brook Peak Ten-Year Flood Flows: Estimates from Different Sources

Figure H-1 shows a plan and profile of the University Circle Culvert.

Different sources give many conflicting figures for the basic data about the brook. Where possible, the information given here has been confirmed by direct measurement. Where measurement was not possible, different data sources were examined and the information that appeared to be most reliable was included.

H.1 Flood Return Periods: What Do We Mean by the 100-Year Flood?

When we talk about flooding on Doan Brook, we talk about what will be under water during a "ten-year flood," or a "100-year flood." But what do we mean by the ten-year flood? Flood frequency, flood return period, and flood magnitude have technical definitions that are not obvious and require some explanation.

A ten-year flood is defined as a flood[1] that has a one in ten chance of being equaled or exceeded in any given year. This can be restated in two different ways:

> *(1) There is a one in ten (ten percent) chance that a flood as large (or larger) than the ten-year flood will occur in any year. (2) On average, one flood with the magnitude of the ten-year flood, or a larger flood, will occur in any given ten-year period. (Note that the second statement does not imply that two ten-year floods cannot occur in two consecutive years.)*

The definition of the ten-year flood can be applied to a flood with any return period. Thus there is a one in X chance that the X-year flood will be equaled or exceeded in a given year.

Before we go on to discuss flood frequencies on Doan Brook, it is worth noting several points about the nature of flood return periods and flood magnitudes:

- Historical records are used to estimate the magnitudes of the floods that can be expected on a stream. Where actual historical data on stream flow are available (from a stream gage), these data are used. Where not enough stream flow data are available (as for Doan Brook), rainfall data are used in conjunction with runoff modeling and the available stream flow data to estimate flood levels.
- The magnitude of the ten-year flood is an

1 Ten years is the *flood frequency* or *flood return period*. The *magnitude* (usually expressed in cubic feet per second, or cfs) of the ten-year flood is the peak flow during the flood that has a ten-year return period.

estimate. There are many different techniques for estimating flood magnitudes, and two different techniques may give very different results. As a glance at Table H-3 will show, estimates for the ten-year flood on Doan Brook vary widely (see further discussion below).

- Floods are independent events, with each one having no impact on any other.[2] Thus the fact that a 100-year flood may, for example, have occurred last year does not change the likelihood (one in a hundred) that a 100-year flood, or a larger flood, will occur this year.[3]

Table H-3 dramatically illustrates that the magnitude of the ten-year flood is an estimate. In 1999, Montgomery Watson estimated that the ten-year flood flow in Doan Brook at University Circle would be approximately 2,243 cfs. More than thirty years earlier, the Stanley Engineering Company estimated that the ten-year flood at the same spot would be 5,515 cfs — over twice as large. The Doan Brook watershed changed little between 1964 and 1999. Why are these estimates so different and which is correct?

The answer to this question stems from the fact that two valid but very different techniques were used to estimate the two flood flows. Generally stated, the methods used by Stanley and Montgomery Watson can be described as follows:

- The authors of the Stanley report had no stream gage data from Doan Brook that they could use to correlate rainfall with flow in the brook. They therefore used rainfall data for the watershed to estimate flood flows. To do this, they divided the watershed into logical subwatersheds, evaluated the land use in each subwatershed, estimated the runoff from each area that would result from a given rainfall, and "routed" the runoff from the subwatersheds to estimate flows in Doan Brook. While a complete evaluation of the work described in the Stanley report is far beyond the scope of this handbook, the methods used were generally appropriate in the absence of stream flow data.
- Unlike the engineers who prepared the Stanley report, Montgomery Watson's hydrologists had access to some stream flow data. For a four-month period in the spring and summer of 1998, Montgomery Watson installed stream gages at a number of points on Doan Brook and collected rainfall and stream flow data from the watershed. The sampling period contained one moderate flood with about a one- to two-year return period. They used their rainfall and stream flow data to create a computer model of the way that the watershed responds to rainfall, checking their watershed model by seeing whether it could predict some of the storms they had actually observed. They then put historical rainfall data into their model and used it to extrapolate larger floods such as the five-, ten-, and fifty-year flows. Like the methods described in the Stanley report, the methods used by Montgomery Watson were generally appropriate given the information they had to work with.

These two apparently appropriate models of Doan Brook result in two estimates of the ten-year flood, one twice as large as the other. Which should we believe? One's first instinct is to rely on the estimate given by Montgomery Watson. It is based on some actual data from the watershed, and Montgomery Watson's engineers had the benefit of the hydrologic models and computers available in the year 2000. The results of their model can certainly be expected to be accurate for small floods like those that they observed while their stream gages were in place. However, the use of this kind of model to estimate larger floods may give less accurate results. For these larger floods, the results of techniques like those used by Stanley must still be considered, and the strengths and weaknesses of each approach to estimating flood magnitude must be taken into account.

Historical records of flooding in University Circle do not shed much light on the appropriate size of the ten-year flood. However, records do show that several feet of water have inundated University Circle seven times since 1959, or about once every six years. Montgomery Watson's estimates do not predict that there should be significant flooding in University Circle quite so often. Stanley's estimates, by contrast, predict that flooding might be more frequent. The historical data therefore suggest that the "true" ten-year flood flow may lie somewhere between the estimate developed by Montgomery Watson and the estimate developed by Stanley.

2 While this statement does not always hold for floods that are caused by a single weather pattern, it is generally valid.

3 The occurrence of several 100-year or larger floods within the space of a few years suggests (but does not prove) that the estimated magnitude of the 100-year flood should be reevaluated.

H.2
Hydrologic Data Summaries

Table H-1	Summary of Doan Brook Hydrologic Information	
Item	**Values**	**Notes**
Stream Length	About 8.4 miles (along the north branch)	
Total Surface Watershed	11.7 square miles (7,500 acres)	Montgomery Watson 1999 (b)
Total Sewershed	20.1 square miles (12,900 acres) in 1999 9.8 square miles (6,300 acres) after completion of the Heights/Hilltop Interceptor	Montgomery Watson 1999 (b, c)
University Circle Watershed	8.7 square miles (5,560 acres)	Montgomery Watson 1999 (d)
Lower Shaker Lake	Watershed: 5.0 square miles (3,190 acres) Surface Area: 17.6 acres (19.2 acres including Lily Pond marsh) Volume: 2,454,000 cubic feet Average Depth: 3.2 feet Maximum Depth: 8.3 feet Elevation of Dam: 905.3 feet MSL Top Width of Dam: 45 feet Top Length of Dam: 600 feet Maximum Dam Height: 17.3 feet Spillway: 39.5-foot crested masonry drop structure at elevation 903 feet MSL. Three feet clearance to bridge.	Montgomery Watson 1999 (a, d); Dam data from ODNR 1980 (a); Notes: Data on dam may have changed due to subsequent repairs. Watershed reflects adjustment to Horseshoe Lake watershed.
Horseshoe Lake	Watershed: 1.9 square miles (1,200 acres) Surface Area: 12.5 acres Volume: 1,547,000 cubic feet Average Depth: 2.8 feet Maximum Depth: 6.5 feet Outlet Elevation: 978.0 feet MSL Elevation of Dam: 982.2 feet MSL Top Width of Dam: 14 feet Top Length of Dam: 615 feet Maximum Dam Height: 30 feet Spillway: 10-foot diameter drop inlet at elevation 978 feet MSL	Montgomery Watson 1999 (a, d); ODNR 1980 (b) for dam data; Notes: Data on dam may have changed due to subsequent repairs. Watershed area includes some area between lake arms not included in Montgomery Watson area.
Green Lake	Watershed: 1.5 square miles (967 acres) Surface Area: 7.4 acres Volume: 940,000 cubic feet Average Depth: 2.9 feet Maximum Depth: 5.3 feet	Montgomery Watson 1999 (a)
Marshall Lake	Watershed: 1.8 square miles (1,440 acres) Surface Area: 6.3 acres Volume: 924,000 cubic feet Average Depth: 3.4 feet Maximum Depth: 6.6 feet	Montgomery Watson 1999 (a)
Martin Luther King, Jr., Boulevard Detention Basin	Watershed: 5.7 square miles (3,660 acres) Elevation of Dam: 761.9 feet MSL Outlet: 9-foot by 6.5-foot box culvert with upstream invert at 733.9 feet MSL (at the base of the dam) Maximum Dam Height: 28 feet (approximate)	Montgomery Watson 1999 (c)

Table H-2	Summary of Information About Major Doan Brook Culverts	
Culvert	**Data**	**Source**
South Branch – Canterbury Golf Course to Shaker Country Club Golf Course	Length: 2000 feet (very approximate)	USGS topographic maps
Middle Branch – South Park to Courtland	Length: 950 feet (very approximate)	USGS topographic maps
Under MLK at North Park	Length: 340 feet Cross-Section: 8-foot by 12.5-foot concrete box culvert	Stanley 1964
University Circle Culvert	Length: 5,160 feet (approximate) Cross-Section: Varies – (see figure H-1)	Montgomery Watson 1999 (b)
Rockefeller Park Culvert (at MLK and East 105th)	Length: 650 feet (approximate) Cross-Section: Varies – 11-foot maximum height by 36-foot arch at the inlet; divided 24-foot wide by 9-foot maximum height at outlet	Montgomery Watson 1999 (b)
Gordon Park	Length: 3,300 feet Cross-Section: Varies – entrance is a 14.3-foot by 17-foot box culvert	COE 1976; Montgomery Watson 1999 (b)

Table H-3	Doan Brook Peak 10-Year Flood Flows: Estimates from Different Sources			
Location	**Estimated Flow for 10-Year Flood (cfs)**			
	Montgomery Watson (2000)		Stanley (1964)	ODNR (1977 a, b)
Inflow to Green Lake	1,298		--	--
• Flow reduction from Green Lake	(592)		--	--
Outflow from Green Lake	706		--	--
Inflow to Marshall Lake	713		392	--
• Flow reduction from Marshall Lake	(135)		(29)	--
Outflow from Marshall Lake	578		363	--
Inflow to Horseshoe Lake	2,600		797	612
• Flow reduction from Horseshoe Lake	(2,310)		(478)	--
Outflow from Horseshoe Lake	290		319	356
Inflow to Lily Pond	1,033		1,623	--
• Flow reduction from Lily Pond Marsh	(188)		(577)	--
Inflow to Lower Lake	845		1,046	1,523
• Flow reduction from Lower Lake	(185)		(378)	--
Outflow from Lower Lake	660		668	1,162
D/S from Fairhill Road	1,025		--	--
U/S from Martin Luther King, Jr., Blvd.	673		1,685	--
• Flow reduction from MLK detention dam	(0)		NA	--
Doan Brook Culvert Inlet	668		1,843	--
• Inflow from Giddings Brook Culvert	750	684	1,702	--
• Inflow from Cedar Glen Culvert	??	687	610	--
• Inflow Cedar Glen to Euclid Avenue Culvert	??	159	1,369	--
University Circle	2,243		5,515	--
• Inflow from East 105th St. Culvert	590	493	--	--
• Inflow from Ashbury and Superior Culverts	620	144	--	--
Doan Brook at Superior Avenue	2,419		--	--
Mouth of Doan Brook	2,187		--	--

Notes:

1. In general, all figures represent the peak flow at the point shown. Where there are two figures shown for inflows to the brook, the left number shows the peak inflow and the right number shows the difference in the peak flow in the channel upstream and downstream from the inflow point.
2. Bulleted entries indicate flow reduction from a dam or other control structure or inflows to the brook (rather than flow in the stream itself).

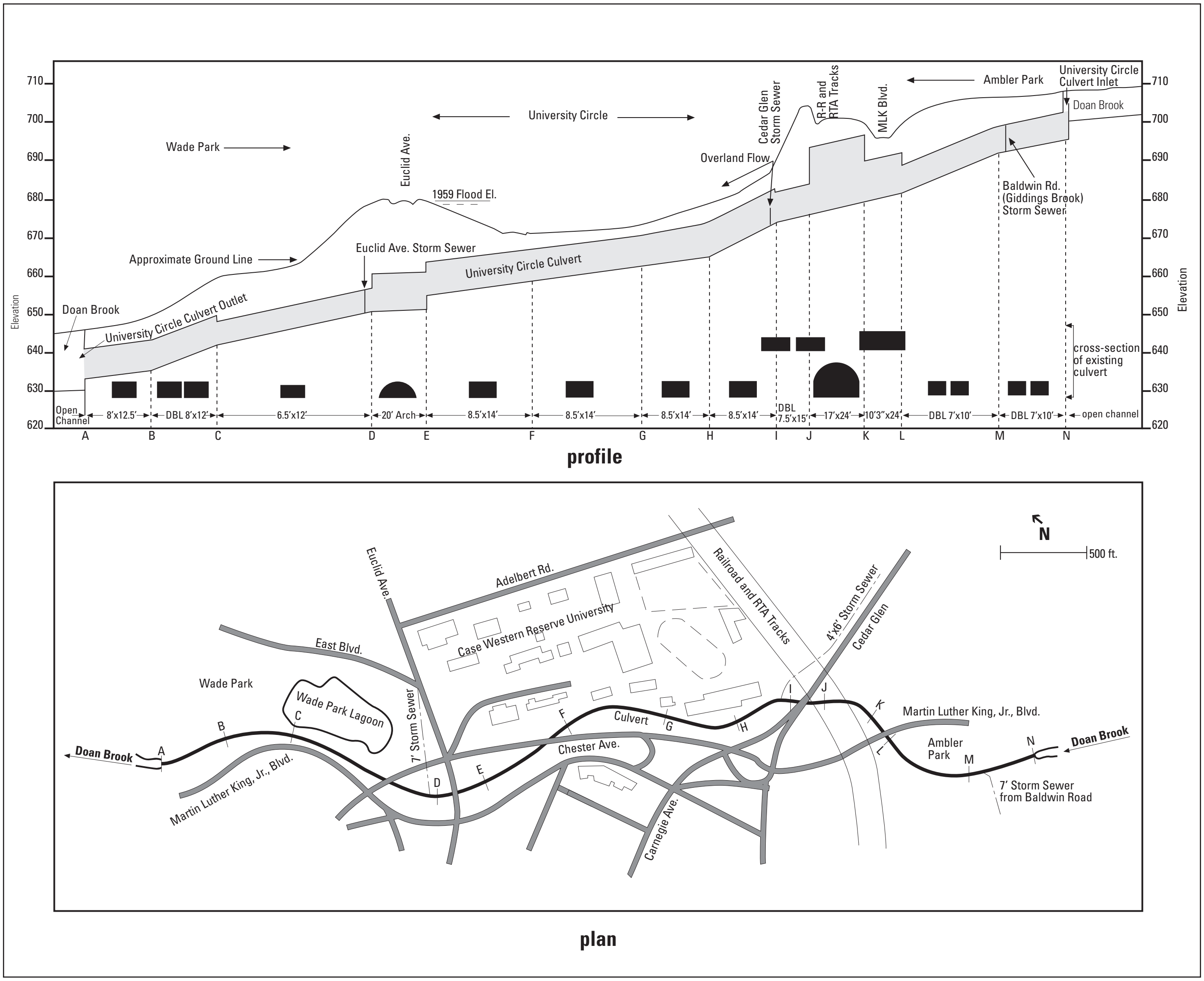


Figure H-1 University Circle Culvert – Plan and Profile. After Stanley 1964.

H.3
Hydrology References

Cleveland Department of Public Utilities, Water Quality Program. 1976. *Doan Brook: Shaker Lakes Water Quality Assessment and Watershed Management Plan.* Cleveland, Ohio.

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Appendix I

Water quality samples were taken from Doan Brook in 1966–67, 1973 and 1974. Annual water quality sampling by the Northeast Ohio Regional Sewer District (NEORSD) began in 1987. Although it is not possible to include all of the voluminous sampling data here, as many of the data as possible are summarized in the tables that follow. Table I-1 gives an overview of the sampling that has been performed. Figures I-1, I-2, and I-3 show sampling locations. Notes that apply to all sampling follow.

List of Figures

List of Water Quality Data Tables

Key to Water Quality Sampling Sites
See Figures I-1 through I-3 for actual sampling locations.

Site #	Site Description
H-#	Havens and Emerson 1966-67 Sampling Site.
C-#	City of Cleveland 1973-74 Sampling Site.
O	City of Cleveland 1973-74 Outfall Sampling Site.
A-#	City of Cleveland 1974 Chemical Sampling Site.
AB-#	City of Cleveland 1974 Bacteria Sampling Site.
L-#	City of Cleveland 1974 Lake Sampling Site.
R-71	NEORSD 1991 Dry Weather Sampling Site.
N-##	NEORSD 1987-1998 Stream Sampling Site.
B-#	NEORSD 1998 Biological Sampling Site.
NS-#	NEORSD 1998 Sediment Sampling Site.
SS##	NEORSD 1998 Stream Sampling Site.
SR##	NEORSD 1998 Continuous Stream Sampling Site (locations are the same as NEORSD stream sampling sites SS01 through SS04).
GLW-#	NEORSD 1998 Green Lake Sampling Site.
MLW-#	NEORSD 1998 Marshall Lake Sampling Site.
USW-#	NEORSD 1998 Horseshoe Lake Sampling Site.
LSW-#	NEORSD 1998 Lower Shaker Lake Sampling Site.

Notes and references apply to all water quality sampling tables. References are indicated by numbers in parentheses ( ). Notes are indicated by numbers in square brackets [ ].

References:

(1) Havens and Emerson. 1968. *Master Plan for Pollution Abatement, Cleveland, Ohio.* Cleveland, Ohio.
(2) Hina, Charles E. 1975. *Water Quality Index Using Chemical Parameters Which Are Correlated to the Trophic Condition.* Masters Thesis, Biology Department, Cleveland State University. Cleveland, Ohio.
(3) Ohio EPA. 1973-74. Water Quality Sampling Results, published in reference 4.
(**4)** Water Quality Program: Cleveland Department of Public Utilities. 1976. *Doan Brook – Shaker Lakes Water Quality Assessment and Watershed Management Plan.* Cleveland.
(5) City of Cleveland (Garlauskas, A.B., S. Nacht, R. Kalynchuk, A. Pliodzinskas, and J. Eakin). 1974. P*reliminary Assessment for Restoration of Doan Brook and Shaker Lakes: City of Cleveland Water Quality Program.*
(6) Havens and Emerson. 1991. *CSO Facilities Plan Phase I Study.* Prepared for NEORSD. Cleveland, Ohio.
(7) NEORSD Sampling results. Dates vary.
(8) Manahan, Stanley E. 1991. *Environmental Chemistry.* Fifth Edition. Lewis Publishers. Chelsea Michigan.
(9) Firehock, Karen. 1995. *Hands on Save Our Streams: Teacher's Manual.* Save Our Streams Program, Izaak Walton League of America.
(10) Water Quality data from the USGS gage on the Grand River near Painesville, Ohio, Water Year October 1993 to September 1994. Source of underlined values.
(11) Cox, Craig A., and George H. Colvin. March 1995. *Investigation of Background Metal Concentrations in Ohio Soils*. Draft Copy. Cox-Colvin Associates, Inc. Hilliard, Ohio.
(12) Biotest Laboratory, Department of Biology, University of Akron. January 1978. *Trophic Assessment of Ten Publicly-Owned N.E. Ohio Lakes*. Prepared for the Northeast Ohio Areawide Coordinating Agency.
(13) City of Cleveland. June 1996. *Application for Department of the Army Permit: Lower Shaker Lake Dredging. Sediment Sampling Results.*

Notes:

[1] Reference 4 contains conflicting information about sampling locations for the City of Cleveland 1974 sampling program in the brook. The locations shown on Figure I-1 may or may not be correct.

[2] Water quality criteria listed on the Appendix I tables are Ohio maximum values outside the mixing zone for warm water habitat, human health criteria, or agricultural use criteria, whichever is lowest. Values that are underlined in the tables indicate a probable violation of some criteria; however, a strict application is complicated, and some underlined entries may meet criteria. Criteria marked with asterisks depend on temperature, pH, or hardness. For these criteria, a range of values is given. Possible violations are evaluated on the basis of measured pH, temperature and hardness and underlined where appropriate.

[3] Mean concentrations in natural waters were taken from a variety of sources (see references). They are intended to give a sense of concentrations generally found. However, it should be kept in mind that natural waters vary considerably, and that a measured value greater than the range given does not necessarily represent human-generated contamination. Measured values in the Doan Brook which are felt to represent concentrations significantly greater than those generally found in natural waters are in bold type.

[4] Sampling locations are shown on Figures I-1 through I-3.

[5] Metal concentrations in Ohio Soils are the 95% upper confidence limit on the mean concentration of samples taken from non-industrial sites. There is a strong probability that metal concentrations in excess of the values given are the result of contamination.

[6] Bacteria criteria are set for primary contact recreation, and are based on *E. coli* and Fecal coliform concentrations. Criteria are not set for single values, but rather for the averages of a number of values taken over a period of time. Underlined entries on Table I-8 are those in excess of the average requirement. Because they are not directly comparable to the criteria, they may or may not represent actual violations. Criteria are: Fecal coliform — geometric mean based on not less than 5 samples within a 30-day period < 1,000 cells/100 ml; not more than 10% of samples > 2,000 cells/100 ml. *E. coli* geometric mean based on not less than 5 samples within a 30-day period < 126 cells/100 ml; not more than 10% of samples > 235 cells/100 ml. Where the volume of sample used is unknown (1995–96), a 100 ml sample is assumed in evaluating the results.

[7] Some of the maximum and minimum values for City of Cleveland data from 1973–74 appear to be reversed in the original data table. That is, maximum values were recorded in the minimum column and minimum values in the maximum column. This apparent error has not been corrected in this data summary.

[8] NEORSD averages from 8/30/90 and 9/26/90 are from a different source from the data for 8/30/90. Although the two data sets probably overlap, they are both given in the summary tables.

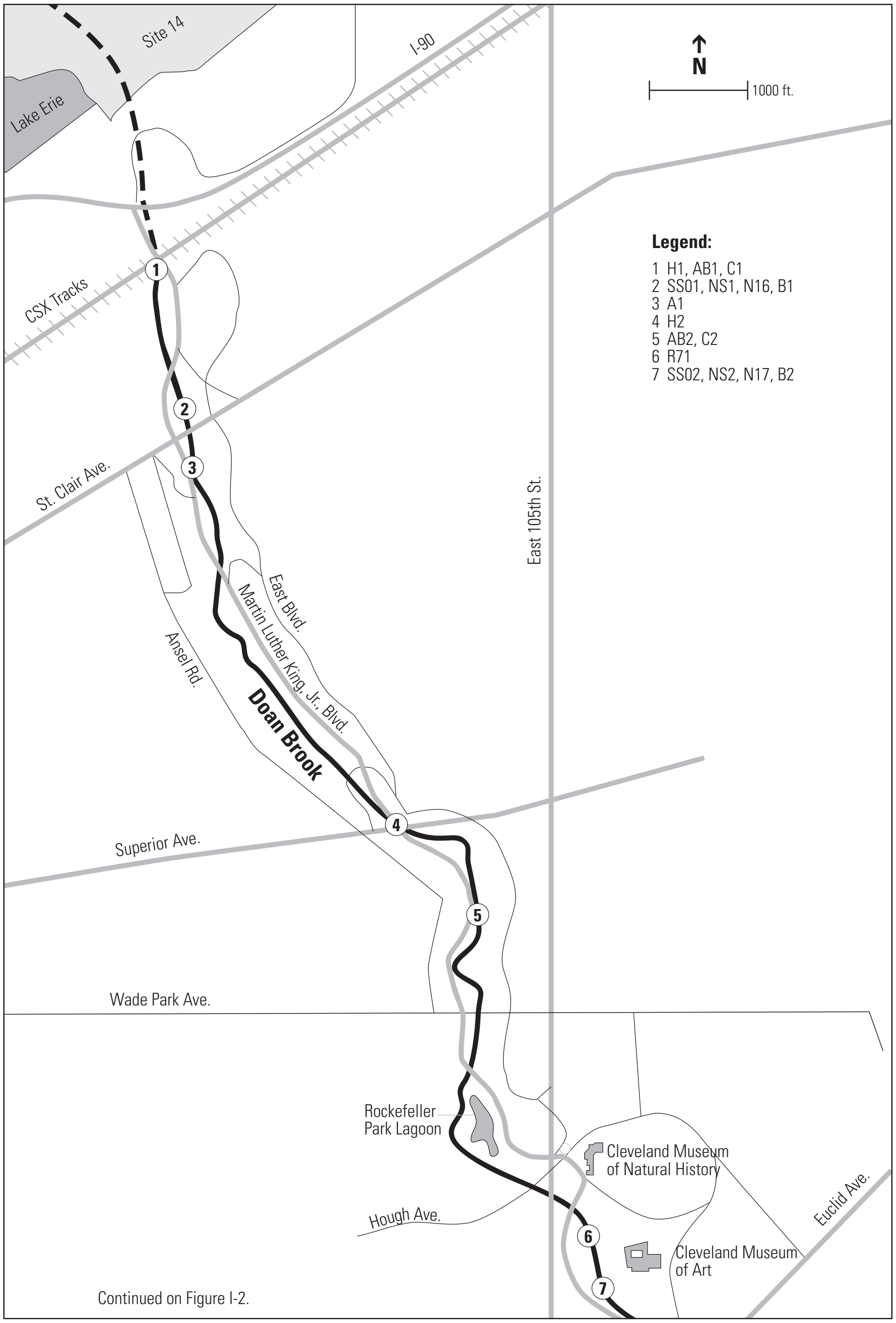

Figure I-1 Doan Brook Sampling Locations: Lower Watershed

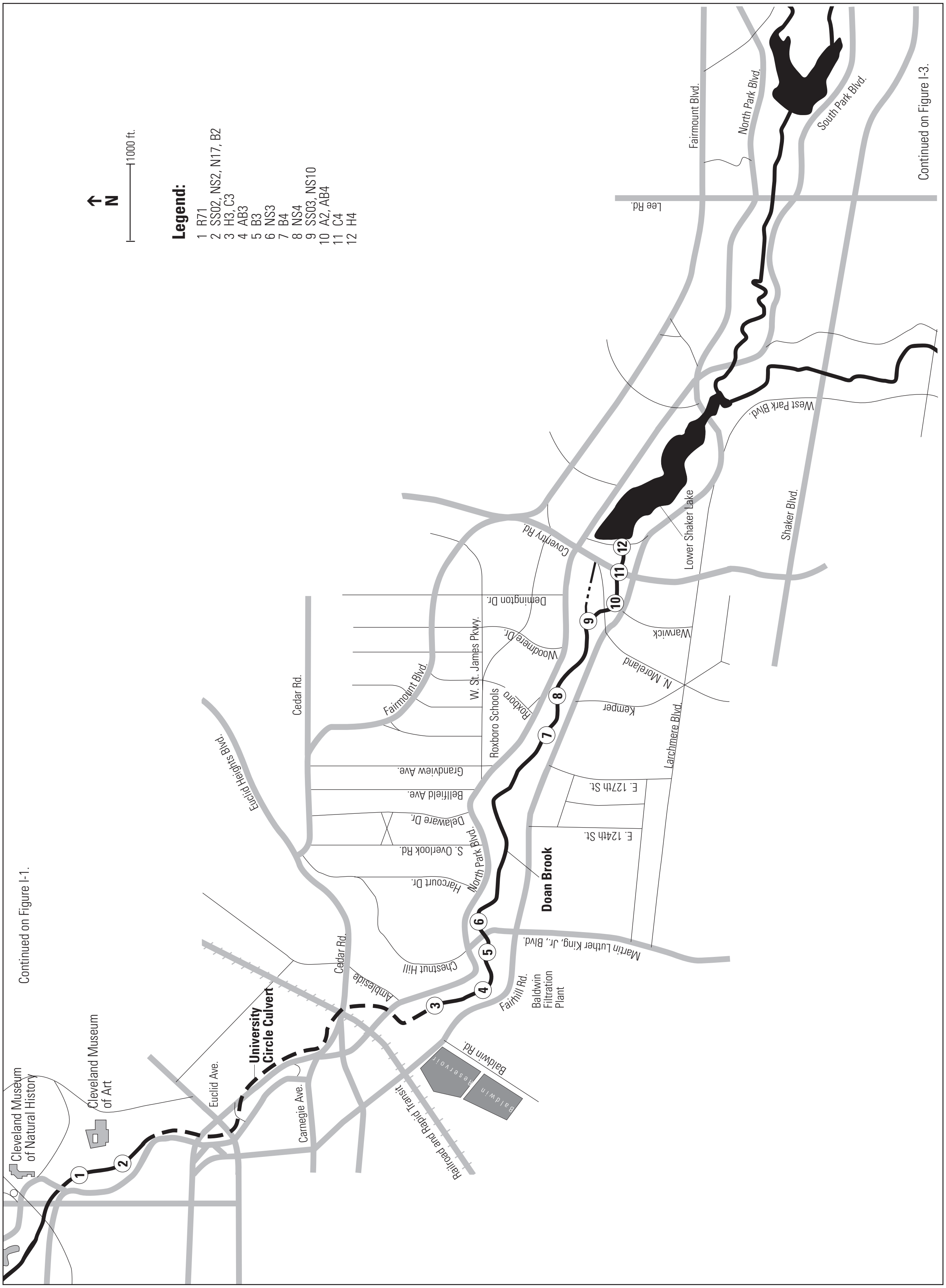

Figure I-2 Doan Brook Sampling Locations: University Circle to Lower Shaker Lake

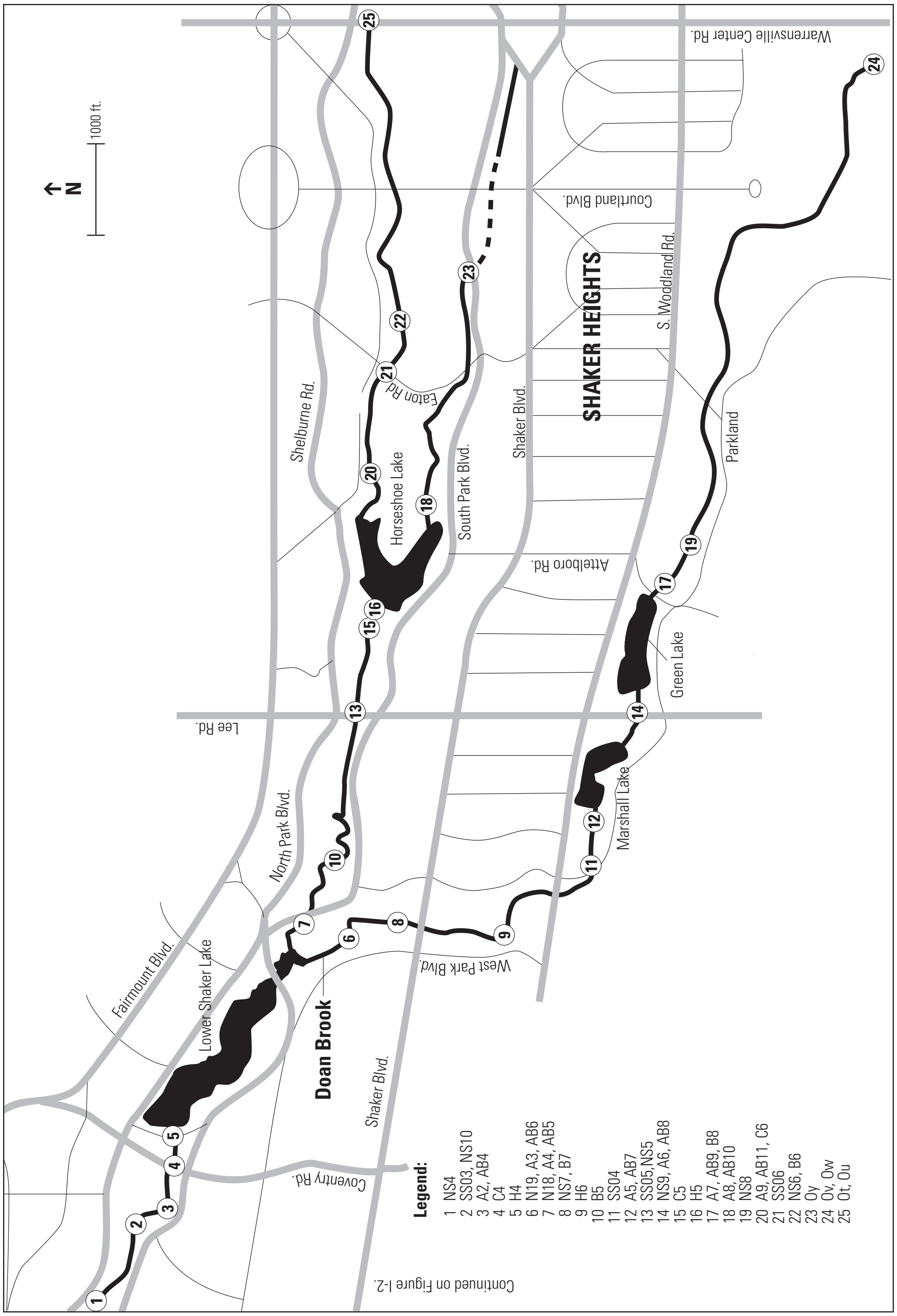

Figure I-3 Doan Brook Sampling Locations: Upper Watershed

Table I-1 Summary of Doan Brook Sampling

Entries in the table below indicate the table in which the data can be found.

Sampling Location	Sampling		Water Samples			Sediment Samples		
	Ref.	Date	Bacteria	Chemical	Biological	Bacteria	Chemical	Biological
N. Fork U/S from Horseshoe Lake								
C-6	(5)	1973-74		I-2				
Outfall @ Warrensville (O-t)	(4)	1974	I-9					
Outfall @ Warrensville (O-u)	(4)	1974	I-9					
AB-11	(4)	1974	I-9					
SS-06	(7)	1998	I-9	I-2				
B-6 & NS-6	(7)	1998					I-14	I-10
Middle Fork U/S from Horseshoe Lake								
Outfall @ Warrensville (O-y)	(4)	1974	I-9					
AB-10	(4)	1974	I-9					
South Fork U/S From Green Lake:								
Outfall @ Warrensville (O-v)	(4)	1974	I-9					
Outfall @ Warrensville (O-w)	(4)	1974	I-9					
A-7	(4)	1974						I-11
AB-9	(4)	1974	I-9					
B-8 & NS-8	(7)	1998					I-14	I-10
Green Lake:								
L-4	(4)	1974	I-9					I-11
GLW-1 through GLW-6	(7)	1998	I-9	I-3;I-4;I-8			I-13	I-10
U/S From Marshall Lake								
A-6	(4)	1974						I-11
AB-8	(4)	1974	I-9					
NS-9	(7)	1998					I-14	
Marshall Lake:								
L-3	(4)	1974	I-9					I-11
MLW-1 through MLW-4	(7)	1998	I-9	I-3;I-4;I-7			I-13	I-10
Doan Brook S. - Marshall Lake to Lower Lake:								
U/S From Shaker Boulevard:								
A-5	(4)	1974						I-11
AB-7	(4)	1974	I-9					
SS-04/SR-04	(7)	1998	I-9	I-2				
H-6	(1)	1966-67		I-2				
Doan Brook S. - D/S from Shaker Blvd.								
B-7 & NS-7	(7)	1998					I-14	I-10
A-3	(4)	1974						I-11
AB-6	(4)	1974	I-9					
N-19	(7)	7/7&11/4/87	I-9	I-2				
N-19	(7)	01/26/88	I-9	I-2				
N-19	(7)	07/11/89	I-9	I-2				
N-19 [8]	(7)	8/30&9/26/90	I-9	I-2				
N-19 [8]	(7)	08/30/90	I-9	I-2				
N-19	(7)	05/16/91	I-9	I-2				
N-19	(7)	06/18/91	I-9	I-2				
N-19	(7)	07/29/91	I-9	I-2				
N-19	(7)	08/27/93	I-9	I-2				
N-19	(7)	08/18/94	I-9	I-2				
N-19	(7)	10/18/94	I-9	I-2				
N-19	(7)	06/07/95	I-9	I-2				
N-19	(7)	08/07/96	I-9	I-2				
N-19	(7)	07/31/97	I-9	I-2				

Table I-1 Summary of Doan Brook Sampling, continued

Entries in the table below indicate the table in which the data can be found.

Sampling Location	Sampling		Water Samples			Sediment Samples		
	Ref.	Date	Bacteria	Chemical	Biological	Bacteria	Chemical	Biological
Horseshoe Lake:								
Outfall grab (H-5)	(1)	1966-67	I-9	I-6				
Lake (OEPA)	(3)	9/19/73		I-6;I-12				
Outfall grab (C-5)	(5)	1973-74		I-6				
Lake (COC)	(4)	1974	I-9					I-11
Outfall grab (COC)	(4)	1974	I-9					
Lake (2 locations)	(12)	08/17/77	I-9	I-6				
Lake (2 locations)	(12)	11/03/77		I-6				
Outfall grab	(7)	8/29/90	I-9	I-6			I-13	
Outfall grab	(7)	08/30/90	I-9					
Lake (USW-1 to USW-6)	(7)	1998	I-9	I-3;I-4;I-6			I-13	I-10
Doan Brook North -U/S From Lower Lake								
A-4	(4)	1974						I-11
AB-5	(4)	1974	I-9					
N-18	(7)	7/7&11/4/87	I-9	I-2				
N-18	(7)	01/26/88	I-9	I-2				
N-18	(7)	07/11/89	I-9	I-2				
N-18 [8]	(7)	8/30&9/26/90	I-9	I-2				
N-18 [8]	(7)	08/30/90	I-9	I-2				
N-18	(7)	05/16/91	I-9	I-2				
N-18	(7)	06/18/91	I-9	I-2				
N-18	(7)	07/29/91	I-9	I-2				
N-18	(7)	08/27/93	I-9	I-2				
N-18	(7)	08/18/94	I-9	I-2				
N-18	(7)	10/18/94	I-9	I-2				
N-18	(7)	06/07/95	I-9	I-2				
N-18	(7)	08/07/96	I-9	I-2				
N-18	(7)	07/31/97	I-9	I-2				
SS-05	(7)	1998	I-9	I-2				
B-5	(7)	1998						I-10
NS-5	(7)	1998					I-14	
Lower Lake:								
Outfall grab (H-4)	(1)	1966-67	I-9	I-5				
Outfall grab (C-4)	(5)	1973-74		I-5				
Lake (OEPA)	(3)	09/19/73		I-5;I-12				
Lake (3 locations - OEPA)	(3)	12/08/73					I-13	
Lake (many - COC)	(4)	1974	I-9			I-13	I-13	I-11
Outfall grab (Hina)	(2)	1973		I-5				
Outfall grab (C-4)	(4)	1974		I-5				
Lake (2 locations)	(12)	08/17/77	I-9	I-5				
Lake (2 locations)	(12)	11/03/77		I-5				
Outfall grab	(7)	8/29/90	I-9	I-5			I-13	
Outfall grab	(7)	08/30/90	I-9					
Lake (4 locations)	(13)	04/95					I-13	
Lake (LSW-1 to LSW-8)	(7)	1998	I-9	I-3;I-4;I-5			I-13	I-10
D/S from Lower Lake:								
A-2	(4)	1974						I-11
AB-4	(4)	1974	I-9					
SS-03/SR-03	(7)	1998	I-9	I-2				
B-4	(7)	1998						I-10
NS-4	(7)	1998					I-14	
NS-10	(7)	1998					I-14	

Table I-1 Summary of Doan Brook Sampling, continued

Entries in the table below indicate the table in which the data can be found.

Sampling Location	Sampling		Water Samples			Sediment Samples		
	Ref.	Date	Bacteria	Chemical	Biological	Bacteria	Chemical	Biological
At University Circle Culvert Entrance:								
H-3	(1)	1966-67		I-2				
C-3	(5)	1973-74		I-2				
AB-3	(4)	1974	I-9					
B-3 & NS-3	(7)	1998					I-14	I-10
Doan Brook MLK @ 105 (University Circle Culvert Outlet):								
N-17	(7)	7/7&11/4/87	I-9	I-2				
N-17	(7)	01/26/88	I-9	I-2				
N-17	(7)	07/11/89	I-9	I-2				
N-17	(7)	09/26/90	I-9	I-2				
H&E R-7-1	(6)	05/22/91	I-9					
H&E R-7-1	(6)	06/07/91	I-9					
N-17	(7)	05/16/91	I-9	I-2				
N-17	(7)	06/18/91	I-9	I-2				
N-17	(7)	07/29/91	I-9	I-2				
N-17	(7)	08/27/93	I-9	I-2				
N-17	(7)	08/18/94	I-9	I-2				
N-17	(7)	10/18/94	I-9	I-2				
N-17	(7)	06/07/95	I-9	I-2				
N-17	(7)	08/07/96	I-9	I-2				
N-17	(7)	07/31/97	I-9	I-2				
SS-02/SR-02	(7)	1998	I-9	I-2				
B-2 & NS-2	(7)	1998					I-14	I-10
MLK at Ansel								
C-2	(5)	1973-74		I-2				
AB-2	(4)	1974	I-9					
D/S from Superior:								
H-2	(1)	1966-67		I-2				
A-1	(4)	1974						I-11
Doan Brook MLK @ St. Clair:								
N-16	(7)	7/7&11/4/87	I-9	I-2				
N-16	(7)	01/26/88	I-9	I-2				
N-16	(7)	07/11/89	I-9	I-2				
N-16	(7)	09/26/90	I-9	I-2				
N-16	(7)	05/16/91	I-9	I-2				
N-16	(7)	06/18/91	I-9	I-2				
N-16	(7)	07/29/91	I-9	I-2				
N-16	(7)	08/27/93	I-9	I-2				
N-16	(7)	08/18/94	I-9	I-2				
N-16	(7)	10/18/94	I-9	I-2				
N-16	(7)	06/07/95	I-9	I-2				
N-16	(7)	08/07/96	I-9	I-2				
N-16	(7)	05/14/97	I-9	I-2				
SS-01/SR-01	(7)	1998	I-9	I-2				
B-1 & NS-1	(7)	1998					I-14	I-10
Inlet of Culvert to Lake:								
H-1	(1)	1966-67	I-9	I-2				
AB-1	(4)	1974	I-9					

Table I-2 Water Quality Sampling Results for the Brook

Units are in mg/L unless noted.

Parameter	Mean Conc. in Natural Waters (8,9,10)[3]	Water Quality Criteria [2]	Near the Mouth of the Brook: H&E (1) 1966-67 (H-1)	NEORSD - Sampling Point N-16 (7): 7/7 & 11/4/87 Average	1/26/88	7/11/89	9/26/90	5/16/91	6/18/91	7/29/91	8/27/93	8/18/94	10/18/94
Temperature (C)				18.5	1.5	23.5		19.1	21.5	12.9	21.5	21.4	14
D.O. (ppm)		4	2.7	4.7	7.0		8.8	8.2	6.2	6.6	5.1	6.2	6.4
BOD			9.7	16	20	4	2	4	6	5		2	5
COD			292	103	31	10	11	12	25	14	<10	<10	14
TOC													
DOC													
Suspended Solids			44	17	46		4	1	3	1	5	<1	18
Total Solids			363				380	602	542	577	425	278	541
Total Dissolved Solids		1500			1266		333	600	539	529	390	257	453
Specific Conductance (umhos/cm)	243-420			1010	1874	720	542	915	880	820	750	510	330
Turbidity				4			2	2	4	2	1	3	2.4
Ammonia	0.01-0.04	* 1.1-13.0	2.4	0.41	1.08	0.2	0.24	0.29	0.46	0.23	<0.01	0.1	0.09
Phosphorus	0.1	1	1.4	1.09	0.5	0.24	0.14	0.27	0.38	0.32	0.24	0.04	0.21
Soluble Phosphorus					0.14	0.2	0.12	0.25	0.37	0.31	0.21	0.04	0.17
Nitrites				0.03	0.06	0.08	0.02	0.17	0.09				
Nitrates	1		2.3	0.32	0.84	1.01	0.84	0.77	0.48		0.8	0.64	1.05
Nitrate/Nitrite Total	0.1-0.5	100						0.94	0.57				
Total Kjeldahl Nitrogen	0.3-0.8				3.92	2.74	2.35	1.41	1.35	0.86	0.6	0.43	1.51
Chlorides	24-43		36	200	410	112	78	198	192		314	78	140
Sulfates	24-45		42	87	153	66	51	80	83		54	39	57
Alkalinity	31-91		98		337	138	110	145	157		157	89	151
Hardness	68-140		200		316	198	140	255	243	238	178	145	230
Nickel		* 1.60-6.30		0.01	<0.01	0.02	<0.01	0.02	0.01	0.02	0.004	0.003	0.004
Copper	0.015	* .018-.090		0.01	0.01	0.02	0.01	0.02	0.01	0.01	0.01	0.02	0.01
Total Chromium	0.01	* 1.8-6.7		0.01	<0.01	<0.01	0.01	0.03	0.01	0.02	0.002	0.001	0.003
Hexavalent Chromium		0.015					<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc	0.064	* .120-.450		0.04	0.04	0.01	0.02	0.05	0.04	0.04	0.06	0.03	0.02
Iron	0.052	1	0.6	0.1	2.9	0.4	0.2	0.28	0.4	0.24	0.24	0.15	0.56
Calcium													
Cadmium	0.01	* .0056-.032		0.01	0.01	<0.01	<0.01	<0.01	0.01	0.01	<0.001	<0.001	<0.001
Lead	0.023	* .130-1.00		0.01	<0.01	0.12	<0.01	0.03	<0.01	0.03	<0.003	<0.003	0.003
Mercury (ug/L)		1.1			0.1		<0.2		<0.2	<0.2	<0.2	<0.2	<0.2
Total coliform (per 100 ml or as noted)			5000000	28425 units?	20000	5100	5800	4300	6200	2700			
Fecal coliform (per 100 ml or as noted)		2000/100 ml		20838 units?	540	760	2500	2500	2700	540	200	90	300
Fecal streptococus (per 100 ml or as noted)				2301 units?	450	360	380	260	1000	420			
pH (S.U.)		6.5-9	5.3-8.1			7.3	7.5	7.7	7.6	7.6	7.7	7.7	7.7
Phenolics								<0.05	<0.05		<0.05		
E Coli (per 100 ml or as noted)		235/100 ml									150	60	290
Antimony		0.65											
Arsenic	0.064	0.36										0.006	<0.005
Selenium		0.02											
Thallium		0.071										<0.007	<0.007
Silver	0.003	* .0016-.0063										<0.001	<0.001
Beryllium		* .520-7.00										<0.001	<0.001
Potassium												2.3	4.3
Cobalt												<0.001	0.001

Table I-2 Water Quality Sampling Results for the Brook, continued

Units are in mg/L unless noted.

Parameter	Mean Conc. in Natural Waters (8,9,10)[3]	Water Quality Criteria [2]	Near the Mouth of the Brook, cont.										
			NEORSD - Sampling Point N-16, cont.			NEORSD - SS-01 - dry weather							
			6/7/95	8/7/96	5/14/97	5/21/98	5/28/98	6/11/98	6/19/98	7/1/98	7/7/98	8/18/98	11/4/98
Temperature (C)			19.8	24.0	17		22.6				20.8	23.2	7.1
D.O. (ppm)		4	2.9	3.0	7.2		5.42				9.20	5.52	11.80
BOD			8	6	2		2.3			<2.	<2.	8.6	
COD			16	10	< 10								
TOC													
DOC							4.8			5.2	7.7	12.7	
Suspended Solids			1	19	2		1.5			<1.	1	4	
Total Solids			741	445									
Total Dissolved Solids		1500	717	410									
Specific Conductance (umhos/cm)	243-420		**1300**	**1100**	**1600**		740				**1286**	710	**1078**
Turbidity			1.00	2.50									
Ammonia	0.01-0.04	* 1.1-13.0	**0.40**	**0.40**	**0.2**		<0.1			<0.1	<0.1	<0.1	
Phosphorus	0.1	1	**0.21**	0.19	0.05		0.11			0.14	0.1	0.16	0.12
Soluble Phosphorus			0.17	0.17			0.05			0.08	0.06	0.04	0.08
Nitrites							<0.01			<0.01	<0.05	0.03	
Nitrates	1		0.81	0.50	0.6		**2.5**			**2.7**	1.89	1.38	
Nitrate/Nitrite Total	0.1-0.5	100			0.62								
Total Kjeldahl Nitrogen	0.3-0.8		**2.30**	**1.60**	1		0.4			0.3	<0.2	0.89	
Chlorides	24-43		**254**	**144**	**290**						**261**		
Sulfates	24-45		81	54							76		
Alkalinity	31-91		146	122	157						157		
Hardness	68-140		274	186	272		**320**			245	**308**	175	
Nickel		* 1.60-6.30	0.002	0.008	0.007		<0.02			<0.02	<0.02	<0.02	
Copper	0.015	* .018-.090	0.007	0.012	0.015		0.011			0.0062	<0.01	0.012	
Total Chromium	0.01	* 1.8-6.7	0.004	0.001	0.005		<0.01			<0.01	<0.01	<0.01	
Hexavalent Chromium		0.015	< 0.01	< 0.01	< 0.01								
Zinc	0.064	* .120-.450	0.02	0.06	0.04		0.019			0.05	<0.01	0.016	
Iron	0.052	1	**0.58**	**0.3**	**0.44**		**0.152**			**0.525**	**0.478**	**0.536**	
Calcium													
Cadmium	0.01	* .0056-.032	< 0.001	< 0.001	< 0.001		<0.001			<0.001	<0.001	<0.001	
Lead	0.023	* .130-1.00	< 0.003	0.005	0.003		<0.003			<0.003	0.003	0.0034	
Mercury (ug/L)		1.1	0.3	< 0.2	< 0.2								
Total coliform (per 100 ml or as noted)													
Fecal coliform (per 100 ml or as noted)		'2000/100 ml	1400	520	720	300	200	1,600	25,000	1,600	1,400	≥20000	
Fecal streptococus (per 100 ml or as noted)													
pH (S.U.)		6.5-9	7.3	7.1	6.7						8.06	6.98	8.05
Phenolics													
E Coli (per 100 ml or as noted)		235/100 ml		360	520	210	200	1,200	11,000	240	490	≥9600	
Antimony		0.65	< 0.007		< 0.007								
Arsenic	0.064	0.36	< 0.005	< 0.005	< 0.005								
Selenium		0.02			< 0.005								
Thallium		0.071	< 0.007	< 0.007									
Silver	0.003	* .0016-.0063	0.002	< 0.001	0.001								
Beryllium		* .520-7.00	< 0.0005	< 0.001	< 0.001								
Potassium				3.10									
Cobalt			< 0.001	< 0.001									

Table I-2 Water Quality Sampling Results for the Brook, continued

Units are in mg/L unless noted.

Parameter	Mean Conc. in Natural Waters (8,9,10)[3]	Water Quality Criteria [2]	Near the Mouth of the Brook, cont. NEORSD SR-01 - wet weather: 5/31/98 Min	5/31/98 Max	5/31/98 Average	6/12/98 Min	6/12/98 Max	6/12/98 Average	6/27/98 Min.	6/27/98 Max.	6/27/98 Avg.	Lower Brook to Univ. Circle Culvert: H&E (1) 1966-67 (H-2)	COC (5) - C-2 1973-74 [7] Max.	COC (5) - C-2 1973-74 [7] Min.
Temperature (C)													20.5	3
D.O. (ppm)		4										4.3	13.6	8.1
BOD								> 28.			58.8	8.7	16	2
COD												227	57	12
TOC													18	7
DOC														
Suspended Solids								186			129	43		
Total Solids												510	596	338
Total Dissolved Solids		1500												
Specific Conductance (umhos/cm)	243-420													
Turbidity														
Ammonia	0.01-0.04	* 1.1-13.0						1.14			3.7	3.6	0.1	0.6
Phosphorus	0.1	1						0.4			0.8	1.2	0.7	0.1
Soluble Phosphorus								0.25			0.27		0.2	0.01
Nitrites													1	0.018
Nitrates	1											2.3	1.27	0.12
Nitrate/Nitrite Total	0.1-0.5	100												
Total Kjeldahl Nitrogen	0.3-0.8							5.8			8.6		1.2	4.2
Chlorides	24-43											78	190	45
Sulfates	24-45											70		
Alkalinity	31-91											108	116	94
Hardness	68-140							79.2			127		237	
Nickel		* 1.60-6.30	< .02	0.025	< .021	< .02	< .02	< .02	<.02	<.02	<.02			
Copper	0.015	* .018-.090	0.063	0.101	0.083	0.042	0.125	0.072	0.016	0.064	0.037		< 0.1	< 0.01
Total Chromium	0.01	* 1.8-6.7	< .01	0.018	< .012	< .01	0.012	0.011	<.01	<.01	<.01		< 0.5	
Hexavalent Chromium		0.015												
Zinc	0.064	* .120-.450	0.171	0.326	0.244	0.169	0.509	0.292	0.137	0.22	0.17		0.05	< 0.01
Iron	0.052	1	3.73	8.52	6.87	2.80	6.94	4.53	1.15	1.84	1.55	0.5	3.88	0.3
Calcium													94	61
Cadmium	0.01	* .0056-.032	< .001	0.002	< .001	< .001	0.002	0.001	<.001	<.001	<.001			
Lead	0.023	* .130-1.00	0.064	0.199	0.119	0.0320	0.1760	0.0770	0.0102	0.0613	0.0321		< 0.05	
Mercury (ug/L)		1.1											< 1	
Total coliform (per 100 ml or as noted)														
Fecal coliform (per 100 ml or as noted)		2000/100 ml	150,000	1,800,000	900,000	210,000	400,000	330,000	830,000	5,800,000	3,400,000			
Fecal streptococus (per 100 ml or as noted)														
pH (S.U.)		6.5-9										8.1-8.3	7.9	8.2
Phenolics														
E Coli (per 100 ml or as noted)		235/100 ml	58,000	220,000	120,000	110,000	440,000	310,000	480,000	1,200,000	900,000			
Antimony		0.65												
Arsenic	0.064	0.36												
Selenium		0.02												
Thallium		0.071												
Silver	0.003	* .0016-.0063												
Beryllium		* .520-7.00												
Potassium														
Cobalt														

Table I-2 Water Quality Sampling Results for the Brook, continued

Units are in mg/L unless noted.

Parameter	Mean Conc. in Natural Waters (8,9,10)[3]	Water Quality Criteria [2]	University Circle Culvert Outlet NEORSD - Sampling Point N-17 (7)									
			7/7 & 11/4/87 Average	1/26/88	7/11/89	9/26/90	5/16/91	6/18/91	7/29/91	8/27/93	8/18/94	10/18/94
Temperature (C)			18.0	1.8	22.2		18.7	21.6	14	21	20	15
D.O. (ppm)		4	7.8	14	3.6	8.3	6.6	6.4	3.8	3.1	6.1	5.6
BOD			7		9	3	22	14	8	20	4	7
COD			90	20	21	<10	30	27	25	40	13	<10
TOC												
DOC												
Suspended Solids			22	6	22	9	6	22	9	18	2	7
Total Solids						310	427	406	430	375	614	415
Total Dissolved Solids		1500		540	505	265	421	378	393	331	575	365
Specific Conductance (umhos/cm)	243-420		410	855	700	428	630	650	650	540	1100	385
Turbidity			12			3	4.5	74	4	3	5	1.8
Ammonia	0.01-0.04	* 1.1-13.0	0.7	0.72	2.17	0.41	1.31	1.2	3.15	1.9	0.5	1.04
Phosphorus	0.1	1	0.33	0.35	0.75	0.2	0.67	0.64	0.89	0.81	0.26	0.5
Soluble Phosphorus				0.27	0.73	0.18	0.59	0.42	0.77	0.59	0.24	0.45
Nitrites			0.04	0.02	0.03	<0.01	0.01	0.04				
Nitrates	1		0.32	0.53	0.24	0.57	0.45	0.5		0.12	0.77	0.27
Nitrate/Nitrite Total	0.1-0.5	100					0.46	0.54				
Total Kjeldahl Nitrogen	0.3-0.8			2.8	3.25	2.58	3.71	2.83	4.12	4.08	1.9	3.09
Chlorides	24-43		77	222	118	68	126	192		110	198	118
Sulfates	24-45		50	52	59	39	71	77		49	81	49
Alkalinity	31-91			102	135	109	117	131		121	109	113
Hardness	68-140			157	189	90	188	172	188	172	223	194
Nickel		* 1.60-6.30	0.01	<0.01	0.02	<0.01	0.01	0.01	0.01	0.002	0.003	0.003
Copper	0.015	* .018-.090	0.01	0.01	0.02	<0.01	0.02	0.01	0.01	0.02	0.02	0.01
Total Chromium	0.01	* 1.8-6.7	0.01	<0.01	<0.01	<0.01	0.02	0.01	0.02	0.001	0.001	0.002
Hexavalent Chromium		0.015	0.01			<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc	0.064	* .120-.450	0.12	0.01	0.01	0.01	0.06	0.09	0.04	0.03	0.02	0.01
Iron	0.052	1	0.6	0.20	0.20	0.10	0.47	2.1	0.3	0.27	0.11	0.20
Calcium												
Cadmium	0.01	* .0056-.032	0.01	<0.01	<0.01	<0.01	<0.01	0.01	0.01	<0.001	0.001	<0.001
Lead	0.023	* .130-1.00	0.02	0.02	0.07	<0.01	<0.01	<0.01	0.01	<0.003	0.006	<0.003
Mercury (ug/L)		1.1		0.05	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Total coliform (per 100 ml or as noted)			114000 units?	230000	>180000	>200000	>80000	>80000	>160000			
Fecal coliform (per 100 ml or as noted)		2000/100 ml	29400 units?	3000	110000	100000	>60000	>60000	180000	32000	40000	97000
Fecal streptococus (per 100 ml or as noted)			13600 units?	7800	35000	39000	95000	67000	39000			
pH (S.U.)		6.5-9			7.3	7.6	7.4	7.7	7.6	7.3	7.7	7.6
Phenolics							0.07	<0.05		<0.05		
E Coli (per 100 ml or as noted)		235/100 ml								30000	24000	31000
Antimony		0.65										
Arsenic	0.064	0.36									0.005	<0.005
Selenium		0.02										
Thallium		0.071									<0.007	<0.007
Silver	0.003	* .0016-.0063									<0.001	0.001
Beryllium		* .520-7.00									<0.001	<0.001
Potassium											3.6	2.4
Cobalt											<0.001	0.001

Table I-2 Water Quality Sampling Results for the Brook, continued

Units are in mg/L unless noted.

Parameter	Mean Conc. In Natural Waters (8,9,10)[3]	Water Quality Criteria [2]	University Circle Culvert Outlet, cont. NEORSD - Sampling Point N-17 (7), cont. 6/7/95	8/7/96	7/31/97	NEORSD SS-02 - dry weather 5/21/98	5/28/98	6/11/98	6/19/98	7/1/98	7/7/98	8/18/98	11/4/98
Temperature (C)			19.1	23.4	21.0		21.6				20.8	22.3	
D.O. (ppm)		4	4.8	3.5	6.3								
BOD			10	6	2		2.7			<2.	<2.	2.9	
COD			25	20	16								
TOC													
DOC							4.1			6.0	5.6	8.5	
Suspended Solids			6	4	4		0.5			<1.	1.5	2	
Total Solids			536	521	540								
Total Dissolved Solids		1500	522	441	500								
Specific Conductance (umhos/cm)	243-420		**870**	**1100**	**1200**		**1417**				**916**	694	640
Turbidity			2.00	2.00	1.40								
Ammonia	0.01-0.04	* 1.1-13.0	**0.80**	**1.40**	**0.10**		<0.1			<0.1	<0.1	<0.1	
Phosphorus	0.1	1	**0.38**	**0.54**	**0.28**		0.15			0.18	**0.2**	0.15	0.1
Soluble Phosphorus			0.33	0.52	0.26		0.1			0.11	0.12	0.1	0.07
Nitrites							0.03			<0.01	<0.05	0.03	
Nitrates	1		0.50	0.10	1.30		**2.9**			**2.7**	**2.22**	1.45	
Nitrate/Nitrite Total	0.1-0.5	100			**1.34**								
Total Kjeldahl Nitrogen	0.3-0.8		**3.50**	**2.80**	0.80		0.4			0.39	<0.2	0.37	
Chlorides	24-43		**174**	**172**	**158**						**169**		
Sulfates	24-45		60	60	79						58		
Alkalinity	31-91		112	126	143						121		
Hardness	68-140		202	184	199		240			193	244	186	
Nickel		* 1.60-6.30	0.002	0.006	0.002		<0.02			<0.02	<0.02	<0.02	
Copper	0.015	* .018-.090	0.007	0.013	0.006		0.029			0.01	0.008	0.0089	
Total Chromium	0.01	* 1.8-6.7	0.004	0.003	0.001		<0.01			<0.01	<0.01	<0.01	
Hexavalent Chromium		0.015	< 0.01	< 0.01									
Zinc	0.064	* .120-.450	0.01	**0.14**	0.40		0.02			0.027	<0.01	<0.01	
Iron	0.052	1	**0.16**	**0.19**	**0.12**		**0.162**			**0.353**	**0.41**	**0.406**	
Calcium													
Cadmium	0.01	* .0056-.032	< 0.001	< 0.001	< 0.001		<0.001			<0.001	<0.001	<0.001	
Lead	0.023	* .130-1.00	< 0.003	< 0.003	< 0.003		<0.003			<0.003	<0.003	<0.003	
Mercury (ug/L)		1.1	< 0.2	< 0.2	< 0.2								
Total coliform (per 100 ml or as noted)													
Fecal coliform (per 100 ml or as noted)		2000/100 ml	89000	71000	1900	3,900	14,000	960	17,000	4,800	780	52,000	
Fecal streptococus (per 100 ml or as noted)													
pH (S.U.)		6.5-9	7.5	7.1	7.2		8.9				7.4	7.3	8.1
Phenolics													
E Coli (per 100 ml or as noted)		235/100 ml		46000	1000	<2400	>2400	460	11,000	500	240	>9600	
Antimony		0.65	< 0.0070		< 0.0070								
Arsenic	0.064	0.36	< 0.005	< 0.005	< 0.005								
Selenium		0.02			< 0.0050								
Thallium		0.071	< 0.007	< 0.007	< 0.007								
Silver	0.003	* .0016-.0063	0.0020	< 0.0010	< 0.0010								
Beryllium		* .520-7.00	< 0.0005	< 0.0010	< 0.0010								
Potassium				3.20	3.60								
Cobalt			< 0.0010	< 0.0010									

Table I-2 Water Quality Sampling Results for the Brook, continued

Units are in mg/L unless noted.

Parameter	Mean Conc. in Natural Waters (8,9,10)[3]	Water Quality Criteria [2]	University Circle Culvert Outlet, cont. NEORSD SR-02 - wet weather 5/31/98 Min	5/31/98 Max	5/31/98 Average	6/12/98 Min	6/12/98 Max	6/12/98 Average	6/27/98 Min.	6/27/98 Max.	6/27/98 Avg.	University Circle Culvert Inlet H&E (1) 1966-67 (H-3)	COC(5) C-3 1973-74 [7] Max.	COC(5) C-3 1973-74 [7] Min.
Temperature (C)													21.5	3
D.O. (ppm)		4										5.3	14	8.6
BOD					30.3			< 2.			11.3	5.3	7	3
COD												118	35	16
TOC													13	11
DOC														
Suspended Solids					270			74			95	45		
Total Solids												590	383	306
Total Dissolved Solids		1500												
Specific Conductance (umhos/cm)	243-420													
Turbidity														
Ammonia	0.01-0.04	* 1.1-13.0			**0.85**			**0.55**			**0.88**	**2.5**	**0.2**	< 0.1
Phosphorus	0.1	1			0.14			**0.3**			**0.46**	1.4	**0.3**	0.1
Soluble Phosphorus					0.07			0.17			0.11		0.1	< 0.1
Nitrites													0.122	< 0.001
Nitrates	1											1.2	0.18	0.009
Nitrate/Nitrite Total	0.1-0.5	100												
Total Kjeldahl Nitrogen	0.3-0.8				**7.3**			**3.9**			**3**		**2.6**	1.1
Chlorides	24-43											**111**	**281**	31
Sulfates	24-45											75		
Alkalinity	31-91											114	121	68
Hardness	68-140				131			57.8			79.2		234	
Nickel		* 1.60-6.30	< .02	< .031	< .021	< .02	< .02	< .02	<.02	<.02	<.02			
Copper	0.015	* .018-.090	0.017	0.843	0.161	0.031	0.167	0.071	0.031	0.066	0.044		< 0.1	
Total Chromium	0.01	* 1.8-6.7	< .01	**0.044**	< .016	< .01	0.015	< .011	<.01	**0.021**	<.013		< 0.5	
Hexavalent Chromium		0.015												
Zinc	0.064	* .120-.450	0.020	0.812	0.237	0.040	0.314	0.144	0.062	0.337	0.141		< 0.05	
Iron	0.052	1	**0.708**	19.2	5.516	0.051	9.23	3.24	**0.764**	2.9	1.678	**0.4**	3.8	**0.14**
Calcium													93	
Cadmium	0.01	* .0056-.032	< .001	0.004	< .001	< .001	0.001	< .001	<.001	0.0024	<.001			
Lead	0.023	* .130-1.00	0.0031	0.236	**0.081**	0.0099	0.244	0.068	0.0122	**0.0611**	0.0337		< 0.5	
Mercury (ug/L)		1.1											< 1	
Total coliform (per 100 ml or as noted)														
Fecal coliform (per 100 ml or as noted)	-	2000/100 ml	< 1,000.	700,000	220,000	12,000	250,000	140,000	≤10000	990,000	500,000			
Fecal streptococus (per 100 ml or as noted)														
pH (S.U.)		6.5-9										6.7-8.4	8.2	7.9
Phenolics														
E Coli (per 100 ml or as noted)		235/100 ml	≤ 2,000.	380,000	90,000	17,000	190,000	90,000	3,100	380,000	200,000			
Antimony		0.65												
Arsenic	0.064	0.36												
Selenium		0.02												
Thallium		0.071												
Silver	0.003	* .0016-.0063												
Beryllium		* .520-7.00												
Potassium														
Cobalt														

Table I-2 Water Quality Sampling Results for the Brook, continued

Units are in mg/L unless noted.

Parameter	Mean Conc. in Natural Waters (8,9,10)[3]	Water Quality Criteria [2]	Downstream from Lower Lake (Below Coventry)										
			NEORSD SS-03 - dry weather								NEORSD SR-03 - wet weather		
			5/21/98	5/28/98	6/11/98	6/19/98	7/1/98	7/7/98	8/18/98	11/4/98	5/31/98		
											Min	Max	Average
Temperature (C)				20.9				23.7	24.6	7.5			
D.O. (ppm)		4		10.0				4.7	6.0	10.3			
BOD				3.4			3.5	<2.	2.9				11.8
COD													
TOC													
DOC				11.6			8	12	10				
Suspended Solids				<0.5			<1.	3.5	6				133
Total Solids													
Total Dissolved Solids		1500											
Specific Conductance (umhos/cm)	243-420			**963**				424	323	469			
Turbidity													
Ammonia	0.01-0.04	* 1.1-13.0		<0.1			**0.3**	**0.15**	<0.1				**0.68**
Phosphorus	0.1	1		0.11			**0.25**	**0.2**	0.13	0.07			**0.35**
Soluble Phosphorus				0.05			0.11	0.15	0.06	<0.01			0.19
Nitrites				<0.01			<0.01	<0.05	0.06				
Nitrates	1			1			1.6	1.38	1				
Nitrate/Nitrite Total	0.1-0.5	100											
Total Kjeldahl Nitrogen	0.3-0.8			0.5			1.02	<0.2	1				**3.44**
Chlorides	24-43							59.1					
Sulfates	24-45							22.8					
Alkalinity	31-91							86					
Hardness	68-140			154			105	117	96				74
Nickel		* 1.60-6.30		<0.02			<0.02	<0.02	<0.02		< .02	< .02	< .02
Copper	0.015	* .018-.090		0.007			<0.01	<0.01	<0.01		0.008	0.903	0.135
Total Chromium	0.01	* 1.8-6.7		<0.01			<0.01	<0.01	<0.01		< .01	**0.052**	< .016
Hexavalent Chromium		0.015											
Zinc	0.064	* .120-.450		0.021			0.023	<0.01	<0.01		0.021	0.796	0.162
Iron	0.052	1		**0.162**			**0.416**	**0.376**	**0.372**		**0.394**	15.2	3.392
Calcium													
Cadmium	0.01	* .0056-.032		<0.001			<0.001	<0.001	<0.001		< .001	0.003	< .001
Lead	0.023	* .130-1.00		<0.003			<0.003	<0.003	<0.003		0.0051	0.319	**0.063**
Mercury (ug/L)		1.1											
Total coliform (per 100 ml or as noted)													
Fecal coliform (per 100 ml or as noted)		2000/100 ml	41	38	30	26,000	320	200	70		27,000	94,000	50,000
Fecal streptococus (per 100 ml or as noted)													
pH (S.U.)		6.5-9		8.2				7.1	7.1	7.8			
Phenolics													
E Coli (per 100 ml or as noted)		235/100 ml	62	36	60	24,000	110	60	310		3,100	140,000	40,000
Antimony		0.65											
Arsenic	0.064	0.36											
Selenium		0.02											
Thallium		0.071											
Silver	0.003	* .0016-.0063											
Beryllium		* .520-7.00											
Potassium													
Cobalt													

Table I-2 Water Quality Sampling Results for the Brook, continued

Units are in mg/L unless noted.

Parameter	Mean Conc. in Natural Waters (8,9,10)[3]	Water Quality Criteria [2]	Downstream from Lower Lake (Below Coventry), continued — NEORSD SR-03 - wet weather, continued — 6/12/98 Min	6/12/98 Max	6/12/98 Average	6/27/98 Min.	6/27/98 Max.	6/27/98 Avg.	N. Fork U/S From Lower Lake — NEORSD - Sampling Point N-18 (7) — 7/7 & 11/4/87 Average	1/26/88	7/11/89	8/30&9/26/90 Avg. [8]	8/30/90 [8]
Temperature (C)									16.0	1.0	23.3		
D.O. (ppm)		4							6.1	11.5	7.9	8.3	
BOD					3.9			2.7	3		1.0	1.0	< 1
COD									45	22	7	<10	
TOC													
DOC													
Suspended Solids					13			10	6	14	7	4	< 1
Total Solids												369	
Total Dissolved Solids		1500								1069	343	340	
Specific Conductance (umhos/cm)	243-420								535	**1764**	700	498	463
Turbidity									2			2	1
Ammonia	0.01-0.04	* 1.1-13.0			**0.53**			**0.49**	0.01	**0.22**	**0.09**	**0.20**	**0.4**
Phosphorus	0.1	1			**0.24**			0.01	0.11	0.06	0.13	0.06	0.06
Soluble Phosphorus					0.16			0.09		0.04	0.12	0.03	
Nitrites									0.02	0.07	0.01	<0.01	< 0.01
Nitrates	1								0.34	1.01	0.39	0.22	0.17
Nitrate/Nitrite Total	0.1-0.5	100											
Total Kjeldahl Nitrogen	0.3-0.8				**1.9**			1.2		**2.24**	1.01	**2.00**	0.56
Chlorides	24-43								**94**	**485**	73	76	66
Sulfates	24-45								40	66	36	46	41
Alkalinity	31-91									131	139	129	127
Hardness	68-140				48.2			63.1		**291**	141.0	97.0	84
Nickel		* 1.60-6.30	< .02	< .02	< .02	<.02	<.02	<.02	0.01	<.01	0.02	<0.01	< 0.01
Copper	0.015	* .018-.090	0.037	0.088	0.056	0.027	0.097	0.045	0.02	0.02	0.02	<0.01	< 0.01
Total Chromium	0.01	* 1.8-6.7	< .01	< .01	< .01	<.01	0.016	<.011	0.01	<.01	0.01	<0.01	< 0.01
Hexavalent Chromium		0.015										<0.01	< 0.01
Zinc	0.064	* .120-.450	0.042	0.104	0.057	0.045	0.172	0.091	0.06	0.04	<.01	0.01	< 0.01
Iron	0.052	1	**0.353**	2.34	0.814	**0.528**	2.13	1.246	**0.3**	1.2	**0.2**	**0.2**	**0.3**
Calcium													
Cadmium	0.01	* .0056-.032	< .001	< .001	< .001	<.001	<.001	<.001	0.01	<.01	<.01	<0.01	< 0.01
Lead	0.023	* .130-1.00	0.0062	**0.0517**	0.016	0.0064	**0.0512**	0.0227	0.01	0.01	**0.07**	<0.01	< 0.01
Mercury (ug/L)		1.1								0.1	<.2	<0.2	< 0.1
Total coliform (per 100 ml or as noted)									748 units?	300	2500	2000	320/? ml
Fecal coliform (per 100 ml or as noted)		2000/100 ml	26,000	110,000	70,000	50,000	8,200,000	2,900,000	386 units?	60	160	210	180/? ml
Fecal streptococus (per 100 ml or as noted)									315 units?	40	20	160	650/? ml
pH (S.U.)		6.5-9									7.3	7.5	7.5
Phenolics													NS
E Coli (per 100 ml or as noted)		235/100 ml	21,000	120,000	> 60,000	7,300	140,000	100,000					
Antimony		0.65											
Arsenic	0.064	0.36											
Selenium		0.02											
Thallium		0.071											
Silver	0.003	* .0016-.0063											
Beryllium		* .520-7.00											
Potassium													
Cobalt													

Table I-2 Water Quality Sampling Results for the Brook, continued

Units are in mg/L unless noted.

Parameter	Mean Conc. in Natural Waters (8,9,10)[3]	Water Quality Criteria [2]	N. Fork U/S From Lower Lake, continued — NEORSD - Sampling Point N-18 (7), continued								
			5/16/91	6/18/91	7/29/91	8/27/93	8/18/94	10/18/94	6/7/95	8/7/96	7/31/97
Temperature (C)			19.9	21.4	13.7	21	19	12.5	20.7	23.5	19.0
D.O. (ppm)		4	6.1	6.8	7.2	6.0	6.0	9.0	5.1	6.5	5.1
BOD			7	6	4	2	3	3	5	20	< 2
COD			26	26	16	< 10	12	< 10	< 10	84	19
TOC											
DOC											
Suspended Solids			20	8	10	< 1	1	2	6	62	3
Total Solids			454	314	339	314	405	260	322	381	353
Total Dissolved Solids		1500	433	301	297	271	387	233	297	280	330
Specific Conductance (umhos/cm)	243-420		715	510	470	440	710	185	530	490	**900**
Turbidity			2	2.4	3	1.4	1	1.7	0	25	2.4
Ammonia	0.01-0.04	* 1.1-13.0	**0.22**	**0.3**	**0.1**	< 0.01	**0.2**	0.02	**0.10**	**0.20**	**0.10**
Phosphorus	0.1	1	0.19	0.12	0.11	0.11	0.05	0.06	0.14	**0.54**	0.15
Soluble Phosphorus			0.16	0.09	0.08	0.1	0.04	0.03	0.14	0.11	0.13
Nitrites			0.02	< 0.01							
Nitrates	1		0.36	0.25		0.33	0.72	0.2	0.30	0.20	0.40
Nitrate/Nitrite Total	0.1-0.5	100	0.38	0.25							0.41
Total Kjeldahl Nitrogen	0.3-0.8		1.29	1.21	0.39	1.01	0.9	1.3	1.30	**5.60**	0.70
Chlorides	24-43		**154**	**114**		70	**126**	50	**92**	**116**	**116**
Sulfates	24-45		51	42		22	58	36	31	33	29
Alkalinity	31-91		138	131		110	100	102	95	90	120
Hardness	68-140		209	148	148	163	173	148	150	114	137
Nickel		* 1.60-6.30	0.01	0.01	0.01	0.004	0.004	0.006	0.003	0.008	0.011
Copper	0.015	* .018-.090	0.07	0.01	0.01	0.01	0.02	0.01	0.005	0.023	0.012
Total Chromium	0.01	* 1.8-6.7	**0.15**	0.01	**0.02**	0.001	0.002	0.002	0.004	0.002	0.001
Hexavalent Chromium		0.015	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	
Zinc	0.064	* .120-.450	0.07	0.1	0.07	0.02	0.04	0.02	0.01	0.09	0.05
Iron	0.052	1	**0.8**	**0.3**	**0.62**	**0.33**	**0.18**	**0.19**	**0.22**	1.2	**0.39**
Calcium											
Cadmium	0.01	* .0056-.032	< 0.01	< 0.01	< 0.01	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Lead	0.023	* .130-1.00	0.02	< 0.01	0.01	< 0.003	< 0.003	< 0.003	< 0.003	0.006	< 0.003
Mercury (ug/L)		1.1	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
Total coliform (per 100 ml or as noted)			280	400	1200						
Fecal coliform (per 100 ml or as noted)		2000/100 ml	160	160	200	290	700	60	250	18000	240
Fecal streptococus (per 100 ml or as noted)			80	960	460						
pH (S.U.)		6.5-9	7.4	7.6	7.7	7.6	7.7	7.7	7.7	7.7	7.1
Phenolics			< 0.05	< 0.05		< 0.05					
E Coli (per 100 ml or as noted)		235/100 ml				250	300	75		13000	58
Antimony		0.65							< 0.007		< 0.007
Arsenic	0.064	0.36					0.006	< 0.005	0.005	< 0.005	< 0.005
Selenium		0.02									< 0.005
Thallium		0.071					< 0.001	< 0.007	< 0.007	< 0.007	< 0.007
Silver	0.003	* .0016-.0063					< 0.001	0.001	0.001	< 0.001	< 0.001
Beryllium		* .520-7.00					< 0.001	< 0.001	< 0.0005	< 0.001	< 0.001
Potassium							3.2	2.1		3.70	2.00
Cobalt							< 0.001	0.001	< 0.0010	< 0.0010	

Table I-2 Water Quality Sampling Results for the Brook, continued

Units are in mg/L unless noted.

Parameter	Mean Conc. in Natural Waters (8,9,10)[3]	Water Quality Criteria [2]	N. Fork U/S from Lower Lake, continued — NEORSD SS-05 - dry weather 4/23/98	5/21/98	5/28/98	6/11/98	6/19/98	7/1/98	7/7/98	8/18/98	11/4/98	S. Fork U/S From Lower Lake — H&E (1) 1966-67 (H-6)	NEORSD - Sampling Point N-19 (7) 7/7 & 11/4/87 Average	1/26/88	7/11/89
Temperature (C)					24.0				22.6	22.1	7.1		18.0	1.0	22.9
D.O. (ppm)		4			7.1				6.6	6.3	10.2	5.5	8.3	11.0	7.7
BOD			<2.		3			3.2	<2.	<2.		3.4	2		<1
COD												78	22	16	12
TOC															
DOC					8.8			8.3	11.5	9.2					
Suspended Solids			<2.		3.5			<1.	1.5	2		86	4	20	12
Total Solids												257			
Total Dissolved Solids		1500												1056	398
Specific Conductance (umhos/cm)	243-420				685				433	502	498		242	**1693**	550
Turbidity													2		
Ammonia	0.01-0.04	* 1.1-13.0	<0.1		<0.1			**0.2**	**0.1**	<0.1		**1.3**	0.03	**0.44**	0.04
Phosphorus	0.1	1	0.07		0.13			**0.2**	**0.23**	0.11	0.05	1.2	0.18	0.10	0.08
Soluble Phosphorus			0.06		0.07			0.11	0.15	0.08	<0.01			0.06	0.06
Nitrites					<0.01			0.08	<0.05	<0.02			0.03	0.04	0.01
Nitrates	1				1.3			**8**	**1.97**	1.27		1.8	0.08	0.90	0.43
Nitrate/Nitrite Total	0.1-0.5	100													
Total Kjeldahl Nitrogen	0.3-0.8		1		0.7			0.29	<0.2	<0.2				**1.96**	1.51
Chlorides	24-43								60.8			31	69	**498**	78
Sulfates	24-45								13.4			22	36	60	52
Alkalinity	31-91								97.2			108		122	113
Hardness	68-140		158		168			125	126	152				**297**	124
Nickel		* 1.60-6.30	<0.02		<0.02			<0.02	<0.02	<0.02			0.01	<0.01	0.02
Copper	0.015	* .018-.090	0.01		0.008			<0.01	<0.01	<0.01			0.02	<0.01	0.02
Total Chromium	0.01	* 1.8-6.7	0.016		<0.01			<0.01	<0.01	<0.01			0.01	0.01	<0.01
Hexavalent Chromium		0.015													
Zinc	0.064	* .120-.450	0.02		0.022			0.018	<0.01	<0.01			0.05	<0.01	<0.01
Iron	0.052	1	**0.254**		**0.338**			**0.375**	**0.382**	**0.287**		0.7	**0.2**	**0.90**	**0.20**
Calcium															
Cadmium	0.01	* .0056-.032	<0.001		<0.001			<0.001	<0.001	<0.001			0.01	<0.01	<0.01
Lead	0.023	* .130-1.00	<0.003		<0.003			<0.003	<0.003	<0.003			0.02	<0.01	**0.14**
Mercury (ug/L)		1.1													0.9
Total coliform (per 100 ml or as noted)													4800 units?	2500	1200
Fecal coliform (per 100 ml or as noted)		2000/100 ml	27	110	560	200	11,000	200	1,900	980			1500 units?	220	220
Fecal streptococus (per 100 ml or as noted)													1000 units?	350	60
pH (S.U.)		6.5-9			7.1				7.1	7.48	8.1	5.0-8.2			7.7
Phenolics															
E Coli (per 100 ml or as noted)		235/100 ml	22	64	120	140	8,700	30	120	580					
Antimony		0.65													
Arsenic	0.064	0.36													
Selenium		0.02													
Thallium		0.071													
Silver	0.003	* .0016-.0063													
Beryllium		* .520-7.00													
Potassium															
Cobalt															

Table I-2 Water Quality Sampling Results for the Brook, continued

Units are in mg/L unless noted.

Parameter	Mean Conc. in Natural Waters (8,9,10)[3]	Water Quality Criteria [2]	S. Fork U/S From Lower Lake, continued NEORSD - Sampling Point N-19 (7), continued										
			8/30&9/26/90 Avg. [8]	8/30/90 [8]	5/16/91	6/18/91	7/29/91	8/27/93	8/18/94	10/18/94	6/7/95	8/7/96	7/31/97
Temperature (C)					19.2	20.2	13.3	22	20	11.5	20.1	23.5	19.0
D.O. (ppm)		4	7.6		5.2	6.1	6.2	7.2	6	8.6	6.0	6.5	2.8
BOD			2	1	6	4	4	2	3	2	5	3	< 2
COD			11		16	24	11	< 10	14	< 10	< 10	16	21
TOC													
DOC													
Suspended Solids			5	4	2	8	12	1	4	1	1	2	2
Total Solids			424		450	300	603	293	347	247	449	425	464
Total Dissolved Solids		1500	390		426	292	562	255	321	234	423	373	426
Specific Conductance (umhos/cm)	243-420		482	408	710	515	810	420	590	185	690	900	1100
Turbidity			2	1	2	1.6	4	1.2	6	0.94	1.00	1.60	2.20
Ammonia	0.01-0.04	* 1.1-13.0	0.26	0.52	0.18	0.22	0.16	0.1	0.02	0.01	0.20	0.20	0.10
Phosphorus	0.1	1	0.06	0.08	0.07	0.13	0.11	0.12	0.07	0.06	0.10	0.09	0.17
Soluble Phosphorus			0.04		0.03	0.12	0.08	0.12	0.04	0.05	0.10	0.09	0.15
Nitrites			<0.01	< 0.01	< 0.01	< 0.01							
Nitrates	1		0.44	0.22	0.22	0.3		0.18	0.91	0.2	0.30	0.30	0.10
Nitrate/Nitrite Total	0.1-0.5	100			0.22	0.3							0.11
Total Kjeldahl Nitrogen	0.3-0.8		1.96	2.8	1.07	0.95	0.37	0.8	0.73	1.2	1.50	0.90	0.70
Chlorides	24-43		88	64	150	114		68	94	52	122	134	152
Sulfates	24-45		48	44	51	44		24	50	31	43	34	35
Alkalinity	31-91		128	121	149	127		111	109	104	116	127	160
Hardness	68-140		104	76	213	156	200	136	144	140	180	147	172
Nickel		* 1.60-6.30	0.01	0.01	0.01	0.01	0.01	0.003	0.003	0.004	0.002	0.005	0.002
Copper	0.015	* .018-.090	0.02	0.02	0.01	0.01	0.01	0.005	0.02	0.01	0.006	0.008	0.009
Total Chromium	0.01	* 1.8-6.7	<0.01	< 0.01	0.02	0.01	0.02	0.001	0.001	0.001	0.003	0.001	0.001
Hexavalent Chromium		0.015	<0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	
Zinc	0.064	* .120-.450	<0.01	< 0.01	0.03	0.02	0.07	0.01	0.04	0.01	0.02	0.04	0.02
Iron	0.052	1	0.20	0.2	0.32	0.25	0.54	0.18	0.27	0.09	0.45	0.29	0.34
Calcium													
Cadmium	0.01	* .0056-.032	<0.01	< 0.01	< 0.01	< 0.01	0.01	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Lead	0.023	* .130-1.00	<0.01	< 0.01	< 0.01	< 0.01	0.01	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003	0.005
Mercury (ug/L)		1.1	<0.2	0.1	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
Total coliform (per 100 ml or as noted)			1100	1270/? ml	220	1700	2100						
Fecal coliform (per 100 ml or as noted)		2000/100 ml	340	954	80	350	160	200	260	95	800.0	580.0	230
Fecal streptococus (per 100 ml or as noted)			150	440	60	450	660						
pH (S.U.)		6.5-9	7.4-7.6	7.6	7.4	7.6	7.6	7.8	7.7	7.7	7.5	7.6	6.9
Phenolics					< 0.05	< 0.05		< 0.05					
E Coli (per 100 ml or as noted)		235/100 ml						170	200	35		300	180
Antimony		0.65									< 0.007		< 0.007
Arsenic	0.064	0.36							0.005	< 0.005	< 0.005	< 0.005	< 0.005
Selenium		0.02											< 0.005
Thallium		0.071							< 0.007	< 0.007	< 0.007	< 0.007	< 0.007
Silver	0.003	* .0016-.0063							< 0.001	0.001	< 0.001	0.001	< 0.001
Beryllium		* .520-7.00							< 0.001	< 0.001	< 0.0005	< 0.001	< 0.001
Potassium									2.8	2.1		3.00	2.40
Cobalt									< 0.001	< 0.001	< 0.001	< 0.001	

Table I-2 Water Quality Sampling Results for the Brook, continued

Units are in mg/L unless noted.

Parameter	Mean Conc. in Natural Waters (8,9,10)[3]	Water Quality Criteria [2]	S. Fork U/S from Lower Lake, continued — NEORSD SS-04 - dry weather: 4/23/98	5/21/98	5/28/98	6/11/98	6/19/98	7/1/98	7/7/98	8/18/98	11/4/98	NEORSD SR-04 - wet weather, 5/31/98: Min	Max	Average
Temperature (C)					23.7				23.4	24.0	6.2			
D.O. (ppm)		4			7.9				8.2	8.4	12.0			
BOD			<2.		2.5			<2.	<2.	4.3				9.3
COD														
TOC														
DOC					8.6			8.1	7.3	9.2				
Suspended Solids			14		2			<1.	<0.5	6				23
Total Solids														
Total Dissolved Solids		1500												
Specific Conductance (umhos/cm)	243-420				689				585	233	489			
Turbidity														
Ammonia	0.01-0.04	* 1.1-13.0	<0.1		<0.1			<0.1	**0.15**	<0.1				**0.35**
Phosphorus	0.1	1	0.12		0.16			**0.21**	0.09	0.15	0.14			**0.24**
Soluble Phosphorus			0.08		0.1			0.11	0.05	0.06	0.02			0.2
Nitrites					0.01			<0.01	<0.05	0.05				
Nitrates	1				1.3			1.8	**3.4**	0.52				
Nitrate/Nitrite Total	0.1-0.5	100												
Total Kjeldahl Nitrogen	0.3-0.8		1.4		0.5			0.63	**5.46**	0.57				**2.94**
Chlorides	24-43								**106**					
Sulfates	24-45								27.1					
Alkalinity	31-91								81					
Hardness	68-140		140		186			107	136	74.9				122
Nickel		* 1.60-6.30	<0.02		<0.02			<0.02	<0.02	<0.02		< .02	< .02	< .02
Copper	0.015	* .018-.090	0.009		0.006			<0.005	0.0086	<0.005		0.038	0.257	0.101
Total Chromium	0.01	* 1.8-6.7	0.014		<0.01			<0.01	<0.01	<0.01		< .01	0.017	< .012
Hexavalent Chromium		0.015												
Zinc	0.064	* .120-.450	0.024		0.079			0.023	<0.01	<0.01		0.033	0.376	**0.135**
Iron	0.052	1	**0.399**		**0.254**			**0.374**	**0.379**	**0.225**		**0.643**	10.8	3.677
Calcium														
Cadmium	0.01	* .0056-.032	<0.001		<0.001			<0.001	<0.001	<0.001		< .001	0.002	< .001
Lead	0.023	* .130-1.00	0.0082		<0.003			<0.003	<0.003	<0.003		0.0044	0.218	**0.048**
Mercury (ug/L)		1.1												
Total coliform (per 100 ml or as noted)														
Fecal coliform (per 100 ml or as noted)		'2000/100 ml	50	1,900	600	1,800	8,800	1,600	3,200	3,700		31,000	670,000	210,000
Fecal streptococus (per 100 ml or as noted)														
pH (S.U.)		6.5-9			8.1				7.8	7.5	8.3			
Phenolics														
E Coli (per 100 ml or as noted)		235/100 ml	48	920	580	730	3,700	160	1,900	1,400		9,800	110,000	40,000
Antimony		0.65												
Arsenic	0.064	0.36												
Selenium		0.02												
Thallium		0.071												
Silver	0.003	* .0016-.0063												
Beryllium		* .520-7.00												
Potassium														
Cobalt														

Table I-2 Water Quality Sampling Results for the Brook, continued   Units are in mg/L unless noted.

Parameter	Mean Conc. in Natural Waters (8,9,10)[3]	Water Quality Criteria [2]	S. Fork U/S from Lower Lake, continued						U/S From Horseshoe Lake	
			NEORSD SR-04 - wet weather, continued						COC(5) C-6	
			6/12/98			6/27/98			1973-74 [7]	
			Min.	Max.	Average	Min.	Max.	Avg.	Max.	Min.
Temperature (C)									18.7	1.5
D.O. (ppm)		4							12.4	9.8
BOD					3.6			2	6	2
COD									46	14
TOC									22	12
DOC										
Suspended Solids					13					
Total Solids									589	325
Total Dissolved Solids		1500								
Specific Conductance (umhos/cm)	243-420									
Turbidity										
Ammonia	0.01-0.04	* 1.1-13.0			0.28			0.22	0.1	< 0.1
Phosphorus	0.1	1			0.25			0.04	0.2	0.1
Soluble Phosphorus					0.14			0.01	0.1	< 0.1
Nitrites									0.019	0.012
Nitrates	1								1.68	0.05
Nitrate/Nitrite Total	0.1-0.5	100								
Total Kjeldahl Nitrogen	0.3-0.8				1.8			1.7	2.7	1.7
Chlorides	24-43								159	37
Sulfates	24-45									
Alkalinity	31-91								163	121
Hardness	68-140				68.5			143	288	
Nickel		* 1.60-6.30	< .02	< .02	< .02	<.02	<.02	<.02		
Copper	0.015	* .018-.090	0.032	0.078	0.044	0.011	0.04	0.033	< 0.1	
Total Chromium	0.01	* 1.8-6.7	< .01	< .01	< .01	<.01	0.021	<.014	< 0.5	
Hexavalent Chromium		0.015								
Zinc	0.064	* .120-.450	0.038	0.163	0.066	0.067	0.568	0.154	< 0.05	
Iron	0.052	1	0.389	3.19	0.987	0.719	3.87	1.652	0.6	0.36
Calcium									114	
Cadmium	0.01	* .0056-.032	< .001	< .001	< .001	<.001	<.001	<.001		
Lead	0.023	* .130-1.00	0.0066	0.137	0.027	0.0053	0.0516	0.0119	< 0.5	
Mercury (ug/L)		1.1							< 1	
Total coliform (per 100 ml or as noted)										
Fecal coliform (per 100 ml or as noted)		2000/100 ml	17,000	60,000	30,000	10,000	300,000	160,000		
Fecal streptococus (per 100 ml or as noted)										
pH (S.U.)		6.5-9							8.7	8
Phenolics										
E Coli (per 100 ml or as noted)		235/100 ml	6,700	31,000	20,000	15,000	110,000	36,000		
Antimony		0.65								
Arsenic	0.064	0.36								
Selenium		0.02								
Thallium		0.071								
Silver	0.003	* .0016-.0063								
Beryllium		* .520-7.00								
Potassium										
Cobalt										

Table I-2 Water Quality Sampling Results for the Brook, continued   Units are in mg/L unless noted.

Parameter	Mean Conc. in Natural Waters (8,9,10)[3]	Water Quality Criteria [2]	U/S From Horseshoe Lake, continued NEORSD SS-06 - dry weather 4/23/98	5/21/98	5/28/98	6/11/98	6/19/98	7/1/98	7/7/98	8/18/98	11/4/98
Temperature (C)					20.5				21.0	21.3	7.0
D.O. (ppm)		4			7.7				5.4	6.0	13.8
BOD			<2.		3.2			14.4	<2.	4.2	
COD											
TOC											
DOC					6.5			10.9	6.1	11.8	
Suspended Solids			<2.		1.5			40	0.5	2	
Total Solids											
Total Dissolved Solids		1500									
Specific Conductance (umhos/cm)	243-420				568				707	628	440
Turbidity											
Ammonia	0.01-0.04	* 1.1-13.0	<0.1		**0.1**			**0.3**	**0.2**	<0.1	
Phosphorus	0.1	1	0.05		**0.27**			**0.2**	**0.23**	**0.2**	**0.2**
Soluble Phosphorus			0.05		0.2			0.09	0.15	0.13	0.14
Nitrites					0.04			<0.01	<0.05	0.02	
Nitrates	1				**2.8**			**2.9**	**3**	1.59	
Nitrate/Nitrite Total	0.1-0.5	100									
Total Kjeldahl Nitrogen	0.3-0.8		0.8		0.5			**2.7**	**3.44**	<0.2	
Chlorides	24-43								**104**		
Sulfates	24-45								58.4		
Alkalinity	31-91								132		
Hardness	68-140		**292**		202			236	233	211	
Nickel		* 1.60-6.30	<0.02		<0.02			<0.02	<0.02	<0.02	
Copper	0.015	* .018-.090	0.013		0.011			0.077	0.006	0.014	
Total Chromium	0.01	* 1.8-6.7	<0.01		<0.01			<0.01	<0.01	<0.01	
Hexavalent Chromium		0.015									
Zinc	0.064	* .120-.450	0.019		0.019			**0.14**	<0.01	<0.01	
Iron	0.052	1	**0.243**		**0.447**			2.38	**0.455**	**0.599**	
Calcium											
Cadmium	0.01	* .0056-.032	0.001		<0.001			<0.001	<0.001	<0.001	
Lead	0.023	* .130-1.00	<0.003		0.007			**0.051**	<0.003	<0.003	
Mercury (ug/L)		1.1									
Total coliform (per 100 ml or as noted)											
Fecal coliform (per 100 ml or as noted)	*	2000/100 ml	2,100	1,800	1,800	1,100	16,000	110,000	>4000	36,000	
Fecal streptococus (per 100 ml or as noted)											
pH (S.U.)		6.5-9			7.0				7.22	7.21	7.92
Phenolics											
E Coli (per 100 ml or as noted)		235/100 ml	1,000	1,400	1,300	720	9,800	110,000	>2400	5,200	
Antimony		0.65									
Arsenic	0.064	0.36									
Selenium		0.02									
Thallium		0.071									
Silver	0.003	* .0016-.0063									
Beryllium		* .520-7.00									
Potassium											
Cobalt											

Table I-3 Summary of 1998 Lake Sampling

Units are in mg/L unless noted.

Parameter	Mean Conc. in Natural Waters (8,9,10)[3]	Water Quality Criteria [2]	NEORSD 1998 Averaages																			
			Lower Shaker Lake					Horseshoe Lake					Marshall Lake					Green Lake				
			4/22/98	5/27/98	7/6/98	8/19/98	11/4/98	4/22/98	5/28/98	7/7/98	8/19/98	11/5/98	4/23/98	5/28/98	7/7/98	8/19/98	11/4/98	4/23/98	5/28/98	7/7/98	8/19/98	11/5/98
Temperature (C)																						
D.O.		4																				
BOD				6.3	3.8	8.0			10	27	12			9.4	10.8	7.3			15.0	14.3	3.2	
COD																						
TOC				12.6	9.8	16.8			15.3	10.9	11.8			12.0	10.4	11.1			9.2	9.8	28.1	
Suspended Solids				8.5	4.8	20.5			18.0	34.0	21.0			4.5	7.0	12.0			27.0	7.0	4.0	
Total Solids																						
TDS		1500																				
Specific Conductance	243-420																					
Turbidity																						
Ammonia	0.01-0.04	* 1.1-13.0		**0.2**	**0.5**	**0.1**			**0.11**	**1.65**	**0.12**			<0.1	<0.1	**0.38**			<0.1	**0.63**	**0.9**	
Phosphorus	0.1	1	0.10	0.14	0.17	**0.21**	0.13	0.09	0.12	**0.32**	**0.29**	0.10	**0.21**	**0.23**	**0.33**	**0.25**	**0.24**	**0.22**	**0.39**	**0.43**	**0.31**	0.12
Soluble Phosphorus			0.05	0.02	0.05	0.01	<0.01	0.055	0.032	0.045	0.045	0.017	0.11	0.10	0.07	0.03	0.04	0.13	0.09	0.01	0.14	0.01
Nitrites				0.01	0.03	<0.02			<0.01	<0.05	<0.02			<0.01	<0.05	0.04			<0.01	0.34	<0.02	
Nitrates	1			0.67	0.52	0.23			0.75	1.68	0.415			0.6	0.23	0.22			1.0	0.57	0.54	
Nitrate/Nitrite Total	0.1-0.5	100																				
Total Kjeldahl Nitrogen	0.3-0.8			0.9	0.6	0.9			1.25	**5.18**	**4.02**			1.0	<0.2	**3.6**			**2.0**	**2.3**	**2.8**	
Chlorides	24-43				78.1	49.0				58.6	46.9				52.1	27.8				47.8	39.1	
Sulfates	24-45				27.7	35.6				25.5	38.9				14.4	20.8				29.5	24.2	
Alkalinity	31-91				92	76				93	91				86	61				86	96	
Hardness	68-140			176	136	108			168	121	119			159	105	181			196	121	120	
Nickel		* 1.60-6.30		<0.02	<0.02	<0.02			<0.02	<0.02	<0.02			<0.02	<0.02	<0.02			<0.02	<0.02	<0.02	
Copper	0.015	* .018-.090		0.010	<0.005	0.005			0.008	<0.008	<0.006			0.006	<0.005	<0.005			0.008	<0.005	<0.005	
Total Chrome	0.01	* 1.8-6.7		0.01	<0.01	<0.01			<0.01	<0.01	<0.01			<0.01	<0.01	<0.01			<0.01	<0.01	<0.01	
Hexavelent Chrome		0.015																				
Zinc	0.064	* .120-.450		0.03	<0.01	0.01			0.018	0.018	0.016			0.02	<0.01	<0.01			0.02	<0.01	<0.01	
Iron	0.052	1		**0.58**	**0.58**	**0.71**			**0.52**	1.07	**0.60**			**0:18**	**0.42**	**0.37**			**0.68**	**0.55**	**0.56**	
Calcium																						
Cadmium	0.01	* .0056-.032		<0.001	<0.001	<0.001			<0.001	<0.001	<0.001			<0.001	<0.001	<0.001			<0.001	<0.001	<0.001	
Lead	0.023	* .130-1.00		0.005	<0.003	0.004			0.003	0.009	0.014			0.014	<0.003	<0.003			<0.003	<0.003	<0.003	
Mercury (ug/L)		0.012																				
Total coliform																						
Fecal coliform		2000/100 ml		42	30	500			100	100	<100.			4	100.	<100.			170	<100.	<100.	
Fecal streptococus																						
pH (S.U.)		6.5-9				7.2	7.8			8.5		7.8			6.8		7.9			7.3		7.8
Phenolics																						
E Coli		235/100 ml		8	8	600			8	<100.	<100.			2	100	200			16	100	100	
Chlrophyll-a			5.4	15.4	48.7	58.5	42.2	13	45	370	99	95	84	43	87	79	93	28	60	99	11	57

Each of the lakes was sampled at between four and eight sampling points on each date listed in the table. The results listed here are the arithmetic mean of the results from all points on the date given. See the individual tables for complete results. Results of temperature, pH, and dissolved oxygen profile data are summarized elsewhere.

Table I-4 Temperature, pH, and D.O. Profiles of the Shaker Lakes

Parameter	Depth* (inches)	NEORSD 1998 Averages																			
		Lower Shaker Lake					Horseshoe Lake					Green Lake					Marshall Lake				
		4/22/98	5/28/98	7/6/98	8/18/98	11/4/98	4/22/98	5/28/98	7/7/98	8/19/98	11/4/98	4/23/98	5/28/98	7/7/98	8/19/98	11/5/98	4/23/98	5/28/98	7/7/98	8/19/98	11/4/98
Temperature (C)	8						16.7	21.6	23.4	22.7			24					24.3			
	12	14.1	22.9	24.5	25.7	8.2	14.8	21.7	24	23.4	8.1	16.2	23.9	24.6	23.6	7.6	15.8		24.9	24.1	8.9
	18	14.2	22.3	24.8			16.4					16.5		24.4			16.4				
	24	14.6	21.2	23.8	25.9	8.6	13.4	20.7	24.4		8.1	14.9	22.5	24.6	23.6	7.5	15.9	23.7		23.4	8.9
	30		21.8	23.8		8.1	15.2	21.3	24.1				21.5						24.3		
	36	13.9	20.4	23.3	25.8	8.5	14.5	21.3	24.1	23.4	8.1	14.9	20.4	24.4	23.5	7.6	15.1	22.3	24.4	23.5	8.6
	48	15.4	20.5	23.6	25.8		14.5	20.5	23.4	23.5	8.1		21.2	23	24	7.4	14.6		23.9	23.7	9.1
	54		20.9			9.1	12.7	19.6	23.4			14.3	19.4	22.4			13.1	21.5	23.6		
	60	13.8	20.6		24.9	9.1		8.4	22.9		8.1					7.8	13		23.1		
	72	15.1		23	24.8	9.1															
	90		17.2	18.6		9															
D.O.	8						11	11.2	6.4	3.5			11.8					11			
	12	8.6	8.9	7.1	5.6	8.4	9.9	6.7	8.1	4.7	6.9	8.1	10.9	8.5	2.5	7.3	16.6		10.7	7.8	8.4
	18	9.5	8.8	7.1			10.4					8.6		6.1			16.1				
	24	9.8	7.3	2.6	4	8.2	8.4	7.3	11.7		6.7	8	9.4	5.7	1.7	7.2	15.9	9.5		6.6	8.3
	30		8.1	8.4		7.2	10.1	9.6	6.9				6.9						4.2		
	36	8.2	5.5	3.7	6.5	8.3	6.5	10.6	1.9	3.6	7	7.4	1	0.4	2.8	7.4	4.5	7.8	5.6	5.4	8.2
	48	7.4	6.7	6.3	5.4		6.6	5.3	0.4	3.5	7		4.2	0.3	2.4	7.3	7.2		3.6	4.3	8.2
	54		6.9			8.3	5.8	0.3	0.3			2.8	0.3	0.2			1.3	2.7	0.6		
	60	3.6	6.4		6.6	8.6		0.6	0.3		7					6.8	1.3	0.5	0.6		
	72	3.3		3.1	6.3	8.2															
	90		0.9	0.5		8.2															
pH (S.U.)	8						7.8	8.9					8.8					8.7			
	12	7.3	8.4	8.5		8.2	7.5					8.3					10				
	18	7.3	8.5	8.2			7.7					8.5					9.8				
	24	7.6	8.2	7.9		8	7.4	8.4				8.3	8.7				10	8.7			
	30		8.2	8.8		7.7	7.6	8.7					8.4								
	36	7.2	7.9	7.8		8.2	7.5	8.8				8.4	7.2				9.2	8.4			
	48	8	8.4	8.6			7.6	7.9					8.1				9.2				
	54		8.4				7.2	8				8.4	7.6				8.1	8.1			
	60	7.1	8.3					8									8.5				
	72	8		8.3																	
	90			7.9																	

* Some data were recorded at odd depths. These are shown at the nearest regular depth.
Data shown are the arithmetic means of samples taken from a number of sampling points at the depth indicated.

Table I-5 Water Quality Sampling Results – Lower Shaker Lake

Units are mg/L unless noted.

Parameter	Mean Conc. in Natural Waters (8,9,10)[3]	Water Quality Criteria [2]	In-Lake Sampling																		
			OEPA 1973 Lake (3)	NOACA Averages		NEORSD 1998															
						4/22/98								5/27/98							
			9/19/73	8/17/77	11/3/77	LSW-01	LSW-02	LSW-03	LSW-04	LSW-05	LSW-06	LSW-07	LSW-08	LSW-01	LSW-02	LSW-03	LSW-04	LSW-05	LSW-06	LSW-07	LSW-08
Temperature (C)																					
D.O.		4																			
BOD			6.6												8						4.7
COD																					
TOC															13.1						12
Suspended Solids															6						11
Total Solids			258																		
TDS		1500	239																		
Specific Conductance	243-420			288	390																
Turbidity																					
Ammonia	0.01-0.04	* 1.1-13.0	0.3	0.18	<0.01										<.1						0.2
Phosphorus	0.1	1	0.1	0.162	0.118	0.16	0.12	0.11	0.06	0.06	0.07	0.12	0.11	<.12	0.13	0.09	0.12	0.16	0.15	0.16	0.16
Soluble Phosphorus				0.043	0.05	0.06	0.04	0.05	0.05	0.04	0.06	0.06	0.08	0.02	0.01	0.02	0.02	0.02	0.03	0.03	0.05
Nitrites			0.01												<.01						<.01
Nitrates	1		ND	0.9	6.0										0.58						0.76
Nitrate/Nitrite Total	0.1-0.5	100																			
Total Kjeldahl Nitrogen	0.3-0.8		1	0.41	0.57										1.1						0.7
Chlorides	24-43		39																		
Sulfates	24-45		49																		
Alkalinity	31-91		98	88.1	111.6																
Hardness	68-140		140												153						199
Nickel		* 1.60-6.30	ND												<.02						<.02
Copper	0.015	* .018-.090	ND												0.007						0.012
Total Chrome	0.01	* 1.8-6.7	ND												<.01						<.01
Hexavelent Chrome		0.015																			
Zinc	0.064	* .120-.450	ND												<.019						0.036
Iron	0.052	1	0.6												0.377						0.778
Calcium			44																		
Cadmium	0.01	* .0056-.032	ND												<.001						<.001
Lead	0.023	* .130-1.00	ND												<.003						0.0061
Mercury (ug/L)		0.012	ND																		
Total coliform			See Table I-9 for results of bacteriological sampling.																		
Fecal coliform		2000/100 ml	See Table I-9 for results of bacteriological sampling.												<3						80
Fecal streptococus			See Table I-9 for results of bacteriological sampling.																		
pH (S.U.)		6.5-9	8.5	7.9	8.0																
Phenolics																					
E Coli		235/100 ml	See Table I-9 for results of bacteriological sampling.																		8
Antimony		0.65																			
Arsenic	0.064	0.36																			
Manganese	0.058		0.18																		
Selenium		0.02																			
Thallium		0.071																			
Silver	0.003	* .0016-.0063																			
Beryllium		* 0.520-7.00	ND																		
Magnesium (total)			8																		
Potassium (total)			5.1																		
Cobalt																					
Sodium (total)			27																		
Aluminum			0.3																		
Barium			0.2																		
Chlrophyll-a				43.2	11.1	11.49	3.84	3.84	4.81	2.88	5.77	3.84	6.73	15	21.4	10.7	12.8	8.54	24.6	20.3	9.61

Table I-5 Water Quality Sampling Results – Lower Shaker Lake, continued

Units are mg/L unless noted.

Parameter	Mean Conc. in Natural Waters (8,9,10)[3]	Water Quality Criteria [2]	In-Lake Sampling NEORSD 1998, continued															
			7/6/98								8/18/98							
			LSW-01	LSW-02	LSW-03	LSW-04	LSW-05	LSW-06	LSW-07	LSW-08	LSW-01	LSW-02	LSW-03	LSW-04	LSW-05	LSW-06	LSW-07	LSW-08
Temperature (C)																		
D.O.		4																
BOD				5.5						<2.		9.2						6.9
COD																		
TOC				8.8						10.8		12.3						21.3
Suspended Solids				9						<.5		17						24
Total Solids																		
TDS		1500																
Specific Conductance	243-420																	
Turbidity																		
Ammonia	0.01-0.04	* 1.1-13.0		**0.88**						<.1		<.1						**0.12**
Phosphorus	0.1	1	0.17	0.18	**0.2**	0.17	0.17	0.15	0.15	0.13	**0.2**	0.19	**0.2**	**0.23**	**0.23**			**0.23**
Soluble Phosphorus			0.02	0.03	0.03	0.03	0.04	0.05	0.06	0.14	0.01	0.01	0.01	<.01	<.01	<.01	0.01	0.02
Nitrites				0.01						0.06		<.02						<.02
Nitrates	1			0.18						0.85		0.13						0.33
Nitrate/Nitrite Total	0.1-0.5	100																
Total Kjeldahl Nitrogen	0.3-0.8			0.87						0.37		1.03						0.69
Chlorides	24-43			60.8						**95.5**		40.8						57.3
Sulfates	24-45			25.2						30.1		33.2						38
Alkalinity	31-91			81						103		70.8						81
Hardness	68-140			110						161		97.4						119
Nickel		* 1.60-6.30		<.02						<.02		<.02						<.02
Copper	0.015	* .018-.090		<.005						<.005		<.005						0.0053
Total Chrome	0.01	* 1.8-6.7		<.01						<.01		<.01						<.01
Hexavelent Chrome		0.015																
Zinc	0.064	* .120-.450		<.01						<.01		<.01						0.014
Iron	0.052	1		**0.522**						**0.629**		**0.446**						**0.964**
Calcium																		
Cadmium	0.01	* .0056-.032		<.001						<.001		<.001						<.001
Lead	0.023	* .130-1.00		<.003						<.003		<.003						0.0053
Mercury (ug/L)		0.012																
Total coliform																		
Fecal coliform		2000/100 ml		32						28		<100.						900
Fecal streptococus																		
pH (S.U.)		6.5-9										7.42						6.92
Phenolics																		
E Coli		235/100 ml		8						8		<100.						1100
Antimony		0.65																
Arsenic	0.064	0.36																
Manganese	0.058																	
Selenium		0.02																
Thallium		0.071																
Silver	0.003	* .0016-.0063																
Beryllium		* 0.520-7.00																
Magnesium (total)																		
Potassium (total)																		
Cobalt																		
Sodium (total)																		
Aluminum																		
Barium																		
Chlrophyll-a			67.6	65.3	66.8	50.7	56.1	42.7	34.7	5.34	52.3	68.4	77.9	69.4	56.6	44.9	58.7	39.5

Table I-5 Water Quality Sampling Results – Lower Shaker Lake, continued

Units are mg/L unless noted.

Parameter	Mean Conc. in Natural Waters (8,9,10)[3]	Water Quality Criteria [2]	In-Lake Sampling NEORSD 1998, continued 11/4/98 LSW-01	LSW-02	LSW-03	LSW-04	LSW-05	LSW-06	LSW-07	LSW-08	Outfall Sampling H&E (1) 1966-67 SP#H-4	Hina 1973 (2)	COC 1973-74 SP#C-4 Lower Lake Outlet (5) Max.	Min.	COC 1974 (4)	NEORSD 8/29/90
Temperature (C)													21.2	12		
D.O.		4									6.2		13.2	6.2		
BOD											4.3	5	7	1.7	5.7	6
COD											54	30	43	20	30.4	
TOC													14	8		
Suspended Solids																8
Total Solids											470	433	743	283		
TDS		1500									420	400			234	
Specific Conductance	243-420															472
Turbidity																4
Ammonia	0.01-0.04	* 1.1-13.0									2.5	0.16	0.2	< 0.1		0.1
Phosphorus	0.1	1	0.12	0.13	0.13	0.12	0.11	0.13	0.13	0.14	0.7	0.16	0.2	0.1	0.2	0.11
Soluble Phosphorus			<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01			0.1	< 0.1		
Nitrites													0.246	< 0.001		< 0.01
Nitrates	1										1.6	0.4	0.82	0.004		0.03
Nitrate/Nitrite Total	0.1-0.5	100														
Total Kjeldahl Nitrogen	0.3-0.8											1.44	2.5	1.2	1.3	1.12
Chlorides	24-43										173	115	288	28		45
Sulfates	24-45										78				475	38
Alkalinity	31-91										114	105	119	84	104	133
Hardness	68-140												216	167		112
Nickel		* 1.60-6.30														< 0.01
Copper	0.015	* .018-.090											< 0.1			0.01
Total Chrome	0.01	* 1.8-6.7											< 0.5			0.01
Hexavelent Chrome		0.015														< 0.01
Zinc	0.064	* .120-.450											< 0.05			0.02
Iron	0.052	1									0.5	1.35	3.64	0.22	0.2	0.1
Calcium													86	46		
Cadmium	0.01	* .0056-.032														< 0.01
Lead	0.023	* .130-1.00											< 0.5			< 0.01
Mercury (ug/L)		0.012											< 1			< 0.1
Total coliform																
Fecal coliform		2000/100 ml									850					
Fecal streptococus											10					
pH (S.U.)		6.5-9	7.91	7.84	7.82	7.86	7.83	7.87	7.87	7.73	5.8-8.3		7.7	8.7		7.6
Phenolics																< 0.05
E Coli		235/100 ml														
Antimony		0.65														
Arsenic	0.064	0.36														
Manganese	0.058															
Selenium		0.02														
Thallium		0.071														
Silver	0.003	* .0016-.0063														
Beryllium		* 0.520-7.00														
Magnesium (total)																
Potassium (total)																
Cobalt																
Sodium (total)																
Aluminum																
Barium																
Chlorophyll-a			37.4	39.5	48.1	43.8	48.1	44.8	47	28.8						

Table I-6 Water Quality Sampling Results – Horseshoe Lake

Units are mg/L unless noted.

Parameter	Mean Conc. In Natural Waters (8,9,10)[3]	Water Quality Criteria [2]	In Lake Sampling: OEPA 1973 Lake (3) 9/19/73	NOACA Averages 08/17/77	NOACA Averages 11/03/77	NEORSD 1998 4/22/98 USW-01	4/22/98 USW-02	4/22/98 USW-03	4/22/98 USW-04	4/22/98 USW-05	4/22/98 USW-06	5/28/98 USW-01	5/28/98 USW-02	5/28/98 USW-03	5/28/98 USW-04	5/28/98 USW-05	5/28/98 USW-06	7/7/98 USW-01	7/7/98 USW-02	7/7/98 USW-03	7/7/98 USW-04	7/7/98 USW-05	7/7/98 USW-06
Temperature (C)						See Table I-4 for data.																	
D.O.		4				See Table I-4 for data.																	
BOD			7.6									9.8				11.1		37.5				16.7	
COD																							
TOC												13.5				17		11.2				10.6	
Suspended Solids												16				20		23				45	
Total Solids			235																				
TDS		1500	275																				
Specific Conductance	243-420			320	390																		
Turbidity																							
Ammonia	0.01-0.04	* 1.1-13.0	0.2	0.1	<0.1							<.1				0.13		2.19				1.11	
Phosphorus	0.1	1	0.3	0.234	0.213	0.12	0.05	0.12	0.05	0.1	0.12	0.15	0.17	0.13	0.07	0.16	0.05	0.43	0.3	0.29	0.31	0.2	0.38
Soluble Phosphorus			ND	0.029	0.051	0.05	0.05	0.06	0.04	0.07	0.06	0.01	0.02	0.02	0.02	0.08	0.04	<.01	0.03	0.01	<.01	0.1	0.11
Nitrites			0.01									<.01				<.01		<.05				<.05	
Nitrates	1		0.1	0.5	7.9							0.7				0.8		0.51				2.85	
Nitrate/Nitrite Total	0.1-0.5	100																					
Total Kjeldahl Nitrogen	0.3-0.8			0.52	1.14							0.9				1.6		6.52				3.84	
Chlorides	24-43		36															56.5				60.8	
Sulfates	24-45		53															26.1				24.9	
Alkalinity	31-91		88	93.7	119													96.1				89	
Hardness	68-140		140									172				164		116				126	
Nickel		* 1.60-6.30	ND									<.02				<.02		<.02				<.02	
Copper	0.015	* .018-.090	ND									0.007				0.008		<.005				<.011	
Total Chrome	0.01	* 1.8-6.7	ND									<.01				<.01		<.01				<.01	
Hexavelent Chrome		0.015																					
Zinc	0.064	* .120-.450	ND									0.019				0.016		<.01				0.026	
Iron	0.052	1	0.5									0.376				0.666		0.509				1.63	
Calcium			40																				
Cadmium	0.01	* .0056-.032	ND									<.001				<.001		<.001				<.001	
Lead	0.023	* .130-1.00	ND									<.003				0.0033		<.003				0.015	
Mercury (ug/L)		0.012	ND																				
Total coliform (cells/100 mL or as noted)			See Table I-9 for results of bacteriological sampling.																				
Fecal coliform (cells/100 mL or as noted)		2000/100 ml	See Table I-9 for results of bacteriological sampling.									40				160		<100.				100	
Fecal streptococus (cells/100 mL or as noted)			See Table I-9 for results of bacteriological sampling.																				
pH (S.U.)		6.5-9	9	8.5	8.1	See Table I-4 for data.												8.6				8.32	
Phenolics																							
E Coli		235/100 ml	See Table I-9 for results of bacteriological sampling.									4				12		<100.				<100.	
Antimony		0.65																					
Arsenic	0.064	0.36																					
Manganese	0.058		0.22		-																		
Selenium		0.02																					
Thallium		0.071																					
Silver	0.003	* .0016-.0063																					
Beryllium		* 0.520-7.00	ND																				
Magnesium (total)			9																				
Potassium (total)			5.6																				
Cobalt																							
Sodium (total)			25																				
Aluminum			0.2																				
Barium			0.2																				
Chlorphyll-a				98.9	21.9	11.5	11.5	18.3	17.3	11.5	10.6	45.4	48.1	37.4	45.4	40.1	53.4	634	549	347	401	190	101

Table I-6 Water Quality Sampling Results – Horseshoe Lake, continued

Units are mg/L unless noted.

Parameter	Mean Conc. in Natural Waters (8,9,10)[3]	Water Quality Criteria [2]	In Lake Sampling, continued NEORSD 1998, continued 8/19/98						11/5/98						At Outfall H&E (1) 1966-67	COC 1973-74 SP#C-5 Horseshoe L. Outlet (5)		NEORSD 8/29/90
			USW-01	USW-02	USW-03	USW-04	USW-05	USW-06	USW-01	USW-02	USW-03	USW-04	USW-05	USW-06	SP#H-5	Max.	Min.	
Temperature (C)																22.8	3	
D.O.		4													5.9	10	7.4	
BOD			10.6				12.6								4.5	10	5	6
COD															51	45	24	
TOC			9.9				13.6									17	10	
Suspended Solids			22				20								90			10
Total Solids															253	781	262	
TDS		1500																
Specific Conductance	243-420																	433
Turbidity																		4
Ammonia	0.01-0.04	* 1.1-13.0	<.1				0.14								4.2	0.1	< 0.1	0.28
Phosphorus	0.1	1	0.29	0.27	0.33	0.29	0.34	0.22	0.1	0.1	0.09	0.11	0.09	0.09	0.8	0.3	0.2	0.14
Soluble Phosphorus			0.04	0.03	0.04	0.03	0.08	0.05	<.01	0.02	0.02	0.02	0.01	0.02		0.1	< 0.1	
Nitrites			<.02				<.02									0.023	< 0.001	< 0.01
Nitrates	1		0.36				0.47								1.2	1.68	0.02	0.12
Nitrate/Nitrite Total	0.1-0.5	100																
Total Kjeldahl Nitrogen	0.3-0.8		4.02				4.02									2.4	1.5	0.56
Chlorides	24-43		46.9				46.9								33	286	38	42
Sulfates	24-45		40				37.8								43			34
Alkalinity	31-91		91.1				90.1								93	150	98	127
Hardness	68-140		117				121									240		112
Nickel		* 1.60-6.30	<.02				<.02											< 0.01
Copper	0.015	* .018-.090	<.005				0.0078									0.1		< 0.01
Total Chrome	0.01	* 1.8-6.7	<.01				<.01									< 0.5		< 0.01
Hexavelent Chrome		0.015														<		< 0.01
Zinc	0.064	* .120-.450	<.01				0.022									0.05		< 0.01
Iron	0.052	1	0.557				0.64								0.3	2.5	0.3	0.2
Calcium																95		
Cadmium	0.01	* .0056-.032	<.001				<.001											< 0.01
Lead	0.023	* .130-1.00	0.003				0.025									0.5		< 0.01
Mercury (ug/L)		0.012														< 1		0.1
Total coliform (cells/100 mL or as noted)															38000			
Fecal coliform (cells/100 mL or as noted)		2000/100 ml	<100.															
Fecal streptococus (cells/100 mL or as noted)																		
pH (S.U.)		6.5-9							7.83	7.77	7.78	7.63	7.75	7.83	5.8-8.2	8.9	7.8	8.6
Phenolics																		< 0.05
E Coli		235/100 ml	<100.															
Antimony		0.65																
Arsenic	0.064	0.36																
Manganese	0.058																	
Selenium		0.02																
Thallium		0.071																
Silver	0.003	* .0016-.0063																
Beryllium		* 0.520-7.00																
Magnesium (total)																		
Potassium (total)																		
Cobalt																		
Sodium (total)																		
Aluminum																		
Barium																		
Chlorphyll-a			114	106	120	120	67.3	67.3	99.3	105	90.8	112	63	101				

Table I-7 Water Quality Sampling Results – Marshall Lake

Units are mg/L unless noted.

Parameter	Mean Conc. in Natural Waters (8,9,10)[3]	Water Quality Criteria [2]	NEORSD 1998																			
			4/23/98				5/28/98				7/7/98				8/19/98				11/4/98			
			MLW-1	MLW-2	MLW-3	MLW-4	MLW-1	MLW-2	MLW-3	MLW-4	MLW-1	MLW-2	MLW-3	MLW-4	MLW-1	MLW-2	MLW-3	MLW-4	MLW-1	MLW-2	MLW-3	MLW-4
Temperature (C)			See Table I-4 for profile data.																			
D.O.		4	See Table I-4 for profile data.																			
BOD							9.4				10.8				7.3							
COD																						
TOC							12				10.4				11.1							
Suspended Solids							4.5				7				12							
Total Solids																						
TDS		1500																				
Specific Conductance	243-420																					
Turbidity																						
Ammonia	0.01-0.04	* 1.1-13.0					<.1				<.1				0.38							
Phosphorus	0.1	1	0.24	0.24	0.23	0.13	0.22	0.25	0.23	0.23	0.31	0.31	0.34	0.35	0.28	0.31	0.21	0.19	0.18	0.19	0.27	0.33
Soluble Phosphorus			0.11	0.11	0.13	0.11	0.1	0.1	0.1	0.1	0.06	0.07	0.08	0.08	0.03	0.04	0.02	0.02	<.01	<.01	0.04	0.1
Nitrites							<.01				<.05				0.04							
Nitrates	1						0.6				0.23				0.22							
Nitrate/Nitrite Total	0.1-0.5	100																				
Total Kjeldahl Nitrogen	0.3-0.8						1				<.2				3.58							
Chlorides	24-43										52.1				27.8							
Sulfates	24-45										14.4				20.8							
Alkalinity	31-91										86				60.7							
Hardness	68-140						159				105				181							
Nickel		1.60-6.30					<.02				<.02				<.02							
Copper	0.015	* .018-.090					0.006				<.005				<.005							
Total Chrome	0.01	1.80-6.70					<.01				<.01				<.01							
Hexavalent Chrome		0.015																				
Zinc	0.064	* .120-.450					0.021				<.01				<.01							
Iron	0.052	1					0.178				0.424				0.369							
Calcium																						
Cadmium	0.01	* .0056-.032					<.001				<.001				<.001							
Lead	0.023	* 0.13-1.00					0.0138				<.003				<.003							
Mercury (ug/L)		0.012																				
Total coliform (per 100 ml or as noted)			See Table I-9.																			
Fecal coliform (per 100 ml or as noted)		2000/100 ml					4				100				<100							
Fecal streptococus (per 100 ml or as noted)																						
pH (S.U.)		6.5-9	See Table I-4 for profile data.								6.83								7.94	7.98	7.83	7.7
Phenolics																						
E Coli (per 100 ml or as noted)		235/100 ml	See Table I-9.				2				100				200							
Antimony		0.65																				
Arsenic	0.064	0.36																				
Manganese	0.058																					
Selenium		0.02																				
Thallium		0.071																				
Silver	0.003	* .0016-.0063																				
Beryllium		* .520-7.00																				
Magnesium (total)																						
Potassium (total)																						
Cobalt																						
Sodium (total)																						
Aluminum																						
Barium																						
Chlorophyll-a			68.2	99	64.4	105	61.4	40.1	32	37.4	85.4	85.4	93.5	85.4	76.9	103	71.6	66.2	86.5	89.7	100	96.1

Table I-8 Water Quality Sampling Results –Green Lake

Units are mg/L unless noted.

Parameter	Mean Conc. in Natural Waters (8,9,10)[3]	Water Quality Criteria [2]	NEORSD 1998																			
			4/23/98				5/28/98				7/7/98				8/19/98				11/5/98			
			GLW-1	GLW-2	GLW-3	GLW-4	GLW-1	GLW-2	GLW-3	GLW-4	GLW-1	GLW-2	GLW-3	GLW-4	GLW-1	GLW-2	GLW-3	GLW-4	GLW-1	GLW-2	GLW-3	GLW-4
Temperature (C)			See Table I-4 for profile data.																			
D.O.		4	See Table I-4 for profile data.																			
BOD							15				14.3				3.2							
COD																						
TOC							9.2				9.8				28.1							
Suspended Solids							27				7				4							
Total Solids																						
TDS		1500																				
Specific Conductance	243-420																					
Turbidity																						
Ammonia	0.01-0.04	* 1.1-13.0					<.1				0.63				0.9							
Phosphorus	0.1	1	0.22	0.23	0.18	0.23	0.42	0.2	0.37	0.55	0.31	0.33	0.35	0.74	0.28	0.34	0.27	0.33	0.13	0.11	0.13	0.13
Soluble Phosphorus			0.13	0.12	0.15	0.14	0.09	0.1	0.09	0.09	<.01	0.01	<.01	0.01	0.13	0.13	0.14	0.18	<.01	<.01	<.01	<.01
Nitrites							<.01				0.34				<.02							
Nitrates	1						1				0.57				0.54							
Nitrate/Nitrite Total	0.1-0.5	100																				
Total Kjeldahl Nitrogen	0.3-0.8						2				2.3				2.8							
Chlorides	24-43										47.8				39.1							
Sulfates	24-45										29.5				24.2							
Alkalinity	31-91										86				96.1							
Hardness	68-140						196				121				120							
Nickel		* 1.60-6.30					<.02				<.02				<.02							
Copper	0.015	* .018-.090					0.008				<.005				<.005							
Total Chrome	0.01	* 1.8-6.7					<.01				<.01				<.01							
Hexavelent Chrome		0.015																				
Zinc	0.064	* .120-.450					0.017				<.01				<.01							
Iron	0.052	1					0.678				0.549				0.555							
Calcium																						
Cadmium	0.01	* .0056-.032					<.001				<.001				<.001							
Lead	0.023	* .130-1.00					<.003				<.003				<.003							
Mercury (ug/L)		0.012																				
Total coliform (per 100 ml or as noted)																						
Fecal coliform (per 100 ml or as noted)		2000/100 ml	See Table I-9.				170				100				<100							
Fecal streptococus (per 100 ml or as noted)																						
pH (S.U.)		6.5-9	See Table I-4.								7.34								7.83	7.84	7.92	7.67
Phenolics																						
E Coli (per 100 ml or as noted)		235/100 ml	See Table I-9.				16				<100				<100							
Antimony		0.65																				
Arsenic	0.064	0.36																				
Manganese	0.058																					
Selenium		0.02																				
Thallium		0.071																				
Silver	0.003	* .0016-.0063																				
Beryllium		* .520-7.00																				
Magnesium (total)																						
Potassium (total)																						
Cobalt																						
Sodium (total)																						
Aluminum																						
Barium																						
Chlrophyll-a			27.9	22.1	32.7	29.8	71.2	69.4	37.4	61.4	85.4	101	101	107	16	10.7	8.5	7.5	68.4	50.2	66.2	44.9

Table I-9 Water Quality Sampling Results – Bacteria [6]

Location	Ref.	Date	Units	Total Coliform		Fecal Coliform		Fecal Streptococci		E. Coli
				Low	High	Low	High	Low	High	(per 100 mL)
North Fork of Doan Brook:										
Outfall nr. Warrensville Ctr Rd (O-t)	(4)	1974	cells/100 ml	--	--	--	< 8	--	< 9	
Outfall nr. Warrensville Ctr Rd (O-u)	(4)	1974	cells/100 ml	--	--	--	3	--	60	
U/S from Horseshoe Lake (COC AB-11)	(4)	1974	cells/100 ml	3,000	82,000	97	75,000	100	25,000	
U/S from Horseshoe Lake (SS-06)	(7)	4/23/98	cells/100 ml	--	--	--	2,100	--	--	1,000
	(7)	5/21/98	cells/100 ml	--	--	--	1,800	--	--	1,400
	(7)	5/28/98	cells/100 ml	--	--	--	1,800	--	--	1,300
	(7)	6/11/98	cells/100 ml	--	--	--	1,100	--	--	720
	(7)	6/19/98	cells/100 ml	--	--	--	16,000	--	--	9,800
	(7)	7/1/98	cells/100 ml	--	--	--	110,000	--	--	110,000
	(7)	7/7/98	cells/100 ml	--	--	--	>4000	--	--	2,400
	(7)	8/18/98	cells/100 ml	--	--	--	36,000	--	--	5,200
Middle Fork of Doan Brook:										
Outfall nr. Warrensville Ctr Rd (O-y)	(4)	1974	cells/100 ml	--	--	--	3,000	--	940	
U/S from Horseshoe Lake (COC AB-10)	(4)	1974	cells/100 ml	--	8,400	--	900	--	1,200	
Horseshoe Lake:										
In Lake:										
City of Cleveland	(4)	1974	cells/100 ml	1,500	630,000	100	60,000	100	64,000	--
NOACA	(12)	8/17/77	cells/100 ml	--	--	28	76	--	--	--
USW-1 through USW-6	(7)	5/28/98	cells/100 ml	--	--	40	160	--	--	4 - 12
USW-1 through USW-6	(7)	7/7/98	cells/100 ml	--	--	<100	100	--	--	<100
USW-1 through USW-6	(7)	8/19/98	cells/100 ml	--	--	--	<100	--	--	<100
At Outfall:										
H-5	(1)	1966-67	cells/100 ml	--	38,000	--	--	--	--	--
COC C-5	(4)	1974	cells/100 ml	900	32,000	< 16	65,000	16	10,000	--
NEORSD	(7)	8/29/90	cells/100 ml	--	20	--	10	--	10	--
NEORSD	(7)	8/30/90	cells/100 ml	--	100	--	30	--	10	--
South Fork of Doan Brook:										
Outfall nr. Warrensville Ctr Rd (O-v)	(4)	1974	cells/100 ml	--	--	--	3,800	--	1,500	--
Outfall nr. Warrensville Ctr Rd (O-w)	(4)	1974	cells/100 ml	--	--	--	≥ 15,000	--	2,100	--
U/S from Green Lake (COC AB-9)	(4)	1974	cells/100 ml	3,500	21,000	270	4,600	500	7,000	--
Green Lake:										
COC L-4	(4)	1974	cells/100 ml	2,500	110,000	< 270	22,000	400	30,000	--
GLW-1 through GLW-4	(7)	5/28/98	cells/100 ml	--	--	--	170	--	--	16
GLW-1 through GLW-4	(7)	7/7/98	cells/100 ml	--	--	--	100	--	--	<100
GLW-1 through GLW-4	(7)	8/19/98	cells/100 ml	--	--	--	<100	--	--	<100
Between Green and Marshall L.:										
COC AB-8	(4)	1974	cells/100 ml	4,000	440,000	<270	33,000	400	3,300	--
Marshall Lake:										
COC L-3	(4)	1974	cells/100 ml	2,000	11,000	< 270	1,100	< 270	400	--
MLW-1 through MLW-4	(7)	5/28/98	cells/100 ml	--	--	--	4	--	--	2
MLW-1 through MLW-4	(7)	7/7/98	cells/100 ml	--	--	--	100	--	--	100
MLW-1 through MLW-4	(7)	8/19/98	cells/100 ml	--	--	--	<100	--	--	200

Table I-9 Water Quality Sampling Results – Bacteria, continued

Location	Ref.	Date	Units	Total Coliform Low	Total Coliform High	Fecal Coliform Low	Fecal Coliform High	Fecal Streptococci Low	Fecal Streptococci High	E. Coli (per 100 mL)
Marshall Lake to Lower Lake:										
U/S From Shaker Boulevard:										
COC AB-7	(4)	1974	cells/100 ml	1,300	6,800	100	450	100	> 1,500,000	--
SS/SR-04	(7)	4/23/98	cells/100 ml	--	--	--	50	--	--	48
SS/SR-04	(7)	5/21/98	cells/100 ml	--	--	--	1,900	--	--	920
SS/SR-04	(7)	5/28/98	cells/100 ml	--	--	--	600	--	--	580
SS/SR-04	(7)	5/31/98	cells/100 ml	--	--	31,000	670,000	--	--	110,000
SS/SR-04	(7)	6/11/98	cells/100 ml	--	--	--	1,800	--	--	730
SS/SR-04	(7)	6/12/98	cells/100 ml	--	--	17,000	60,000	--	--	31,000
SS/SR-04	(7)	6/19/98	cells/100 ml	--	--	--	8,800	--	--	3,700
SS/SR-04	(7)	6/27/98	cells/100 ml	--	--	10,000	300,000	--	--	110,000
SS/SR-04	(7)	7/1/98	cells/100 ml	--	--	--	1,600	--	--	160
SS/SR-04	(7)	7/7/98	cells/100 ml	--	--	--	3,200	--	--	1,900
SS/SR-04	(7)	8/18/98	cells/100 ml	--	--	--	3,700	--	--	1,400
D/S From Shaker Boulevard:										
COC AB-6	(4)	1974	cells/100 ml	--	13,000	--	6,600	--	--	--
N-19	(7)	7/7&11/4/87	??	--	4,752	--	1,466	--	986	--
N-19	(7)	01/26/88	cells/100 ml	--	2,500	--	220	--	350	--
N-19	(7)	07/11/89	cells/100 ml	--	1,200	--	220	--	60	--
N-19	(7)	8/30&9/26/90	cells/100 ml	--	1,100	--	340	--	150	--
N-19	(7)	8/30/90	cells/100 ml		1,270	--	954	--	440	--
N-19	(7)	5/16/91	cells/100 ml	--	220	--	80	--	60	--
N-19	(7)	6/18/91	cells/100 ml	--	1,700	--	350	--	450	--
N-19	(7)	7/29/91	cells/100 ml	--	2,100	--	160	--	660	--
N-19	(7)	8/27/93	cells/100 ml	--	--	--	200	--	--	170
N-19	(7)	8/18/94	cells/100 ml	--	--	--	260	--	--	200
N-19	(7)	10/18/94	cells/100 ml	--	--	--	95	--	--	35
N-19	(7)	6/7/95	cells/100 ml	--	--	--	800	--	--	--
N-19	(7)	8/7/96	cells/100 ml	--	--	--	580	--	--	300
N-19	(7)	7/31/97	cells/100 ml	--	--	--	230	--	--	180
Horseshoe Lake to Lower Lake:										
N. Fork U/S from Lower Lake:										
COC AB-5	(4)	1974	cells/100 ml	--	14,000	--	4,600	--	8,000	--
N-18	(7)	7/7&11/4/87	??	--	748	--	386	--	315	--
N-18	(7)	01/26/88	cells/100 ml	--	300	--	60	--	40	--
N-18	(7)	07/11/89	cells/100 ml	--	2,500	--	160	--	20	--
N-18	(7)	8/30&9/26/90	cells/100 ml	--	1,200	--	220	--	60	--
N-18	(7)	8/30/90	cells/100 ml	--	320	--	180	--	650	--
N-18	(7)	5/16/91	cells/100 ml	--	280	--	160	--	80	--
N-18	(7)	6/18/91	cells/100 ml	--	400	--	160	--	960	--
N-18	(7)	7/29/91	cells/100 ml	--	1,200	--	200	--	460	--
N-18	(7)	8/27/93	cells/100 ml	--	--	--	290	--	--	250
N-18	(7)	8/18/94	cells/100 ml	--	--	--	700	--	--	300
N-18	(7)	10/18/94	cells/100 ml	--	--	--	60	--	--	75
N-18	(7)	6/7/95	cells/100 ml	--	--	--	250	--	--	--
N-18	(7)	8/7/96	cells/100 ml	--	--	--	18,000	--	--	13,000
N-18	(7)	7/21/97	cells/100 ml	--	--	--	240	--	--	58
SS-05	(7)	4/23/98	cells/100 ml	--	--	--	27	--	--	22
SS-05	(7)	5/21/98	cells/100 ml	--	--	--	110	--	--	64
SS-05	(7)	5/28/98	cells/100 ml	--	--	--	560	--	--	120
SS-05	(7)	6/11/98	cells/100 ml	--	--	--	200	--	--	140
SS-05	(7)	6/19/98	cells/100 ml	--	--	--	11,000	--	--	8,700
SS-05	(7)	7/1/98	cells/100 ml	--	--	--	200	--	--	30
SS-05	(7)	7/7/98	cells/100 ml	--	--	--	1,900	--	--	120
SS-05	(7)	8/18/98	cells/100 ml	--	--	--	980	--	--	580
Lower Lake:										
In Lake										
COC	(4)	1974	cells/100 ml	< 200	26,000	< 20	1,600	< 20	2,500	--
NOACA	(12)	08/17/77	cells/100 ml	--	--	56	137	--	--	--
LSW-1 through LSW-8	(7)	5/27/98	cells/100 ml	--	--	<3	80	--	--	8
LSW-1 through LSW-8	(7)	7/6/98	cells/100 ml	--	--	28	32	--	--	8
LSW-1 through LSW-8	(7)	8/18/98	cells/100 ml	--	--	<100	900	--	--	≤100 - 1,100
At Outfall										
H-4	(1)	1966-67	cells/100 ml	--	--	--	850	--	10	--
NEORSD	(7)	8/29/90	cells/100 ml	--	20	--	<10	--	<10	--
NEORSD	(7)	8/30/90	cells/100 ml	--	140	--	<10	--	30	--

Table I-9 Water Quality Sampling Results – Bacteria, continued

Location	Ref.	Date	Units	Total Coliform Low	Total Coliform High	Fecal Coliform Low	Fecal Coliform High	Fecal Streptococci Low	Fecal Streptococci High	E. Coli (per 100 mL)
Lower Lake to University Circle:										
Just Below Lower Lake:										
COC AB-4	(4)	1974	cells/100 ml	1,900	7,200	< 40	4,100	16	1,500	--
SS/SR-03	(7)	5/21/98	cells/100 ml	--	--	--	41	--	--	62
SS/SR-03	(7)	5/28/98	cells/100 ml	--	--	--	38	--	--	36
SS/SR-03	(7)	5/31/98	cells/100 ml	--	--	27,000	94,000	--	--	140,000
SS/SR-03	(7)	6/11/98	cells/100 ml	--	--	--	30	--	--	60
SS/SR-03	(7)	6/12/98	cells/100 ml	--	--	26,000	110,000	--	--	120,000
SS/SR-03	(7)	6/19/98	cells/100 ml	--	--	--	26,000	--	--	24,000
SS/SR-03	(7)	6/27/98	cells/100 ml	--	--	50,000	8,200,000	--	--	140,000
SS/SR-03	(7)	7/1/98	cells/100 ml	--	--	--	320	--	--	110
SS/SR-03	(7)	7/7/98	cells/100 ml	--	--	--	200	--	--	60
SS/SR-03	(7)	8/18/98	cells/100 ml	--	--	--	70	--	--	310
U/S From Univ. Circle Culvert Inlet:										
COC AB-3	(4)	1974	cells/100 ml	1,900	33,000	480	21,000	230	5,600	--
Downstream from University Circle:										
D/S From Univ. Circle culvert outlet:										
N-17	(7)	7/7&11/4/87	??	--	114,456	--	29,374	--	13,565	--
N-17	(7)	1/26/88	cells/100 ml	--	230,000	--	3,000	--	7,800	--
N-17	(7)	7/11&11/7/89	cells/100 ml	--	> 180,000	64,000	190,000	--	35,000	--
N-17	(7)	9/26/90	cells/100 ml	--	> 200,000	--	100,000	--	39,000	--
N-17	(7)	5/16/91	cells/100 ml	* --	> 80,000	--	≥ 60,000	--	95,000	--
H&E R-7-1	(6)	5/22/91	cells/100 ml	--	--	--	63,000	--	--	170
H&E R-7-1	(6)	6/7/91	cells/100 ml	--	--	--	960	--	--	10
N-17	(6)	6/18/91	cells/100 ml	--	> 80,000	--	≥ 60,000	--	67,000	--
N-17	(6)	7/29/91	cells/100 ml	--	> 160,000	--	180,000	--	39,000	--
N-17	(7)	8/27/93	cells/100 ml	* --	--	--	32,000	--	--	30,000
N-17	(7)	8/18/94	cells/100 ml	* --	--	--	40,000	--	--	24,000
N-17	(7)	10/18/94	cells/100 ml	* --	--	--	97,000	--	--	31,000
N-17	(7)	6/7/95	cells/100 ml	--	--	--	88,000	--	--	--
N-17	(7)	8/7/96	cells/100 ml	--	--	--	1,000	--	--	46,000
N-17	(7)	7/31/97	cells/100 ml	--	--	--	1,900	--	--	1,000
SS/SR-02	(7)	5/21/98	cells/100 ml	--	--	--	3,900	--	--	<2400
SS/SR-02	(7)	5/28/98	cells/100 ml	--	--	--	14,000	--	--	≥2400
SS/SR-02	(7)	5/31/98	cells/100 ml	--	--	< 1,000	700,000	--	--	380,000
SS/SR-02	(7)	6/11/98	cells/100 ml	--	--	--	960	--	--	460
SS/SR-02	(7)	6/12/98	cells/100 ml	--	--	12,000	250,000	--	--	190,000
SS/SR-02	(7)	6/19/98	cells/100 ml	--	--	--	17,000	--	--	11,000
SS/SR-02	(7)	6/27/98	cells/100 ml	--	--	<10000	990,000	--	--	380,000
SS/SR-02	(7)	7/1/98	cells/100 ml	--	--	--	4,800	--	--	500
SS/SR-02	(7)	7/7/98	cells/100 ml	--	--	--	780	--	--	240
SS/SR-02	(7)	8/18/98	cells/100 ml	--	--	--	52,000	--	--	≥9600
MLK at Ansel (AB-2)	(4)	1974	cells/100 ml	< 80	150,000	< 20	≥ 75,000	< 16	21,000	--
Near St. Clair Crossing:										
N-16	(7)	7/7&11/4/87	??	--	28,425	--	20,838	--	2,301	--
N-16	(7)	1/26/88	cells/100 ml	--	20,000	--	540	--	450	--
N-16	(7)	7/11/89	cells/100 ml	--	5,100	--	760	--	360	--
N-16	(7)	9/26/90	cells/100 ml	--	5,800	--	2,500	--	380	--
N-16	(7)	5/16/91	cells/100 ml	--	4,300	--	2,500	--	260	--
N-16	(7)	6/18/91	cells/100 ml	--	6,200	--	2,700	--	0	--
N-16	(7)	7/29/91	cells/100 ml	--	2,700	--	540	--	420	--
N-16	(7)	8/27/93	cells/100 ml	--	--	--	200	--	--	150
N-16	(7)	8/18/94	cells/100 ml	--	--	--	90	--	--	60
N-16	(7)	10/18/94	cells/100 ml	--	--	--	300	--	--	290
N-16	(7)	6/7/95	cells/100 ml	--	--	--	1,400	--	--	--
N-16	(7)	8/7/96	cells/100 ml	--	--	--	520	--	--	360
N-16	(7)	5/14/97	cells/100 ml	--	--	--	720	--	--	520
SS/SR-01	(7)	5/21/98	cells/100 ml	--	--	--	300	--	--	210
SS/SR-01	(7)	5/28/98	cells/100 ml	--	--	--	200	--	--	200
SS/SR-01	(7)	5/31/98	cells/100 ml	--	--	150,000	1,800,000	--	--	220,000
SS/SR-01	(7)	6/11/98	cells/100 ml	--	--	--	1,600	--	--	1,200
SS/SR-01	(7)	6/12/98	cells/100 ml	--	--	210,000	400,000	--	--	440,000
SS/SR-01	(7)	6/19/98	cells/100 ml	--	--	--	25,000	--	--	11,000
SS/SR-01	(7)	6/27/98	cells/100 ml	--	--	830,000	5,800,000	--	--	1,200,000
SS/SR-01	(7)	7/1/98	cells/100 ml	--	--	--	1,600	--	--	240
SS/SR-01	(7)	7/7/98	cells/100 ml	--	--	v	1,400	--	--	490
SS/SR-01	(7)	8/18/98	cells/100 ml	--	--	--	>20000	--	--	≥9600
D/S from St. Clair Crossing:										
H-1	(1)	1966-67	cells/100 ml	--	5,000,000	--	--	--	--	--
AB-1	(4)	1974	cells/100 ml	50,000	64,000	1,300	6,500	840	12,000	--

Table I-10 Biological Sampling Results

Index	Water Quality Criteria	Doan Brook Sampling							
		B-1 N-16	B-2 N-17	B-3	B-4	B-5 N-18	B-6	B-7 N-19	B-8
ICI NEORSD 1998	34	16	34	24	38	18	* 2	* 2	* 10
QHEI									
NEORSD 1991-93	62	56.5	70.5			61.5		64	
NEORSD 1998	62	57.75	66.25	56.75	69.25	62.5	61.5	55.5	61

Index	Lake Sampling -- NEORSD 1998			
	Green	Marshall	Horseshoe	Lower Shaker
Trophic Status Index:				
Secchi Disk	68	68	76	72
Chlorophyll-a	70	74	83	67
Total Phosphorus	86	82	70	73
Average	78	78	77	70

* The ICI is questionable for streams with small drainage areas and may not be applicable at these sampling sites.

Table I-11 Water Quality Index Sampling Results

Value	Brook Sampling - Location						
	U/S St. Clair A-1	D/S Lower Lake A-2	S. Fork U/S Lower Lake A-3	N. Fork U/S Lower Lake A-4	S. Fork D/S Marshall L. A-5	S. Fork U/S Marshall L. A-6	S. Fork U/S Green L. A-7
Mean	55.4	55.7	59.5	47.5	53.5	46.2	75.8
Maximum	68.6	72.7	85.1	72.5	54.1	57.9	78.0
Minimum	29.8	40.0	25.2	22.1	53.0	34.6	73.7
Number of Values	15	15	14	12	2	2	2

Value	Lake Sampling - Location						
	Lower L. D/S L-1	Lower L. Middle L-2	Marshall Lake L-3	Green Lake L-4	Horseshoe L. - Nr. Dam L-5	Horseshoe L. - S. Arm L-6	Horseshoe L. - N. Arm L-7
Mean	45.4	45.8	45.2	52.5	35.8	42.0	45.4
Maximum	69.3	62.2	46.9	55.9	--	--	--
Minimum	26.7	27.3	43.5	49.1	--	--	--
Number of Values	7	6	2	2	1	1	1

Source: Water Quality Program: Cleveland Department of Public Utiliities. 1976. Doan Brook - Shaker Lakes Water Quality Assessment and Watershed Management Plan. Cleveland.

Water quality index data were prepared following a methodology described in Hina (1975). Possible values range from 1 to 100, with a score of 100 indicating the highest water quality.

Table I-12 Herbicide and Pesticide Lake Sampling **Units are ug/L.**

Parameter	Mean Conc. in Natural Waters (8,9,10)[3]	Water Quality Criteria [2]	OEPA 1973 (3) - 9/19/73	
			OEPA 1973 Lower Shaker Lake (3) 9/19/73	OEPA 1973 Horseshoe Lake (3) 9/19/73
Aldrin (ug/L)	0	0.00079	ND	ND
DDD (ug/L)	0		ND	ND
DDE (ug/L)	0		ND	ND
DDT (ug/L)	0	0.00024	ND	ND
Dieldrin (ug/L)	0	0.00076	ND	ND
Chlordane (ug/L)	0	0.0048	ND	ND
Endrin (ug/L)	0	0.002	ND	ND
Heptachlor (ug/L)	0	0.001	ND	ND
Hchlr-Epoxide (ug/L)	0		ND	ND
Lindane (ug/L)	0	0.01	ND	ND
Methoxychlor (ug/L)	0	0.005	ND	ND
Malathion (ug/L)	0	0.1	ND	ND
Parathion (ug/L)	0	0.008	ND	ND
Methyl Parathion (ug/L)	0		ND	ND

"ND" indicates that concentrations were below the method detection limits. Detection limits were not given.

Table I-13 Lake Sediment Sampling Results

Units are mg/kg unless noted.

Parameter	Typ. Metals Conc. in Ohio Soils (Upper Bound) (11) [5]	Lower Shaker Lake: 12/8/1973 - Ohio EPA - Locations Unknown: Sample 1 (3)	Sample 2 (3)	Sample 3 (3)	COC 1974 (4)	COC 10/14/75 (4): Min.	Max	Avg.	NEORSD 8/29/90 Nr. Outfall	NEORSD August 1998: Min.	Max.	Avg.
Total Organic Carbon						19,000	29,000	24,500		2.1	8.5	5.6
Total Phosphorus						340	1,030	700		<.1	<.3	<.1
Nickel	73.4	30	20	40		50	110	70	< 10	2.26	11.8	7.0
Copper	61.5	136	71	85		90	240	150	30	10.7	40.2	29.0
Total Chrome	31.5	23	15	28		<50	<50	<50	30	2.18	7.96	6.3
Zinc	192	510	300	420		610	1,550	920	130	29.2	103	76.6
Iron	79,400	22,500	175,000	33,300		8,800	21,000	16,760	22,000	2,880	25,200	10,020
Cadmium	9.7	3	3	3		<10	<10	<10	< 10	<.2	<.2	<.2
Lead	44.9	600	240	420		180	610	330	50	16.1	80.8	45.7
Mercury	5.14	0.5	0.4	0.5		<1	<1	<1	0.2			
Total coliform (cells/100 ml)					27,000-6,600,000							
Fecal coliform (cells/100 ml)					<2400-200,000							
Fecal Streptococcus (cells/100 ml)					<2000-3,600,000							
Arsenic	34.5	41	21	38		1	1	1				
Selenium		0	0	0		<10	<10	<10				
Manganese		452	309	650		660	1,140	980				
Aluminum		12750	800	15250								
Barium	208	130	80	160								
% Volatile Solids									10.46	1.9%	30.5%	10.9%
% Total Solids						29.17	53.65	39.66	4.27	14.6%	81.4%	32.4%

1995 Sampling (13): Sediment samples were collected from the Lower Shaker Lake in April 1995 and analyzed for the metals, volatile organic compounds, semi-volatile organic compounds, pesticides, and herbicides that are included in the list of parameters that make a material a hazardous "by characteristic." The samples were analyzed using the Toxicity Characteristics Leaching Procedure (TCLP). The only compound detected was barium, found at concentrations far below those that would make the sediments a hazardous waste. Because the test and the methods used were intended only to determine whether material dredged from the lake would be considered a hazardous waste, the results cannot be directly compared to other sediment sampling data and should be used with caution.
Characteristic hazardous waste and the TCLP testing procedure are described in the Code of Federal Regulations (40 CFR 261).

Table I-13 Lake Sediment Sampling Results, continued

Units are mg/kg unless noted.

Parameter	Typ. Metals Conc. in Ohio Soils (Upper Bound) (11) [5]	Horseshoe Lake NEORSD 8/30/90 Composite	Horseshoe Lake NEORSD August 1998 Min.	Max.	Avg.	Green Lake NEORSD August 1998 Min.	Max.	Avg.	Marshall Lake NEORSD August 1998 Min.	Max.	Avg.
Total Organic Carbon			5.1	7.0	6.0	1.1	7.7	5.0	2.4	5.9	4.9
Total Phosphorus			<.1	<.2	<.1	<.1	<.7	<.2	<.1	<.1	<.1
Nickel	73.4	40	1.03	7.0	5.5	3.63	10.1	6.8	6.48	12.2	7.9
Copper	61.5	< 10	18.2	**62.3**	46.8	8.5	27.4	20.5	27.0	31.7	28.8
Total Chrome	31.5	**40**	1.69	8.29	6.2	5.01	9.49	7.6	6.14	7.93	7.2
Zinc	192	**410**	36.2	112	80.6	46.8	82.4	65	61.8	87.3	74.3
Iron	79,400	32,000	3,620	14,800	10,760	4,580	21,900	10,500	7,580	16,700	9,940
Cadmium	9.7	< 10	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2	<.2
Lead	44.9	**160**	10.6	**67.6**	**47.5**	15.6	40.4	30.2	15.5	37.7	30.7
Mercury	5.14	ND									
Total coliform (cells/100 ml)											
Fecal coliform (cells/100 ml)											
Fecal Streptococcus (cells/100 ml)											
Arsenic	34.5										
Selenium											
Manganese											
Aluminum											
Barium	208										
% Volatile Solids		12.22	9.7%	20.1%	12.4%	0.9%	23.0%	11.3%	2.2%	12.8%	8.4%
% Total Solids		25.34	19.6%	35.9%	28.9%	17.0%	88.2%	40.4%	22.9%	86.3%	37.8%

Table I-14 Sediment Sampling in the Brook

Units are mg/kg unless noted.

Parameter	Typ. Metals Conc. in Ohio Soils (Upper Bound) (11) [5]	NEORSD Doan Brook Samples August 20, 1998 NS-1	NS-2	NS-3	NS-4	NS-5	NS-6	NS-7	NS-8	NS-9	NS-10
Total Organic Carbon		0.6	0.5	0.4	1.1	0.7	1.0	1.3	1.2	1.9	2.0
Total Phosphorus		0.1	< .1	0.4	0.2	< .1	< .1	< .1	< .1	< .1	< .1
Nickel	73.4	7.66	7.67	12.9	18.3	12.2	10.3	8.07	8.17	18.5	15.8
Copper	61.5	22.6	7.14	10.2	18.3	14.6	6.27	8.87	3.72	9.35	10.0
Total Chrome	31.5	7.43	2.24	5.48	4.56	6.34	21.9	2.08	2.45	8.83	7.04
Zinc	192	86.5	44.3	47.9	56.6	74.9	40.0	44.6	44.1	53.3	72.6
Iron	79,400	14,000	13,600	27,700	22,700	26,000	19,000	22,900	17,400	32,000	36,700
Cadmium	9.7	< .2	< .2	< .2	< .2	< .2	< .2	< .2	< .2	< .2	< .2
Lead	44.9	**74.7**	36.6	10.0	9.97	27.1	**106**	5.98	3.65	5.18	23.9
% Volatile Solids		1.4%	2.0%	3.0%	1.3%	1.8%	1.2%	1.2%	1.4%	1.0%	1.4%
% Total Solids		67.8%	88.2%	84.7%	80.5%	80.3%	84.5%	91.8%	85.5%	88.8%	81.3%

Appendix J

Watershed Restoration Techniques for Doan Brook

The table that follows includes descriptions of many of the techniques that could be used to restore Doan Brook. The restoration measures described match those discussed in Chapter 8. More detailed descriptions are given here to better define many of the techniques. Although the list of techniques is as complete as possible, the reader should keep in mind that other approaches to watershed restoration will arise as a detailed watershed management plan for the brook takes shape, as will new information about various measures that have already been discussed. This table and those in Chapter 8 should be considered only as starting points for an in-depth evaluation of measures included in the Doan Brook watershed management plan.

Table J-1	Description of Watershed Restoration Measures
Measure	**Discussion**
Large Projects	
***[1]Heights/ Hilltop Interceptor**	The HHI is a network of deep, large diameter sanitary sewers that is designed to collect sanitary sewage from a large part of Cleveland's eastern suburbs and divert the sewage directly to the Easterly Wastewater Treatment Center. The HHI (now under construction) will divert sanitary flow from much of the Doan Brook upper watershed and prevent it from flowing into the combined sewer system in the lower watershed. When completed, the HHI will reduce the volume of CSOs to Doan Brook to about 50% of its current level. The HHI will be partially in service in the Doan Brook watershed in 2001 and will be completed during 2005. Although the volume of CSOs will still be large after the HHI is complete (see Chapters 5 and 6), the HHI or a similar diversion is absolutely necessary if water quality in the brook is to be significantly improved.
High Flow CSO Storage	High flow CSO storage is one of the alternatives for meeting Ohio EPA CSO regulations that has been considered by NEORSD. As currently envisioned, the alternative would consist of some combination of the following: 1) a large diameter storage and diversion tunnel running along the brook between Gordon Park and Ambler Park (this is the alternative that is currently favored by NEORSD); or 2) large underground storage tanks at six locations in the lower watershed. Because there is a legal requirement that CSOs be reduced to the extent feasible, and because none of the smaller projects under consideration would accomplish this, some remedy that includes storage or high flow CSO treatment can be expected to be part of NEORSD's work in the watershed. The capacity of a high flow CSO storage system would be designed to control CSOs, not to reduce floods. As a result, the storage systems would probably be designed with enough capacity to contain CSOs from a storm that would occur every 3 to 4 months. This system would not provide enough capacity to have a major impact on flooding problems in the lower watershed.
High Flow CSO Treatment	High flow CSO treatment is among the alternatives NEORSD is considering for meeting Ohio EPA CSO regulations. A high flow CSO treatment system would intercept and treat CSO flows before discharging them to the brook. A preliminary alternative considered by NEORSD would involve small treatment facilities in six different locations in the lower watershed. NEORSD currently favors storage (and subsequent treatment at existing NEORSD treatment plants) rather than the installation of dispersed high flow treatment plants.
*** Optimize the Existing Sewer System**	The performance of the existing sewer system can be optimized to maximize the use of existing storage volume and minimize CSOs.Optimization will be part of any NEORSD effort to reduce CSOs.

1 *Projects that are currently in progress are marked with an asterisk.

Table J-1, continued	Description of Watershed Restoration Measures
Measure	**Discussions**
Large Projects, continued	
Redirect Giddings Brook	Because much of the flooding on Doan Brook can be attributed to the diversion of Giddings Brook into Doan Brook, it is reasonable to consider the possibility of remedying Doan Book flooding by redirecting Giddings Brook flow back into the Giddings Brook watershed. However, given that the Giddings Brook watershed is also a heavily urbanized area with flow constrained almost entirely to a storm sewer system, it is extremely unlikely that such a rediversion would be possible without causing major problems in the old Giddings Brook watershed. It is even more unlikely that a rediversion would be cost effective.
Large New Stormwater Detention	Build additional large surface lakes or detention basins (like the MLK basin). Basins would be most effective at the western edge of the Escarpment or the eastern edge of the Lake Plain and should intercept flow that now goes to the Cedar Glen sewer or the Giddings Brook culvert. The watersheds of both of these culverts are dense urban areas, and it would be very difficult or impossible to find an appropriate location for additional large stormwater detention facilities.
Parallel Stormwater Culvert	Build a large culvert that would parallel the brook (most likely in the lower watershed) to divert non-CSO stormwater from the brook and carry it directly to Lake Erie. Because the volume of stormwater for even relatively small floods (one- to two-year frequency) is very large, it is unlikely that an effective stormwater diversion culvert could be built economically. Engineering issues associated with building such a culvert in the lower watershed would also be significant. Note that a parallel stormwater culvert is not the same as a high flow CSO storage tunnel (see above). A high flow CSO storage tunnel would be designed with sufficient capacity to control CSOs from a storm that could be expected to occur every three to four months. While a large tunnel (perhaps 20 feet in diameter) would be required for this, an additional large tunnel would be required for effective stormwater diversion.
Daylight Brook in University Circle	Recreate a stream channel near the former Doan Brook alignment for some or all of the reach of the stream that is now carried in the University Circle culvert. The channel could be used in conjunction with the existing culvert to carry the full flow of the brook in relatively large floods (up to at least ten-year) without flooding the Circle. Case Western Reserve University and others have recently expressed interest in a restored Doan Brook in University Circle. Daylighting the brook would be difficult and expensive (although not impossible) in this heavily urban area.
Daylight Brook in Gordon Park	Excavate a channel in the dredge spoil material in the Corps of Engineers Site 14 dredge spoil area at the mouth of the brook. Reopening the brook to Lake Erie could be expected to have a significant positive impact on the habitat in the brook; however, the cost of doing so would be extremely high, and the technical challenges involved in building any kind of natural stream channel in the dredge spoil would be significant. The 2000 Holden Parks Trust master plan includes a park on the dredge spoil area, but does not consider daylighting Doan Brook through the area.
Enlarge University Circle Culvert	The University Circle culvert is actually a series of culverts with different capacities and different cross sections that were connected over time. This measure would involve enlarging the culvert, particularly in its most constricted sections, so that it could carry the flow from larger floods. Under current conditions, it is unlikely that it would be feasible to enlarge the culvert enough so that it could convey floods larger than the ten-year flood (and perhaps not that large). This measure would need to be combined with others that reduce flow into the culvert in order to have a significant impact on University Circle flooding. An approach to enlarging the University Circle culvert was included in the 1964 Stanley Engineering study of Doan Brook flooding. Enlarging the University Circle culvert would not decrease flooding downstream from University Circle and might make downstream flooding more severe.

Table J-1, continued	Description of Watershed Restoration Measures
Measure	**Discussions**
Large Projects, continued	
Keep University Circle Culvert Clear of Debris	The University Circle culvert is prone to gradual clogging as debris builds up in the culvert. It is not unusual for debris to fill half of the culvert. This measure involves instituting a program of regular maintenance to keep the culvert relatively free of debris. The concept of keeping the culvert clear is not new – it was recommended by Stanley Engineering in 1964. However, no regular cleaning program has ever been followed.
Enlarge Cedar Glen Sewer	Enlarge the storm sewer that carries flow down the Escarpment beneath Cedar Road and into the University Circle culvert. At present, the sewer is too small to carry flows from a five-year flood, so that water flows in the street down Cedar Hill during larger rains. Enlarging this sewer would be physically difficult, and, by itself, it would not have much impact on flooding except on Cedar Road.
Enlarge Rockefeller Park Channels	Enlarge Rockefeller Park channels so that they could convey larger floods without overflowing into the adjacent road. This measure is practical through most of Rockefeller Park, although limited space may make it difficult in some places. Channel enlargement alone, without accompanying culvert enlargement (see below), would not alleviate all flooding, since much of the flooding in Rockefeller Park results from water that is backed up by constrictions at the culverts that carry water under the historic bridges. Channel enlargement could be done in conjunction with the restoration of a more natural channel shape that would improve habitat. Enlarging the channels, even without channel restoration, would have some ecological benefit, since it would reduce the frequency of channel scouring by high flows.
Enlarge Rockefeller Park Culverts	Enlarge the culverts that carry the brook under the Rockefeller Park bridges. Enlarging the channel at the road crossings would be somewhat expensive in all cases. In addition, several of the bridges are designated as historic landmarks, so that modifications needed to enlarge some culverts could conflict with historic preservation interests. As is mentioned above, the culverts in Rockefeller Park are the greatest channel constrictions in many places, and they create much of the street flooding. Some modification to some of the culverts will almost undoubtedly be needed to alleviate flooding in this area.
Small Projects	
Revise City Codes to Require BMPs	Revise city codes to require that new construction and redevelopment incorporate stormwater "best management practices" (BMPs). Revisions might, for example, require that stormwater detention be included in new parking lot design, that road reconstruction incorporate grassed swales adjacent to the road where possible, or that new home construction incorporate some on-site stormwater detention. Although code revision may be politically difficult, it is essential to the sustained restoration of Doan Brook.
Redesign MLK Detention Basin Outlet	Redesign the outlet of the existing detention basin at MLK to more effectively control flows from the five- to ten-year storm. Preliminary analysis performed as part of the ongoing NEORSD study indicates that the basin outlet could be redesigned to somewhat reduce the area flooded during large floods (25- to 50-year), but that it would be difficult to redesign the basin to control smaller floods without causing the dam to overtop during the 50-year flood. Modification of the basin outlet would be relatively inexpensive.

Table J-1, continued	Description of Watershed Restoration Measures
Measure	**Discussions**
Small Projects, continued	
Stormwater Retrofits	Stormwater retrofits are generally small stormwater management facilities that are added to a developed watershed. Examples of stormwater retrofits are: a small detention pond or wetland at a tributary culvert outlet; a sand filter that catches, temporarily detains, and filters runoff from a parking lot; a grassed roadside swale that captures and detains runoff, allowing some to infiltrate. Stormwater retrofits can be designed to improve water quality (by allowing sediment to settle, filtering contamination, or providing biological treatment of contamination by wetland vegetation), to decrease flooding, or, most often, to combine flood reduction with water quality improvement. They differ from measures described under "Large Projects" primarily in scale. Each large project is intended to address the problems of a substantial part of the watershed. By contrast, a single stormwater retrofit is generally intended to improve water quality or decrease peak outflow from a small part of the total watershed. Benefits to the watershed as a whole result from the cumulative impact of a number of stormwater retrofits strategically located throughout. A study of possible stormwater retrofit locations has been conducted by the Center for Watershed Protection as part of NEORSD's Doan Brook watershed study.
Stream Channel Restoration	Restore existing rigid sections of Doan Brook to more natural channel configurations. In general, a "natural" channel is winding, includes deeper pools and shallower riffles, has a pilot channel for low flows, a "bank full" channel that fills once every year or two, and an adjacent flood plain into which the stream overflows during floods. Restoration of the Doan Brook channel to a more natural shape is feasible to varying degrees along different reaches of the channelized stream, depending upon the space available. It could be undertaken one stretch of the brook at a time.
*** Channel Stabilization**	Stabilize eroding sections of the stream channel and banks. The preferred means of stabilization is to use natural and living materials such as stone, tree roots, and live plantings. Channel stabilization alone, without stream channel restoration, does not address the underlying tendency of the stream to create a channel that matches current flow conditions. As a result, the stream will have a continuing tendency to erode its banks and channel; however, channel stabilization is sometimes necessary to protect roads and bridges. In addition, it reduces the amount of sediment carried by the stream at least temporarily. Holden Parks Trust has installed natural channel stabilization measures and done some channel restoration along two stretches of the lower brook (just downstream from the University Circle culvert outlet and along the side of the Rockefeller Park Lagoon) as part of a pilot project.
*** Stormwater Outfall Monitoring**	Institute a regular monitoring program to verify that stormwater outfalls are not contaminated by sanitary sewage, followed by repairs to problems detected. NEORSD has a monitoring program in place.
*** Sanitary Sewer Maintenance**	Institute a regular sanitary sewer maintenance program to detect and repair cross connections and defects in the sanitary sewers that might lead to sewage discharge to surface water. Sanitary sewer maintenance is now undertaken by the cities and by NEORSD.
*** Reinforce Dams Against Failure**	Take steps to insure that the Shaker Lake dams will not fail during large storms. The Shaker Lakes play a critical role in controlling floods on Doan Brook and in the parks of the upper watershed. Their maintenance is very important.
*** Lake Dredging**	Institute a regular program of dredging for the Shaker Lakes. The lakes accumulate sediment that is washed into them and additional material deposited from the decay of organic matter. Over time, they become shallow and warm and are unable to support a healthy and diverse aquatic ecosystem. Although dredging does not address the sources of contamination to the lakes, it does foster a healthier lake ecosystem. It may also remove accumulated nutrients (primarily phosphorus) that have been deposited in the sediments. These nutrients may be recycled through the lake and add to eutrophication. The lakes have been dredged at irregular intervals; however, high costs have generally led to incomplete and irregular dredging.

Table J-1, continued	Description of Watershed Restoration Measures
Measure	**Discussions**
Small Projects, continued	
*** Lake Aeration**	Install "bubblers" or artificial means of inducing lake circulation at several locations in each of the Shaker Lakes to bubble air through the water column. Aeration would help prevent dissolved oxygen levels in the lakes from falling to the extremely low levels that sometimes occur now, would increase fish and other organism survival, and would reduce the formation of noxious anoxic bacteria. However, aeration alone would not decrease plant growth, and it is unlikely that it would make much real impact on the health of the lakes unless it was combined with other measures. Aerators have been installed in Green Lake.
Aquatic Plant Management in Lakes	Take active measures to remove algae and aquatic plants from the Doan Brook lakes. Possible approaches include use of algacides or other chemicals, plant harvesting, and skimmers that prevent algae and plants from passing out of the lakes. Algacides and other chemical treatments are undesirable because of side effects. Other measures might improve the lakes aesthetically or improve downstream water quality and might remove moderate amounts of phosphorus from the aquatic ecosystem.
Lake or Stream Biofiltration	Install biofilter units in the stream or in the lakes to remove excess nutrients from the water. A pilot project at the outlet from Green Lake in 1999 demonstrated that biofilters effectively remove nutrients from the water. However, the overall effectiveness of biofilters in a natural stream system has not been demonstrated. Although biofiltration may have a significant role to play in restoring health to Doan Brook, the costs and effectiveness of the technology are uncertain.
Encourage Native Species and Discourage Invasive Exotics	Identify existing native and exotic vegetation in the natural areas of the watershed. Protect and encourage native vegetation while discouraging invasive exotic species. Insure that new plantings are of native species where possible and that no new invasive exotic species are introduced.
Species Reintroduction	Over time, a number of plant and animal species that once lived along Doan Brook have been eliminated from the habitat. Fish that once migrated from Lake Erie can no longer pass the culverts and dams; macroinvertebrate populations may have been eliminated by periods of particularly bad weather or high pollution levels; frogs and salamanders may have been killed by poor water quality and lack of breeding habitat; native plants were cleared by the Shakers and by later developers and must compete with exotic vegetation. If the water quality and habitat in the brook are improved, it may be possible to reintroduce some of these native species. Researchers from John Carroll University reintroduced three species of minnow to the brook between Horseshoe Lake and the Nature Center in 1999. Initial results indicated that these relatively hardy fish may once again thrive in the brook. Some species of plants or animals may reappear as the habitat improves, even without active reintroduction. Species reintroduction may enhance the biotic community of the brook, but sensitive new species will not thrive unless the brook habitat and water quality can support them.
Alternative Road Deicing	Use road deicers that are less toxic to aquatic plants and animals than sodium chloride and/or use more restraint when applying deicer.
Improve Golf Course Maintenance	Use less fertilizer, pesticide, and herbicide on golf courses, use low phosphorus fertilizer (as Shaker Heights Country Club already does), incorporate riparian buffer zones adjacent to the stream, restore the stream channel on the golf courses to increase habitat and reduce erosion, and incorporate stormwater retrofits in the golf course design. The golf courses in the Doan Brook watershed are private property, and owners and members must see the benefits to changes in golf course management before they can be implemented. However, there are several national programs that encourage golf courses to adopt environmentally positive practices. Canterbury and Shaker Heights golf courses own a large part of the land immediately adjacent to the south fork of Doan Brook, and the way that the courses manage their land has a major impact on the stream.

Table J-1, continued	Description of Watershed Restoration Measures
Measure	**Discussions**
Small Projects, continued	
Discourage Nuisance Waterfowl	Large numbers of waterfowl, particularly Canada geese, are probably significant contributors to bacterial contamination in Doan Brook and the Shaker Lakes. Geese can be discouraged by limiting lawn areas adjacent to the lakes and allowing taller vegetation to grow up – that is, by promoting proper riparian buffer zones. Artificial means such as "scare goose" balloons can also be used, but they are generally only effective for a short time.
Protect Riparian Corridor	Protect the existing riparian corridor from development and inappropriate vegetation clearing.
Increase Riparian Vegetation	Increase the vegetative buffer adjacent to the brook by reducing lawn areas and encouraging the growth of native vegetation. This approach could be used in manicured parks, on golf courses, and by homeowners with property adjacent to the stream. Encouraging homeowners to plant buffer zones could be particularly useful in the upper reaches of all forks of the stream, since lawns frequently extend to the water's edge in these areas.
* **Street Litter and Debris Cleanup**	Increase cleanup of litter and debris (particularly from lawn care) in the streets. Approaches could include street sweeping, voluntary "adopt a block" programs, and citizen education.
Catch Basin Inspection and Cleaning	A regular program of inspection and cleaning of storm sewer catch basins to remove grit, oil, organic matter, and other contamination before it is carried to the brook.
Erosion Control During Construction	Require that sediment erosion from building sites be controlled.
Flow Augmentation	Increase dry weather flow by artificially introducing additional water to the stream. The most likely source of flow augmentation for Doan Brook would be the direct release of untreated Lake Erie water from the Baldwin Filtration Plant to the brook in Ambler Park.
Citizen Action	
Downspout Disconnects	Disconnect downspouts from the storm drain and divert flow from rooftops onto lawns where it can infiltrate, or at least be stored to some extent, rather than being carried directly to the storm sewers. Although downspout disconnects work well in many places, the clayey tills of the upper Doan Brook watershed make this measure of limited value there. Water will run off almost as fast from a lawn as it did from the rooftop. Because of the heavy clay soil and the associated risk of basement flooding, downspout disconnects should be evaluated with care to see whether they can be accomplished without flooding basements and to see whether they will provide a worthwhile benefit.
Rain Barrel Use	Reroute downspouts so that they flow into rain barrels. Overflow from the barrels can either be routed to the surrounding lawn (effectively a downspout disconnect) or to the storm sewers. Rain barrels will quickly be filled during really heavy rain[2], so that rain barrel storage will have an impact primarily during moderate rains.

2 A 0.1 inch rain will fill a 50-gallon rain barrel that collects rainfall from an 1800 square foot two story home.

Table J-1, continued	Description of Watershed Restoration Measures
Measure	**Discussions**
Citizen Action, continued	
Alternative Landscaping	Encourage individual homeowners to reduce the amount of turf in their yards, increase the amount of natural ground cover and bushes, and plant buffer zones to slow runoff. This could significantly increase infiltration and rainwater storage in each yard. It could also reduce the use of lawn fertilizers, herbicides, and pesticides.
* **Proper Auto Waste Handling**	Encourage proper disposal of automotive waste oil, anti-freeze and other fluids by regulation and public education and by providing convenient means of proper disposal. Existing programs should be reviewed and improved as appropriate.
Proper Car Wash Practices	Encourage residents to wash cars at commercial car washes that drain soapy runoff to the sanitary sewer rather than to the storm drain or, if this is not possible, to wash cars on lawns rather than in driveways and streets. Soap used for washing cars can be a significant source of phosphorus, and grit washed from cars can add sediment and oil to the brook. Use of low-phosphorus soaps for washing cars is also helpful.
* **Household Hazardous Waste Disposal**	Encourage residents to properly dispose of household hazardous waste by regulation and public education and by providing easy proper disposal. Existing programs should be reviewed and revised as needed.
* **Cleaning Pet Waste**	Require residents to pick up pet waste and dispose of it in the sanitary sewer system (not in the storm sewer!) or with household garbage. Pet (mostly dog) waste is probably the most significant single source of bacteria contamination in the watershed after CSOs. Appropriate measures include encouraging proper disposal by regulation and public education. Existing regulations should be reviewed, revised, and enforced as appropriate.
Reduce Lawn Fertilizer, Pesticides and Herbicides	Encourage residents to reduce or eliminate the use of fertilizers, pesticides and herbicides on lawns. Encourage use of low phosphorus fertilizer when fertilizer is used. Appropriate measures include public education and education of lawn care providers.
* **Proper Yard Waste Disposal**	Encourage residents to dispose of yard waste in proper compost piles or in city yard waste pickup, not in gutters, drainage ditches or streams. Appropriate measures include regulation, public education, and city yard waste collection. Existing programs should be reviewed and revised as appropriate.

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"Never index your own book," she stated.

—**Kurt Vonnegut, Jr.**
Cat's Cradle