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

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.