QUANTITY AND QUALITY OF RUNOFF FROM FOUR GOLF COURSES IN THE TWIN CITIES METROPOLITAN AREA

REPORT TO THE LEGISLATIVE COMMISSION ON MINNESOTA RESOURCES

M.L. 93 Chapt.172,Sect.14,Subd.7(a)

PREPARED BY

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September 1995

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

EXECUTIVE SUMMARY

Automatic samplers were installed at four golf courses in the TCMA, (Baker National, Woodhill Country Club, Meadowbrook, and the Minikahda Club) in 1994 to monitor rainfall, rainfall runoff, and collect runoff samples. A total of 67 samples from the four golf courses in the Twin Cities Metropolitan Area were collected and analyzed for the presence of selected nutrients, fungicides, herbicides, and heavy metals. The quantity of runoff leaving the four courses was monitored for all rainfall events, and the total loss of chemicals leaving the courses was calculated. The amounts of pesticides and nutrients applied to the golf courses was recorded.

Application of fertilizer, in particular phosphorus, to the golf courses in 1994 was 20 percent of the amounts typically applied to urban lawns. Five different fungicides were applied to the four courses during the summer. Application frequency was less than normal because of the cool weather. The TCMA experienced only 4 days above 90 degrees Fahrenheit in 1994, significantly less than the average of 14 days.

Rainfall in the area was 6 percent above the 136 year average during the study period. The percent of rainfall leaving the courses as runoff was similar at all four sites, 5.8, 7.8, 5.0, and 5.2 percent at Baker, Meadowbrook, Woodhill, and Minikahda respectively. The mean concentrations of total phosphorus, soluble reactive phosphorus, total Kjeldahl nitrogen, ammonia nitrogen and nitrate and nitrite nitrogen were 0.521, 0.335, 3.104, 0.724, and 1.307 respectively. Nutrient export from the four courses was very small, an order of magnitude less than export rates reported for urban residential areas. The nutrient export rate of the four golf courses was similar to the rates reported for undeveloped land.

Detectable concentrations of fungicides were observed in 40 of 59 (60 percent) of runoff water samples. The most frequently observed fungicide, chlorothalonil (DACONIL®), was observed in 58 percent of runoff samples. DACONIL® was also the fungicide applied in the largest quantity to the golf courses. The concentration of fungicides in runoff water was very low, typically slightly above the detection limits. The median concentration for all fungicides was 0.00 ug/l. As a result, only very small quantities of fungicides were lost from the golf courses in 1994. Approximately 99.5 percent of the fungicides applied to the courses remained on the turf.

Only one of three herbicides, 2,4-D, was detected in the 59 golf course runoff samples, and was found in only one sample. Mercury and cadmium were found in 20 and 8 percent of samples respectively. The median concentration of both metals was 0.00 ug/l.

The data collected in 1994 indicate that golf courses are not a significant source of nutrients or pesticides to water bodies in the TCMA. The low pollutant export rate from golf courses appears to be a function of the management practices used on the golf courses. These practices, which promote rainfall infiltration and limit applications of chemicals, particularly phosphorus, include soil aeration, soil fertility testing, application of organic matter, and maintenance of dense vegetation.

INTRODUCTION

There are an estimated 14,000 golf courses in the United States, with approximately 1.68 million acres of turfgrass (Smith, 1995). In Minnesota alone there are currently more than 380 golf courses, with more being built every year. Over 800,000 Minnesotans play golf each year, the highest number of golfers per capita in the United States.

Historically, a wide variety of pesticides and fertilizers have been applied to golf courses to maintain high-quality turf on greens and fairways. For instance, over 20 different fungicides are used on courses in Minnesota, and almost all courses receive annual applications of fertilizer. Because of this extensive chemical use, golf courses have been implicated as a significant source of water pollution (Selcraig, 1993). The construction of many golf courses adjacent to waterbodies has exacerbated this concern by allowing direct flow of runoff into lakes and streams.

Most information on golf course runoff quality in the United States has been interpolated from studies simulating golf course turf areas (Spectrum Research, Inc.,1990). These studies suggest that fertilizer and pesticide runoff from turf areas is minimal. However, because the majority of the information was collected from experimental plots with controlled applications of fertilizers, pesticides, and often rainfall, the data may not represent runoff water quality from golf courses which must operate under less controlled conditions.

Studies which collected runoff from golf courses found that some movement of pollutants in runoff water did occur. Sudo and Kunimatsu, 1992, found four pesticides in runoff from a golf course in Japan. Data from a study at Baker National Golf Course in Minnesota showed that leachate water from a golf course green can carry high concentrations of dissolved nutrients (Barten, unpublished). This study also found that only six percent of rainfall on a green percolated downward, with the majority of rainfall apparently occurring as runoff, which was not measured. However the available information is insufficient to determine the effect of golf courses on water quality.

Bannerman et. al., 1992, demonstrated that lawns can be a significant source of nutrients to stormwater. Because fertilizer applications on golf courses are similar to lawns, the potential exists for golf courses to be a similar source of nutrients to surface waterbodies. Bannerman, 1992, also demonstrated that runoff water from urban areas contains a significant number of pesticides, some of which are commonly applied to lawns. However, because golf course turf is managed differently than residential and commercial lawns, it may not reasonable to extrapolate this data to golf courses.

As a response to the lack of specific information on golf course runoff quality, this study was initiated. The primary goal was to determine the quantity and quality of runoff from golf courses, and to evaluate the effect of the runoff water on adjacent waterbodies. Runoff from representative areas of four courses in the Twin Cities Metropolitan Area was collected with automatic samplers during rainstorm events in 1994, and analyzed for the presence of potential water pollutants.

STUDY SITES

GENERAL

Sample sites were selected on four golf courses, Baker National Golf Course, Woodhill Country Club, Meadowbrook Golf Course and the Minikahda Club in the Twin Cities Metropolitan Area (TCMA), Figure 1. Two of the sites, the Minikahda Club and Meadowbrook Golf Course, were located in highly developed urban areas of Minneapolis and St. Louis Park, respectively, and two of the courses, Baker National and Woodhill Country Club were located in more rural areas. Two of the course were public and two were private.

Sample sites were chosen to represent a range of conditions found on golf courses in the TCMA relative to soil types, topography, turf grass and levels of management. Typically, turf grass at private courses is more intensively managed than at public facilities. Course managers agreed to follow normal irrigation schedules and application rates and schedules when applying fertilizers and pesticides.

Descriptions of the four golf courses selected for the study are as follows:

BAKER NATIONAL GOLF COURSE

Baker National Golf Course is a public course located near the western edge of the TCMA, in the city of Medina. The course is within Baker Park Reserve and is owned and operated by the Suburban Hennepin Regional Park District. Baker National consists of an 18 hole regulation and a 9 hole executive course. The golf course was constructed in 1960 and upgraded by Hennepin Parks in 1989. The course encompasses 320 aces of Baker Park Reserve, of which 200 acres is maintained as turf, building sites, or roadways, (Table 1). The remainder of the course is maintained as wetland and forest. Hennepin Parks is in the process of establishing large areas of forest on the course, which was originally in the area known as the "Big Woods".

The topography on the course is irregular with 50 percent of slopes between 6 and 12 percent. Soils on the site are well drained clay loam with moderately slow permeability. The water table is generally more than five feet below the surface. Drainage from the course is east to west into the adjacent Spurzem Lake or into a wetland complex downstream from the lake. Approximately ten acres of the course drain to the south toward Lake Minnetonka. An adjacent agricultural area of approximately 100 acres drains through the course beginning at the northeast corner. A one acre pond, which discharges to a 24 inch underground concrete pipe, captures this runoff water. During rainstorm events in excess of 2 inches, the pond frequently overflows and discharges water into a drainage channel which crosses the course and flows to Spurzem Lake.

The 24 inch pipe is installed under the drainage channel and collects runoff from the adjacent turf areas through a series of catch basins in low areas.

MEADOWBROOK GOLF COURSE

Meadowbrook Golf Course is a 380 acre, 18 hole course located in Hopkins and St Louis Park, Minnesota, just west of Minneapolis. The course was constructed in 1926, and is owned and operated by the Minneapolis Park Board. Approximately 170 acres of the course are maintained as turf, building areas or roadways, (Table 1). The topography ranges from steeply rolling along the perimeter on the west, north and south, to a large flat area extending into the center of the course from the east. Over half of the course has slopes ranging from 8 to 18 percent. The hilly areas contain mainly poorly drained loam and clay loam soils with seasonally high water table near the surface. The low flat areas are composed of very poorly drained organic soils which are frequently inundated. Minnehaha Creek, the outflow stream from Lake Minnetonka flows through the course from north to south.

Drainage from the course is west to east into a ditch which discharges to a large backwater of Minnehaha Creek named Meadowbrook Lake. An extensive drainage system consisting of the ditch and a series of tile lines has been installed in the course. Numerous catch basins collect runoff water and divert it into a 12 inch concrete tile line which discharges into the drainage ditch near the outfall to Meadowbrook Lake. Because of the low position in the landscape, water from the ditch is pumped over a dike into the Lake. Approximately 94 acres of the course drain through the concrete tile line. Runoff from areas not entering the tile drainage system flows directly into Meadowbrook Lake or Minnehaha Creek.

WOODHILL COUNTRY CLUB

Woodhill Country Club is a 225 acre, 18 hole private golf course located in the city of Orono near the northeast end of Lake Minnetonka. Woodhill Country Club was established in 1915. Approximately 160 acres of the 225 acre course are maintained as turf. The course also contains 20 acres of wetlands and 40 acres of mature woodlots. The remainder of the course is developed as building sites, parking lots, and roadways. Specific acreages of land use types are shown in Table 1.

The topography on the course varies from gently rolling to very steep, with 10 percent of the slopes in excess of 18 percent. The majority of the course is underlain by well drained loamy soils of the Hayden Series. These soils have a moderate permeability with the water table below five feet in all seasons. The southeast potion of the course includes an extensive level area of organic soils. These soils have low permeability with the water table near the surface.

Drainage from the course is to the south into a large wetland complex which flows into Lake Minnetonka. A portion of the course is near the elevation of the wetland. As a result, runoff from this area is collected in a lift station and pumped into the wetland through a pipe under an adjacent highway. Approximately 30 acres of the course drain to the lift station. A network of shallow 6 inch diameter tile lines discharge water into the lift station. The tile lines link a network of surface inlets connected by 4 inch perforated tile lines approximately one foot below the ground surface. A drainage ditch running parallel to the highway also discharges into the lift station through a tile line. The ditch collects runoff mainly from the golf course. The adjacent highway is sloped to drain to the south away from the ditch.

MINIKAHDA CLUB

The Minikahda Club is a 156 acre, 18 hole private golf course located near downtown Minneapolis, Minnesota, adjacent to the northwest corner of Lake Calhoun. Nine holes of the course were constructed in 1898, with an additional nine holes added in approximately 1902. The course encompasses 156 acres, of which 86 are maintained as turf. The course contains a 10 acre bird sanctuary as well as a four acre prairie. Over 3000 mature Elm, Basswood, Oak and Maple trees are established on the course. Specific acreages of land use types on the course are shown in Table 1.

The topography is mostly gently rolling, with hills having 0 to 8 percent slopes. Approximately 10 percent of the course has steeper hills, with slopes between 8 and 18 percent. The soils are predominantly well drained Dakota loam, with moderate permeability. However a low area of organic Seelyville muck bisects the course north to south.

Runoff from the course flows into Lake Calhoun through the City of Minneapolis storm sewer system. The Club is located downstream of a 1168 acre watershed comprised of residential, commercial, industrial and open areas of the City of Minneapolis. The drainage from the watershed enters the northwest corner of the course in a 36 inch corrugated metal pipe. Approximately 200 feet from the golf course boundary the stormsewer discharges into an open channel. The open channel bisects the course and discharges into a 36 inch concrete pipe at the southeast corner of the golf course. The concrete pipe, in turn, discharges into Lake Calhoun. Runoff from the golf course drains into the channel through a combination of surface sheet flow and shallow tile drains. Three ponds have been constructed near the downstream end of the open channel.

As Table 1 shows, the cut height on the greens and tees were similar for all of the courses. Discussions with golf course managers indicates that these cut heights are typical of golf courses in Minnesota. The turf cut height on the fairways ranged from 7/8 inches at the Baker National Golf Course to 15/32 inches at the Minikahda Club.

The cut height on the roughs ranged from 2.5 inches at the Minikahda Club to 1.75 inches at Baker National.

METHODS AND MATERIALS

SAMPLE SITE SELECTION

Five sample sites were established at the four golf courses. Because the Minikahda Club received runoff from a large upstream watershed, a sample site was established both upstream and downstream of the course. All of the sample site watersheds contained some areas which were not turf, e.g. buildings, roads, and cart paths. The Baker National watershed for example contained approximately 600 feet of a 10 foot wide blacktop cart path. However, the non-turf areas never accounted for more than 3 percent of the study watershed, (Table 1).

At each site a data logger connected to either a pressure transducer level sensor, or a combination level and velocity sensor, was installed. At Baker National, Meadowbrook and two sites at Minikahda, the probes were installed in pipes. Flow was calculated by the data loggers as the product of the velocity and depth of water in the pipe. However, the velocity sensor at the Minikahda Inlet site intermittently provided negative readings. The cause of the problem was discovered to be the amount of debris and scum which coated the probe. The probe was cleaned at least three times weekly, but within 24 hours of cleaning would provide erroneous readings. The level measurements made by the same probe were found to be in agreement with the staff gauge readings on almost all occasions. Therefore, a stage discharge curve was developed from level and velocity readings taken within 12 hours of probe cleaning. The discharge from the equation was in close agreement with the flow from the Minikahda outlet station.

At the Woodhill Country Club, the pressure transducer level sensor was installed in a sump pit. The data logger measured the number of times each day the pit was emptied by a pump. Flow was calculated as the product of pit volume and the number of times each day the pit was emptied.

Automatic samplers at each site were slaved to the dataloggers and collected samples at discrete intervals during runoff events. The samplers were equipped with stainless steel intake strainers and a teflon intake line. Runoff water was discharged into a single glass container in each of the samplers.

BAKER NATIONAL GOLF COURSE

The study site at Baker National consisted of a 46.7 acre watershed area draining to a low area, between the first and third holes of the regulation 18 hole course, (Table 1). An existing 36 inch manhole with a surface inlet collected runoff water from the watershed. The manhole was positioned directly above a 24 inch concrete storm sewer pipe which flowed to Spurzem Lake. An additional 36 inch manhole with a

surface inlet "beehive" was installed adjacent to the existing manhole in the low area. The two manhole structures were connected by 12 feet of 12 inch PVC pipe installed at a slope of 1.0 %. The flow line of the 12 inch pipe was installed 30 inches above the flow line of the 24 inch drain pipe to minimize backflow. The area was graded to divert water into the new manhole, after which the former catch basin was sealed up.

MEADOWBROOK GOLF COURSE

The sample station at the Meadowbrook Golf Course was established near the discharge end of the 12 inch concrete drainage pipe which bisects the course. Runoff from 93.7 acres of the golf course drained through the concrete pipe above the sample station, (Table 1). The concrete pipe was used as the primary measuring device to estimate water flow.

WOODHILL COUNTRY CLUB

The sample station for the Woodhill Country Club was installed in the pumping station at the south edge of the course. Approximately 30 acres of the course drain to the lift station, (Table 1). The pumping station consisted of a 83 inch x 142 inch x 82 inch deep concrete pit, into which a 3 horsepower pump was installed to lift water into a 6 inch discharge line. The pump was equipped with a float system to start and stop the pump at predetermined water level changes.

A tipping bucket rain gauge was installed on the site to trigger the sampler during rainfall events. The data logger was set to initiate the sampler with a minimum of 0.1 inches of rainfall in a 5 minute interval.

MINIKAHDA CLUB

Two sample sites were established at the Minikahda Club, one at the discharge end of a 36 inch corrugated metal pipe at the north end of the course to determine the quality and quantity of the water entering the golf course from the 1168 acre watershed upstream of the course. A second station was established in a driveway culvert 50 feet from the downstream end of the golf course property, where the open channel reenters the storm sewer system. This station was established to determine the quantity and quality of runoff leaving the golf course. The downstream site received runoff from 137 acres of the course (Table 1).

DATA COLLECTION

Each site was visited a minimum of three times weekly to verify proper operation of the flow meters and samplers. Data was retrieved from the data loggers with a laptop computer at least once a week to minimize data loss. Despite the frequency of downloading, approximately three weeks of data was lost at the Meadowbrook site over the course of the season. Missing flow values were estimated from a regression equation developed from rainfall and runoff for events where data was collected.

Flow weighted composite samples were collected by the automatic samplers at each of the sample sites. Samples were transferred to opaque bottles immediately after the end of rainfall runoff flows, iced, and delivered to the laboratory for analysis on the day of collection. Duplicate samples and field blanks were provided as a quality assurance check.

Sample analysis was completed by a commercial laboratory selected by competitive bid. Laboratory methods for the analysis of nutrients and herbicides followed EPA approved methods. Fungicide analysis was completed with methods developed by the laboratory in cooperation with the fungicide manufacturer. Sample bottles were supplied by the laboratory and contained the appropriate preservative.

Water samples were analyzed for the presence of the following parameters:

PARAMETER	DETECTION LIMITS
Total Phosphorus	0.02 mg/l
Soluble reactive phosphorus	0.02 mg/l
Total Kjeldahl nitrogen	0.05 mg/l
Ammonia nitrogen	0.05 mg/l
Nitrate & nitrite nitrogen	0.01 mg/l
Suspended solids	1.00 mg/l
Total dissolved solids	4.00 mg/l
pH	
Conductivity	
Mercury	0.20 ug/l
Cadmium	4.00 ug/l
2,4-D	2.00 ug/l
Dicamba	2.00 ug/l
MCPP	2.00 ug/l

Because of the large number of fungicides used on golf courses and the high cost of analysis, it was not feasible to measure the concentration of each fungicide for each

sample event. Samples were, therefore, analyzed only for specific fungicides applied during the 1994 season.

FERTILIZER AND PESTICIDE APPLICATION

Fertilizers and pesticides were applied to golf course turf areas according to normal application rates and schedules. The golf course managers were unaware of which runoff events were monitored until after the operating season. The specific dates of fertilizer and pesticide applications were not known by Hennepin Parks staff until after the study was completed. However, the golf course managers did indicate the types of fungicides they applied.

RAINFALL

Gauges were installed at four sites to measure rainfall occurring during the study. Tipping bucket gauges were installed at the Woodhill Country Club pump building and approximately one half mile southwest of Baker National Golf Course, at a gatehouse site. Total volume gauges were installed at the sample site at the Meadowbrook course and one quarter mile southwest of the Baker National Golf Course site. In addition, data from an existing tipping bucket gauge maintained by the Minneapolis Park Board at the Minikahda Club was obtained for the study. Rainfall data at the Minikahda, Meadowbrook and Baker Gatehouse sites were not available until May of 1994. Only the Baker Park total rainfall gauge was operational in April. Therefore, it was necessary to use the April data from this site for the other courses.

POLLUTANT EXPORT

Export of pollutants from each course was calculated as the product of the total runoff for a given rainfall event and the flow weighted mean concentration of a pollutant for that event. Total export from base flow during the season was calculated as the product of daily flow and the median concentration of base flow events. For non-monitored rainfall events, export was calculated as the product of the total flow and a concentration calculated by a regression equation between concentration and total flow. Total export from non-sampled events was also calculated as the product of the total flow and the mean and median of the site flow weighted concentrations.

RESULTS AND DISCUSSION

STUDY SITE SELECTION

Selection of sample sites was limited to those courses where permission to establish sampling stations could be obtained. As a result, the four courses included in the study do not have the full range of soil types and topography found on golf courses in the TCMA. For example, none of the sample sites have the sandy soils typical of the north and south TCMA areas. Topography of the courses is also more uniform than desired. All four courses in the study have some slopes greater than 12 percent, which is not true of all courses in the TCMA. Overall, however, the four golf courses do reflect a range of soils, topography, and turf quality typical of most courses in the area.

At the conclusion of the study it was discovered that three of the four courses, (Minikahda, Baker National, and Woodhill) had applied for certification as members of the **Audubon Cooperative Sanctuary System**. The program, which is sponsored by the New York Audubon Society, is designed to promote environmentally sensitive management practices and integrated pest management on golf courses. Currently only three golf courses in Minnesota, including the Minikahda Club and Baker National, are Audubon certified.

Presumably, involvement in this program indicates a higher level of concern for the effects of chemical use on the golf course and adjacent environment. It is unclear, however, to what extent this concern has been translated into reduced chemical use or into management practices which reduce pollutant runoff below that expected from typical golf courses. In any event, the three study courses involved in the program continue to maintain very high turf quality relative to other courses in the TCMA, and therefore, the runoff quality should be representative of typical golf course conditions.

FERTILIZER AND PESTICIDE APPLICATION

The specific fertilizers and pesticides applied to each course in 1994 are shown in Tables 2,3,4 and 5. Baker National received the highest amount of phosphorus per acre, 5.2, and the Minikahda Club received the most nitrogen, 41.7 lbs/acre. However, all four courses received similar amounts, except for Meadowbrook which received only 0.5 lbs/acre of phosphorus. The amount of phosphorus applied to the courses is significantly less than that applied to most urban lawns, approximately 30 lbs/acre, (Creason and Runge, 1992). The fact that the course not involved in the Audubon Cooperative Sanctuary System received amounts of fertilizer and pesticides similar to those that did, supports the contention that the courses in the study

represent average conditions.

The Minikahda Club received the most frequent applications of fungicides, and also received the largest amount per unit area. In addition to the fungicides shown in the tables, Meadowbrook and Woodhill received applications of Metalaxyl (SUBDUE®), and Meadowbrook received applications of Propamocarb Hydrochloride (BANOL®). The application frequency in 1994 was reported to be less than normal, because of the relatively cool temperatures. The TCMA reported only four days with temperatures above 90 degrees Fahrenheit, significantly less than the long term average of 14 days. According to golf course managers, turf diseases are more prevalent during hot weather. Data on the exact decrease in fungicide use in 1994 compared to normal years was not available.

RAINFALL

Rainfall was below the 136 year regional average at the four rain gauge sites in May and June of 1994, but above average at most of the sites during the other months (Figure 2). Rainfall amounts varied widely at the four sample sites, especially in August, when the Meadowbrook Golf course recorded 6.7 inches of rainfall while the Baker Gatehouse site recorded only 2.9 inches. Total rainfall amounts also varied widely for individual events. Overall the Minikahda course received the most rainfall, 27.9 inches and the Baker course received the least, 23.9 inches. The total rainfall at all sites was above the 136 year regional average of 21.33 for the study period.

A number of trees adjacent to the rainfall gauge location at the Woodhill site caused a significant error in the data, thus it is not reported here. However, this was acceptable since the main function of the gauge was to trigger the automatic sampler, which it did for almost all events.

RAINFALL RUNOFF

Flowmeters and automatic samplers were installed at Baker National Golf Course on April 8, 1994, at the Meadowbrook Golf Course on April 11, 1994, at the Woodhill Country Club on April 14, 1994, and at the Minikahda Club on May 13, 1994.

The amount of runoff measured at the four sites varied from 3.3 acre-feet at the Woodhill Country Club to 16.4 acre-feet at the Meadowbrook Golf Course. The difference was due mainly to the different watershed sizes and rainfall amounts. The percent of rainfall leaving the courses as runoff was similar at all four sites, 5.8, 7.8, 5.0, and 5.2 at Baker, Meadowbrook, Woodhill, and Minikahda respectively (Table 9). These values are much lower than those reported by Smith (1995), who found that 42 percent of rainfall water left simulated golf course fairways as runoff. The runoff rates

in this study were also much lower than typical urban area runoff coefficients which range from 0.2 to 0.7 for residential and commercial areas respectively, and are in fact comparable to those estimated for undeveloped areas.

The small runoff rates from the golf courses is probably a function of the management practices on the golf courses which promote rainfall infiltration. These practices include regular soil aeration, addition of organic matter, maintenance of vigorous turf growth. In addition, golf courses do not have the severely compacted subsoil which is typical of many urban lawns.

Although base flow did occur at all of the sites during the study period, it was negligible except at the Minikahda Club. The 1168 acre watershed above the course delivered over 564 acre-feet of water to the course, over half during non-rainfall periods. The watershed contains a large wetland complex upstream of the golf course. The wetlands apparently store water and release it after stormwater flows have abated.

NUTRIENT AND PHYSICAL PARAMETERS

A total of 67 rainfall runoff samples from the four golf courses were collected during the ice free season in 1994. More rainfall events were sampled at the Woodhill site, 19, than any of the other sites. The Woodhill site had the fewest problems with the sampling equipment. In addition, because the runoff water entered a large pit where it was temporarily stored, adequate volume for collection was available during all sampled events. Conversely, at the other sites where samples were collected from an intermittent stream flow, the water depth in the conduit during small events was not sufficient to cover the intake strainer. As a result, only a few milliliters of water were collected, an amount insufficient for analysis. The fewest events, 11, were sampled at the Minikahda inflow site, mainly because of problems with the sampling equipment.

The mean, median, range, and standard deviation of the parameters found in the runoff water are shown on Table 6. As the table shows, there was a wide range in the concentration of most parameters during the study period. For example the total phosphorus concentration ranged from 0.08 mg/l to 3.1 mg/l, and the total Kjeldahl nitrogen concentration ranged from 0.50 mg/l to 8.2 mg/l. The mean concentrations of total phosphorus, soluble reactive phosphorus, total Kjeldahl nitrogen, and nitrate & nitrite nitrogen from the golf course sites were higher than concentrations reported for urban residential or commercial areas (Brach, 1989). However, the concentration of total suspended solids was lower.

The mean concentrations of total phosphorus and soluble reactive phosphorus, 0.52 and 0.34 respectively, were significantly different ($p<0.05$). In addition, the sum of the ammonia nitrogen and the nitrate & nitrite concentrations were significantly less than

the total Kjeldahl nitrogen concentration. This suggests that 35 percent of the nutrients leaving the golf courses are in a particulate form. This was unexpected because loss of soil under well established turf is typically very low. However, visual inspection revealed the presence of grass clippings in most of the samples. The majority of the suspended material appears to be from grass clippings caused by the frequent mowing of the courses. Management practices which prevent the movement of the clipping off of the courses, or remove them from the runoff stream would reduce the export of nutrients from golf courses.

The mean parameter concentrations at each of the sample sites are shown in Table 7. Interquartile boxplots showing the median and range for each of the parameters are shown in Appendix B. Differences between the sites for each parameter were determined by ANOVA procedures performed on the normal log of the concentrations because, although the means were normally distributed, they did not have equal variances.

Significant differences ($p<0.05$) between site means for the different parameters are shown in Table 8. For most of the nutrient parameters, the mean concentrations at the Minikahda inlet and outlet sites were significantly lower than at the other sites, and the mean concentrations at the Meadowbrook site were higher (Table 8). The mean total phosphorus concentrations at the Minikahda sites was not significantly different from the Woodhill Country Club. The concentrations of most parameters at Baker National and the Woodhill Country Club were not significantly different. The common perception that the more intensively manicured private courses would have higher pollutant export concentrations is not supported by the data. The data also show that under proper management, high quality turf can be maintained with minimal effect on runoff water quality.

No significant differences were found for any parameters between the Minikahda inlet and outlet sites, showing that the golf course did not significantly increase nutrient concentrations in the stream flow. The Minikahda golf course, therefore, appears to have no negative effect on the water quality of Lake Calhoun, which is immediately downstream of the course.

FUNGICIDES AND HERBICIDES

Detectable concentrations of at least one fungicide were observed in 40 of 59 runoff water samples. Chlorothalonil, (Trade Name DACONIL), the most frequently observed fungicide, (Figure 3), was detected in 34 samples. DACONIL® was also the most frequently applied fungicide. Propiconazole (BANNER®) was detected in 14 samples, and Iprodione (CHIPCO®) in 4 samples. Both Chlorothalonil and Propiconazole were detected in the same sample on 12 occasions, and Chlorothalonil and Iprodione were both detected in 3 samples. Pentachloronitrobenzene (PCNB) was not detected in

any of the samples. Overall, at least one fungicide was found in approximately 60 percent of all samples.

The Minikahda inlet site had detectable concentrations of either Chlorothalonil or Propiconazole in 6 of 10 samples. The source of the fungicide is uncertain. It may originate in the watershed upstream of the course or from a small (less than 5 acre) watershed of the course upstream of the corrugated metal pipe discharge point. The Minikahda outlet site had the lowest frequency of detectable fungicide concentrations, 40 percent. This occurred despite the fact that fungicide application was heaviest on this course (Table 5). During at least one runoff event, DACONIL® was detected at the Minikahda inlet site, but not at the outlet site. Presumably, physical and/or biological processes in the drainage ditch or the ponds along the ditch reduced the concentrations of fungicides in the stream flow.

The concentrations of the fungicides in the runoff water were low, with a mean of 0.48 ug/l, 0.58 ug/l, and 0.29 ug/l for Chlorothalonil, Propiconazole and Iprodione respectively, (Table 6). The median concentration for all fungicides and herbicides was 0.00 ug/l. There were no significant differences between the mean fungicide concentration at the different sample sites as determined by ANOVA procedures, ($p < 0.05$).

Only one of three herbicides, 2,4-D, was detected in runoff from the golf course sites. The chemical was detected on only one occasion in runoff water from the Baker National Golf Course. However, 2,4-D was also detected in one sample at the Minikahda inlet site. The detection frequency is significant lower than the 67 percent occurrence for 2,4-D in stormwater runoff reported by Bannerman, (1990). The difference may be due to a lower detection level used by Bannerman as compared to this study. Neither MCPP or Dicamba was detected in any of the runoff samples.

Mercury and cadmium were found in 20 and 8 percent of samples respectively. Only two of the sites, Woodhill and Meadowbrook, had detectable concentrations of the two metals. The mean concentrations for the two heavy metals were 0.348 ug/l and 0.63 ug/l respectively for mercury and cadmium. Presumably the mercury export is from residue from applications of a fungicide which is no longer in use. Mercury export would be expected to decrease over time since the metal is no longer used on golf courses.

POLLUTANT EXPORT

Export of nutrients from the golf courses in 1994 is shown in Table 9. There was no significant difference between the export amounts calculated by the various methodologies described earlier. The export rates for phosphorus and nitrogen from three of the sites, Baker, Minikahda, and Woodhill were an order of magnitude less

than the reported export rates of 0.94 lbs/ac and 4.8 lbs/acre, respectively, for urban residential areas (Brach, 1992). The phosphorus and nitrogen export rates for Meadowbrook were approximately 30 percent of the urban residential area export rate reported by Brach. There was no relationship between the amount of fertilizer applied to the courses and the export rate. The pollutant export rates from the four courses are comparable to those reported for open, undeveloped areas (Table 9).

The very low phosphorus export rates are probably a response to the small amount of this nutrient applied to the four courses. As indicated earlier, application rates were approximately 20 percent of typical urban lawn rates. Discussions with golf course managers indicate that the application rate for fertilizers is determined by soil fertility testing. Only the amount of each nutrient needed by the soil is applied. Conversely, a recent study of 181 urban lawns found that 67 percent have very high phosphorus levels and still receive over 6 pounds per lawn (approximately 15,000 square feet) annually (Barten, 1994). None of these lawns had been tested for soil fertility prior to the study.

The demonstrated ability of the four golf courses to maintain a quality of turf better than lawns, has significant implications for urban lawn management. Creason and Runge, 1992, estimated that 3,191 tons of phosphorus are applied to lawns in the TCMA. Approximately 67 percent of this phosphorus could be removed from area lawns annually without affecting turf quality. This would probably reduce the high amounts of phosphorus runoff from lawns reported by Bannerman et. al., 1992.

The data indicate that golf courses are not a significant source of nutrient loading to adjacent water bodies. For example, Baker National Golf Course contributes an estimated 26 pounds of phosphorus and 96 pounds of nitrogen to Spurzem Lake. The phosphorus loading to Lake Spurzem from the 1270 acre watershed was estimated by the Reckhow-Simpson Model to range from 1,005 to 2,644 pounds per year. The golf course, therefore, contributes between 0.9 and 2.6 percent of the annual loading to the lake, even though the course represents 16 percent of the watershed.

The fact that there were no significant differences between the inflow and outflow nutrient concentrations at the Minikahda Club indicates that the effect of the course on the receiving water body, Lake Calhoun, was negligible. As is the case with Spurzem Lake, the Minikahda Club represents a significant portion of the watershed, 13 percent, but did not contribute any nutrients to the lake. In fact, nutrient export from the golf courses reflects loading rates from open areas, generally considered the most desirable land use type from a water quality perspective.

Only very small quantities of fungicides, pesticides, and heavy metals were lost from the golf courses in 1994. As Table 10 shows, no course lost more than 0.004 pounds of any fungicide from the monitored area. On an areal basis, no course lost more

than 0.00013 lbs/acre of any fungicide, (Table 10). Fungicide loss as a percent of applied product was also very small, less than 0.5 percent for all of the courses. The course which had the most fungicide applied to it, the Minikahda Club, had the least amount of chemical movement off of the course. No information was available to estimate the effect of the fungicides on downstream waterbodies.

The low export of fungicides is probably a response to both the small amount of runoff leaving the golf courses, as well as the application practices. The report logs from the golf courses indicate that applications of chemicals were made by highly trained full time employees. The reports also show that application equipment was calibrated prior to use, to ensure application of an accurate concentration of chemicals.

Because 2,4-D was found in only one sample, the total export of this herbicide could not be calculated. The total export of mercury and cadmium were very low, 0.00007 and 0.00089 pounds per year from Woodhill and Meadowbrook respectively.

CONCLUSIONS AND RECOMMENDATIONS

The data collected in 1994 indicate that golf courses are not a significant source of nutrients or pesticides to water bodies in the TCMA. The low pollutant export rate from golf courses appears to be a function of the management practices used on the golf courses. These practices, which promote rainfall infiltration and limit applications of chemicals, particularly phosphorus, include soil aeration, soil fertility testing, application of organic matter, and maintenance of dense vegetation.

Inclusion of the following specific practices in the management of all golf courses, as well as urban lawns, is recommended.

> Soil fertility tests should be completed on turf areas prior to the application of fertilizer. In cases where tests are not completed, only phosphorus free fertilizer should be applied. As the four golf courses involved in the study demonstrated, high quality turf can be maintained with significantly less phosphorus than is currently being applied to TCMA lawns.
>
> Turf areas should be aerated regularly to promote rain water infiltration. In addition, compaction of subsoil should be minimized during the development of residential subdivisions. Subsoil compacted by grading should be loosened before topsoil and sod is placed.
>
> Application of weed control chemicals and fertilizer should be made with calibrated equipment to minimize over application of chemicals. Applications should not be made when rainfall is forecast.

Although the quantities of fungicides leaving the golf courses were very small, the presence of the chemicals in 60 percent of samples may be of concern. In years with average temperatures, the frequency of application would probably increase, resulting in an increase in the amount of fungicides lost from golf courses. Management strategies which reduce the frequency of fungicide loss from golf courses should be implemented.

One strategy that could further reduce or eliminate the amount of pollutants, including fungicides, leaving a golf course would be to install detention basins on the course to collect runoff water. Both the DETPOND and PONDSIZ models suggest that phosphorus and nitrogen export could be reduced by approximately 50 percent if detention basins were constructed. The water in the basins could also be used for irrigation. This would in effect, recycle the fungicides and nutrients and could result in

almost zero discharge of pollutants from golf courses. The small volumes of runoff water generated by the golf courses appear to make detention basin construction and irrigation from the basins economically feasible. Detention basins would also remove the grass particles which were observed in most of the runoff samples.

A primary objective of the study was to determine runoff quality from typical golf courses in the TCMA, and every attempt was made to find and monitor typical courses. It is possible, however, that because of their involvement in the Audubon Sanctuary Program, the courses selected for the study are superior relative to the management practices applied to them. Any future research, therefore, should focus on courses not involved in this program. However, even if pollutant runoff were an order of magnitude high than from the courses in this study, the effect on water resources would still be negligible.

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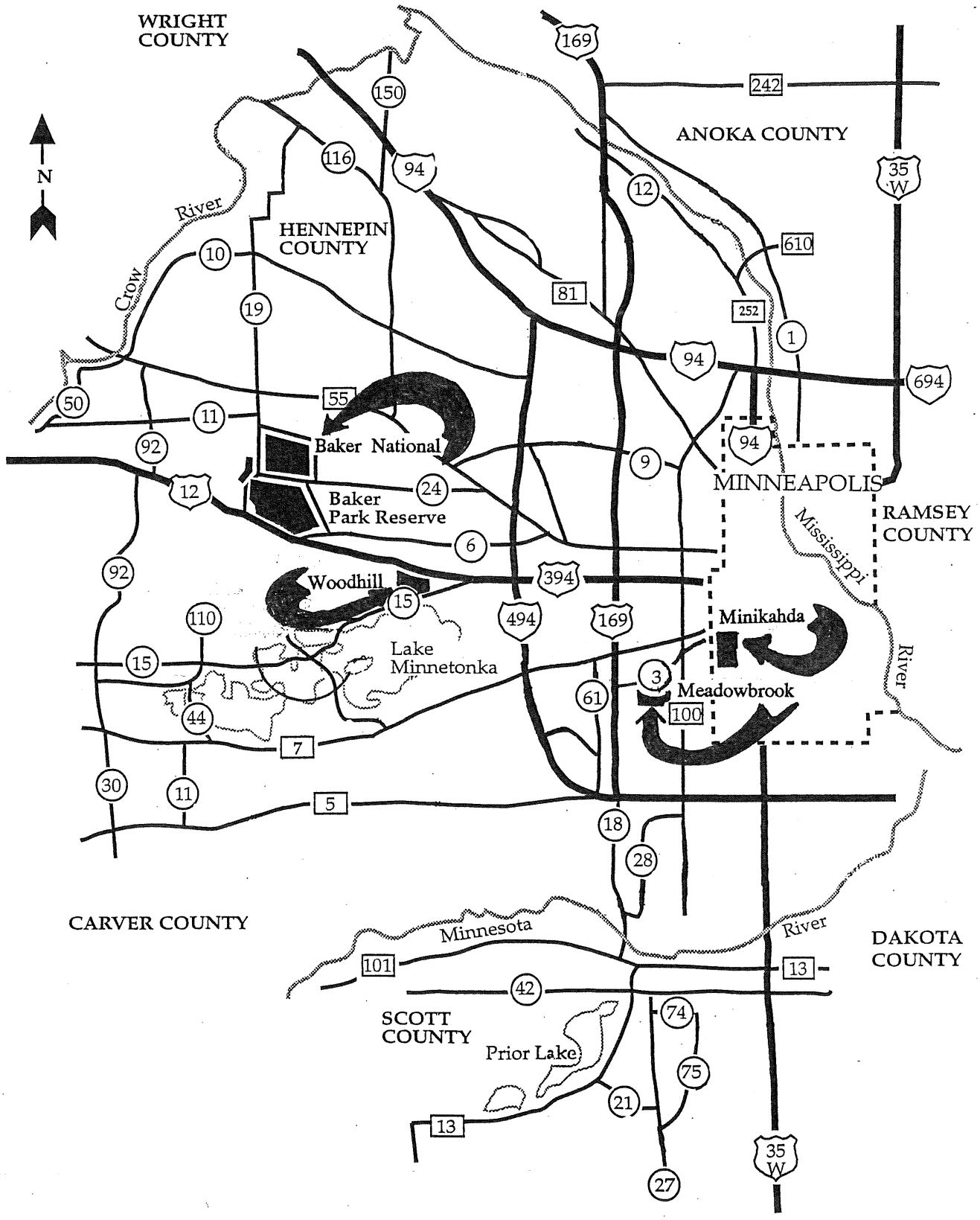

Figure 1. Location of golf course sample sites.

GOLF COURSE LAND USE	BAKER (ACRES)	MEADOWBROOK (ACRES)	WOODHILL (ACRES)	MINIKAHDA (ACRES)
Turf	160	170	160	86
Greens and Tees	6.1	5.1	4	5
Fairways	32	42	22	26
Roughs	122	123	60	55
Building Sites	7	3	10	8
Roadways	5	4	4	4
Wetlands	20	100	20	1.5
Forested	128	103	35	52.5
Prairie				4
Total Area	**320**	**380**	**225**	**156**
Green Cut Height (inches)	5/32	5/32	5/32	9/64
Fairway Cut Height (inches)	7/8	3/4	1/2	15/32
Rough Cut Height (inches)	1.75	2	2	2.5

SUB WATERSHED COMPOSITION

LAND USE TYPE	BAKER (ACRES)	MEADOWBROOK (ACRES)	WOODHILL (ACRES)	MINIKAHDA (ACRES)
Greens	0.9	1.8	0.4	3
Tees	0.5	1.3	0.4	2
Fairways	9.5	22.6	7.3	26
Roughs	33.4	66.4	18.2	55
Roadways	0.4	0.4	0	2
Building Sites	0	1.2	0	4
Wetlands	0	0	0	1.5
Forested	2	0	4.6	42.5
Prairie	0	0	0	4
Total Area Study Site	**46.7**	**93.7**	**30.9**	**137**

Table 1. Size and land use of four golf courses sample sites in the TCMA.

FERTILIZER APPLICATIONS

DATE	APPLICATION RATE LBS N/1000sq.ft.	PRODUCT	LOCATION	PHOSPHORUS APPLIED (LBS)	NITROGEN APPLIED (LBS)
19-May-94	0.5	18-5-9	TEES 1-18	3.2	11.5
23-May-94	0.5	18-0-18	ALL GREENS	0	19.6
25-May-94	0.5	14-0-14	FAIRWAYS SHORT	0	33.6
02-Jun-94	0.5	6-2-0	ALL FAIRWAYS	69	207
06-Jun-94	1.0	0-0-47	ALL GREENS	0	0
15-Jun-94	0.5	18-5-9	ALL TEES	6.1	10.8
27-Jun-94	0.5	6-2-0	ALL GREENS	6.5	19.6
07-Jul-94	0.5	6-2-0	ALL FAIRWAYS	69	207
07-Jul-94	0.5	18-0-18	ALL GREENS	0	19.6
18-Jul-94	0.5	18-0-18	ALL GREENS	0	19.6
19-Jul-94	0.5	40-0-0	ROUGHS 1-18	0	727
25-Jul-94	0.5	6-2-0	ALL TEES	3.6	10.8
01-Aug-94	0.6	22-0-12	ALL GREENS	0	26
02-Aug-94	0.5	6-2-0	ALL FAIRWAYS	69	207
15-Aug-94	0.5	18-0-18	ALL GREENS	0	19.6
29-Aug-94	0.5	8-4-24	GREENS 1-9	5.6	11.5
07-Sep-94	0.5	8-4-24	ALL GREENS	9.8	19.5
08-Sep-94	1.0	40-0-0	FAIRWAYS 1-18	0	347
26-Sep-94	0.6	18-0-18	ALL GREENS	0	26
TOTAL APPLIED TO STUDY AREA				241.8	1942.7

FUNGICIDE APPLICATIONS

DATE	APPLICATION RATE	LOCATION	PRODUCT	AMOUNT APPLIED (LBS)
18-May-94	2.58 QT/AC	ALL GREENS	2PLUS2	2.2
26-May-94	3.0 QT/AC	FAIRWAYS	2PLUS2	26.6
16-Jun-94	5.0 OZ/1000 sq.ft.	ALL GREENS	DACONIL	5
01-Jul-94	4.0 OZ/1000 sq.ft.	ALL GREENS	CHIPCO	2.3
26-Jul-94	3.0 QT/AC	#3 ROUGH	2PLUS2	0.2
28-Jul-94	5 OZ/1000 sq.ft.	ALL GREENS	DACONIL	5
22-Aug-94	1.5 OZ/1000 sq.ft.	REG GREENS	BANNER	0.3
24-Oct-94	12 OZ/1000 sq.ft.	ALL GREENS	PCNB	29.4

NOTE: 2PLUS2 CONTAINS THE HERBICIDES 2,4-D AND MCPP

Table 2. Baker National Golf Course fertilizer and pesticide applications, 1994.

FERTILIZER APPLICATIONS

DATE	APPLICATION RATE LBS N/1000sq. ft.	PRODUCT N-P-K	LOCATION	PHOSPHORUS APPLIED (LBS)	NITROGEN APPLIED (LBS)
12-Apr-94	1.1	18-0-18	ALL GREENS	0	86.2
12-Apr-94	1.2	16-0-29	FAIRWAYS	0	1181
18-Apr-94	5.5	16-0-29	TEES	0	311.5
21-May-94	1.5	18-0-18	GREENS	0	117.6
21-Jun-94	0.5	21-2-21	FAIRWAYS	93.7	984
29-Jun-94	1.4	18-0-18	GREENS	0	109.8
TOTAL APPLIED TO STUDY AREA				93.7	2790.1

FUNGICIDE APPLICATIONS

DATE	APPLICATION RATE OZ/1000 sq.ft.	PRODUCT	LOCATION	AMOUNT APPLIED (LBS)
06-May-94	6.0	CHIPCO	GREENS	6.9
20-Jun-94	2.0	BANOL	GREENS	6.5
21-Jun-94	2.0	BANOL	TEES	4.7
12-Jul-94	7.0	DACONIL	GREENS	13.9
28-Jul-94	5.0	CHIPCO	GREENS & TEES	9.8
20-Oct-94	8.0	PCNB	GREENS	15.7

NOTE: PCNB = Pentachloronitrobenzene

Table 3. Meadowbrook Golf Course fertilizer and pesticide applications, 1994.

FERTILIZER APPLICATIONS

DATE	APPLICATION RATE LBS/1000sq. ft.	PRODUCT N-P-K	LOCATION	NITROGEN APPLIED (LBS)	PHOSPHORUS APPLIED (LBS)
01-Jun-94	1.0	21-0-20	GRNS,TEES,FRWAY	352.8	0
01-Jul-94	0.75	6-2-0	GRNS,TEES,FRWAY	264.6	88
26-Jul-94	0.9	21-0-20	GRNS,TEES,FRWAY	317.5	0
08-Sep-94	1.0	21-0-20	GRNS,TEES,FRWAY	352.8	0
TOTAL APPLIED IN STUDY AREA				1287.7	88

FUNGICIDE APPLICATIONS

DATE	APPLICATION RATE (OZ/1000 sq.ft.)	PRODUCT	LOCATION	QUANTITY APPLIED (LBS)
02-May-94	1.0	2,4-D,MCPP, DICAMBA	GREENS	
02-May-94	4.0	CHIPCO	GREENS	20.6
06-Jun-94	2.0	BANNER	GREENS	6.3
06-Jul-94	4.0	DACONIL	GREENS	35.6
18-Aug-94	4.0	DACONIL	GREENS	35.6
16-Sep-94	4.0	DACONIL	GREENS	35.6
24-Oct-94	4.0	PCNB	GREENS	16.3

Table 4. Woodhill Country Club fertilizer and pesticide applications, 1994.

FERTILIZER APPLICATIONS

DATE	APPLICATION RATE (lbs/1000 sq.ft.)	PRODUCT (N-P-K)	LOCATION	NITROGEN APPLIED (LBS)	PHOSPHORUS APPLIED (LBS)
15-Nov-93	2.5 as N	16-8-12	Greens	326.5	163.3
15-Nov-93	4.0 as N	16-8-12	Tees	522.4	261.2
02-May-94	1.0 as K	20-0-20	Fairway	1132.6	0
23-Jun-94	1.0 as K	20-0-20	Fairway	1132.6	0
07-Jul-94	0.43 as N	5-2-94	Tees	37.5	15
16-Jul-94	0.22 as N	5-2-95	Tees	19.2	7.7
19-Jul-94	0.15 as N	20-5-30	Greens	19.6	4.9
05-Aug-94	0.1 as N	20-5-30	Greens	13.1	3.3
12-Aug-94	0.6 as N	18-4-10	Tees	52.3	11.6
17-Aug-94	0.1 as N	20-5-30	Greens	13.1	3.3
22-Aug-94	0.65 as N	6-2-12	Greens	84.9	28.3
23-Aug-94	0.5 as N	15-0-30	Fairway	566.3	0
26-Sep-94	0.9 as N	18-4-10	Tees	78.4	17.4
05-Oct-94	0.76 as N	8-1-10	Fairway	860.8	107.6
10-Oct-94	0.15 as N	20-5-30	Greens	19.6	4.9
TOTAL APPLIED TO STUDY AREA				4878.9	628.5

FUNGICIDE APPLICATIONS

DATE	APPLICATION RATE (OZ/1000 sq.ft.)	PRODUCT	LOCATION	QUANTITY APPLIED (LBS)
09-May-94	3.0	Chipco	FAIRWAYS	49.5
10-May-94	4.0	Chipco	GREENS & TEES	12.7
06-Jun-94	1.0	Banner	GREEN & TEES	2.0
06-Jun-94	6.0	Daconil	TEES	13.2
08-Jun-94	8.0	Chipco	GREENS	7.6
09-Jun-94	1.75	Banner	FAIRWAYS	17.7
09-Jun-94	3.0	Daconil	FAIRWAYS	85.8
28-Jun-94	6.0	Daconil	TEES	13.2
29-Jun-94	1.0	Banner	FAIRWAYS	10.1
29-Jun-94	3.0	Daconil	FAIRWAYS	85.8
17-Jul-94	3.0	Daconil	FAIRWAYS	85.8
18-Jul-94	6.0	Daconil	TEES	13.2
19-Jul-94	6.0	Daconil	GREENS	19.8
05-Aug-94	6.0	Daconil	GREENS	19.8
08-Aug-94	3.0	Daconil	FAIRWAYS	85.8
11-Aug-94	6.0	Daconil	TEES	13.2
18-Aug-94	3.0	Daconil	FAIRWAYS	85.8
19-Aug-94	6.0	Daconil	GREENS	19.8
19-Aug-94	6.0	Daconil	TEES	13.2
27-Aug-94	1.0	Banner	GREENS	1.2
27-Aug-94	6.0	Daconil	GREENS	19.8
10-Oct-94	6.0	PCNB	GREENS	19.6
20-Oct-94	6.0	PCNB	TEES	13.1
22-Oct-94	6.0	PCNB	FAIRWAYS	169.9

NOTE: PCNB = Pentachloronitrobenzene

Table 5. Minikahda Club fertilizer and pesticide applications, 1994.

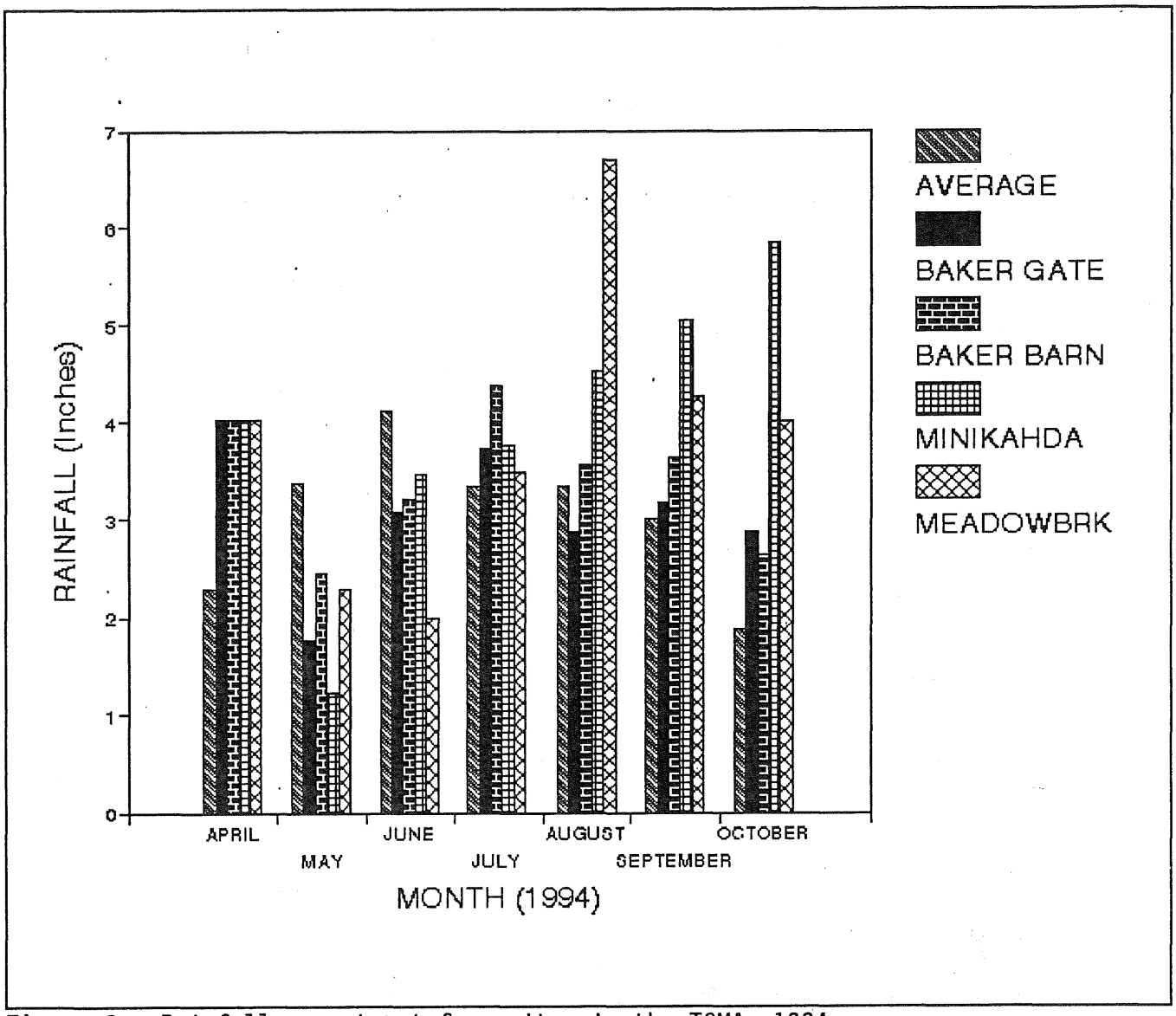

Figure 2. Rainfall amounts at four sites in the TCMA, 1994.

PARAMETER	MEAN	STD DEV	MEDIAN	RANGE	OBSERVATIONS
TOTAL PHOSPHORUS (mg/l)	0.521	0.566	0.34	0.08 - 3.10	67
SOLUBLE REACTIVE PHOSPHORUS (mg/l)	0.335	0.408	0.22	0.20 - 2.30	67
TOTAL KJELDAHL NITROGEN (mg/l)	3.104	2.101	2.3	0.50 - 8.20	65
AMMONIA NITROGEN (mg/l)	0.724	0.626	0.5	0.08 - 3.00	68
NITRATE AND NITRITE NITROGEN (mg/l)	1.307	1.997	0.68	0.01 - 12.0	68
TOTAL DISSOLVED SOLIDS (mg/l)	426.3	216.5	410	120. - 970	54
TOTAL SUSPENDED SOLIDS (mg/l)	59.7	76.6	32.5	4.00 - 430.0	54
pH	7.162	0.414	7.13	6.17 - 7.96	59
CONDUCTIVITY (umho/cm)	593.4	287.1	608	138. - 1452	54
DACONIL (Chlorothalonil)(ug/l)	0.483	1.355	0.00	0.00 - 8.30	59
BANNER (Propiconazole)(ug/l)	0.579	1.517	0.00	0.00 - 9.00	59
CHIPCO (Iprodione)(ug/l)	0.29	1.396	0.00	0.00 - 9.80	59
PENTACHLORONITROBENZENE (ug/l)	0.00	0.00	0.00	0.00 - 0.00	8
2,4-D (ug/l)	0.203	1.562	0.00	0.00 - 12.0	59
MPCC (ug/l)	0.00	0.00	0.00	0.00 - 0.00	59
DICAMBIA (ug/l)	0.00	0.00	0.00	0.00 - 0.00	59
MERCURY (ug/l)	0.348	1.359	0.00	0.00 - 7.50	31
CADMIUM (ug/l)	0.63	1.904	0.00	0.00 - 8.00	27

Table 6. Mean, standard deviation, median, and range of parameters in runoff from four golf courses in the TCMA, 1994.

SITE	MEAN (STD DEV)	RANGE	OBSERVATIONS
TOTAL PHOSPHORUS (mg/l)			
BAKER	0.479 (0.248)	0.10 - 1.00	14
MEADOWBROOK	0.892 (0.677)	0.20 - 2.80	18
WOODHILL	0.476 (0.654)	0.08 - 3.10	20
MINIKAHDA IN	0.204 (0.089)	0.10 - 0.37	11
MINIKAHDA OUT	0.177 (0.076)	0.08 - 0.32	15
SOLUBLE REACTIVE PHOSPHORUS (mg/l)			
BAKER	0.273 (0.148)	0.04 - 0.52	14
MEADOWBROOK	0.596 (0.526)	0.10 - 2.30	18
WOODHILL	0.329 (0.444)	0.03 - 2.10	20
MINIKAHDA IN	0.076 (0.064)	0.02 - 0.21	11
MINIKAHDA OUT	0.087 (0.456)	0.02 - 0.20	15
TOTAL KJELDAHL NITROGEN (mg/l)			
BAKER	2.896 (1.952)	0.87 - 6.30	13
MEADOWBROOK	5.813 (1.420)	3.20 - 8.20	16
WOODHILL	2.405 (1.238)	0.50 - 5.50	21
MINIKAHDA IN	1.198 (0.559)	0.59 - 2.60	11
MINIKAHDA OUT	1.373 (0.445)	0.81 - 2.50	15
AMMONIA NITROGEN (mg/l)			
BAKER	0.412 (0.170)	0.20 - 0.73	14
MEADOWBROOK	1.504 (0.734)	0.40 - 3.00	18
WOODHILL	0.528 (0.180)	0.20 - 0.81	22
MINIKAHDA IN	0.271 (0.166)	0.07 - 0.56	10
MINIKAHDA OUT	0.351 (0.269)	0.80 - 1.20	14
NITRATE & NITRITE NITROGEN (mg/l)			
BAKER	0.321 (0.301)	0.01 - 1.10	14
MEADOWBROOK	1.947 (1.642)	0.47 - 7.00	18
WOODHILL	2.149 (2.900)	0.18 - 12.0	21
MINIKAHDA IN	0.321 (0.147)	0.09 - 0.59	11
MINIKAHDA OUT	0.281 (0.164)	0.08 - 0.60	15
TOTAL DISSOLVED SOLIDS (mg/l)			
BAKER	265.8 (150.6)	120 - 500	12
MEADOWBROOK	447.1 (127.5)	200 - 700	14
WOODHILL	573.9 (235.5)	220 - 970	18
MINIKAHDA IN	275.6 (123.7)	130 - 450	9
MINIKAHDA OUT	360.0 (194.2)	140 - 720	11
TOTAL SUSPENDED SOLIDS (mg/l)			
BAKER	69.8 (75.1)	5.0 - 240.0	13
MEADOWBROOK	87.1 (60.0)	9.0 - 210.0	15
WOODHILL	51.5 (103.6)	4.0 - 430.0	16
MINIKAHDA IN	26.4 (46.8)	4.0 - 150.0	9
MINIKAHDA OUT	18.9 (13.4)	7.0 - 44.0	10

Table 7. Mean, standard deviation and range of selected parameters in runoff from individual golf course sites, 1994.

SITE	MEAN (STD DEV)	RANGE	OBSERVATIONS
DACONIL (Chlorothalonil)(ug/l)			
BAKER	0.234 (0.281)	0.00 - 0.74	11
MEADOWBROOK	0.117 (0.169)	0.00 - 0.55	15
WOODHILL	1.136 (2.258)	0.00 - 8.30	19
MINIKAHDA IN	0.448 (0.761)	0.00 - 2.40	10
MINIKAHDA OUT	0.187 (0.343)	0.00 - 1.10	14
BANNER (Propiconazole)(ug/l)			
BAKER	0.267 (0.640)	0.00 - 2.00	11
MEADOWBROOK	0.440 (1.086)	0.00 - 4.00	15
WOODHILL	0.737 (1.404)	0.00 - 4.80	19
MINIKAHDA IN	0.850 (2.240)	0.00 - 7.10	10
MINIKAHDA OUT	0.800 (2.432)	0.00 - 9.00	14
CHIPCO (Iprodione)(ug/l)			
BAKER	0.373 (1.236)	0.00 - 4.10	11
MEADOWBROOK	0.213 (0.568)	0.00 - 1.80	15
WOODHILL	0.516 (2.248)	0.00 - 9.80	19
MINIKAHDA IN	0.000 (0.000)	0.00 - 0.00	10
MINIKAHDA OUT	0.000 (0.000)	0.00 - 0.00	14
2,4-D (ug/l)			
BAKER	1.091 (3.618)	0.00 - 12.0	11
MEADOWBROOK	0.000 (0.00)	0.00 - 0.00	15
WOODHILL	0.000 (0.00)	0.00 - 0.00	19
MINIKAHDA IN	0.450 (1.423)	0.00 - 4.50	10
MINIKAHDA OUT	0.000 (0.00)	0.00 - 0.00	14
CADMIUM (ug/l)			
BAKER	0.000 (0.00)	0.00 - 0.00	6
MEADOWBROOK	0.500 (1.414)	0.00 - 4.00	8
WOODHILL	1.300 (2.830)	0.00 - 8.00	10
MINIKAHDA IN	0.000 (0.00)	0.00 - 0.00	4
MINIKAHDA OUT	0.000 (0.00)	0.00 - 0.00	3
MERCURY (ug/l)			
BAKER	0.000 (0.00)	0.00 - 0.00	8
MEADOWBROOK	1.020 (3.234)	0.00 - 7.50	10
WOODHILL	0.060 (0.135)	0.00 - 0.40	10
MINIKAHDA IN	0.000 (0.00)	0.00 - 0.00	4
MINIKAHDA OUT	0.000 (0.00)	0.00 - 0.00	3

Table 7 Continued. Mean, standard deviation, and range of selected parameters in runoff from individual golf courses, 1994.

PARAMETER	1 VS 2	1 VS 3	1 VS 4	1 VS 5	2 VS 3	2VS 4	2 VS 5	3 VS 4	3 VS 5	4 VS 5
TOTAL PHOSPHORUS		*	*		*	*	*			
SOLUBLE REACTIVE PHOSPHORUS		*	*		*	*	*		*	*
TOTAL KJELDAHL NITROGEN	*	*	*		*	*	*		*	*
AMMONIA NITROGEN	*				*	*	*		*	
NITRATE & NITRITE NITROGEN	*			*	*	*			*	*
TOTAL SUSPENDED SOLIDS					*	*				
TOTAL DISSOLVED SOLIDS				*					*	*
pH										
CONDUCTIVITY	*			*					*	*
DACONIL (Chlorothalonil)										
BANNER (Propiconazole)										
CHIPCO (Iprodione)										
PENTACHLORONITROBENZENE										
2,4-D										
MPCC										
DICAMBIA										
MERCURY										
CADMIUM										

1 = BAKER NATIONAL GOLF COURSE
2 = MEADOWBROOK GOLF COURSE
3 = MINIKAHDA INLET
4 = MINIKAHDA OUTLET
5 = WOODHILL COUNTRY CLUB

Table 8. Significant differences ($p < 0.05$) between parameters at four golf course sites as determined by two way ANOVA procedures.

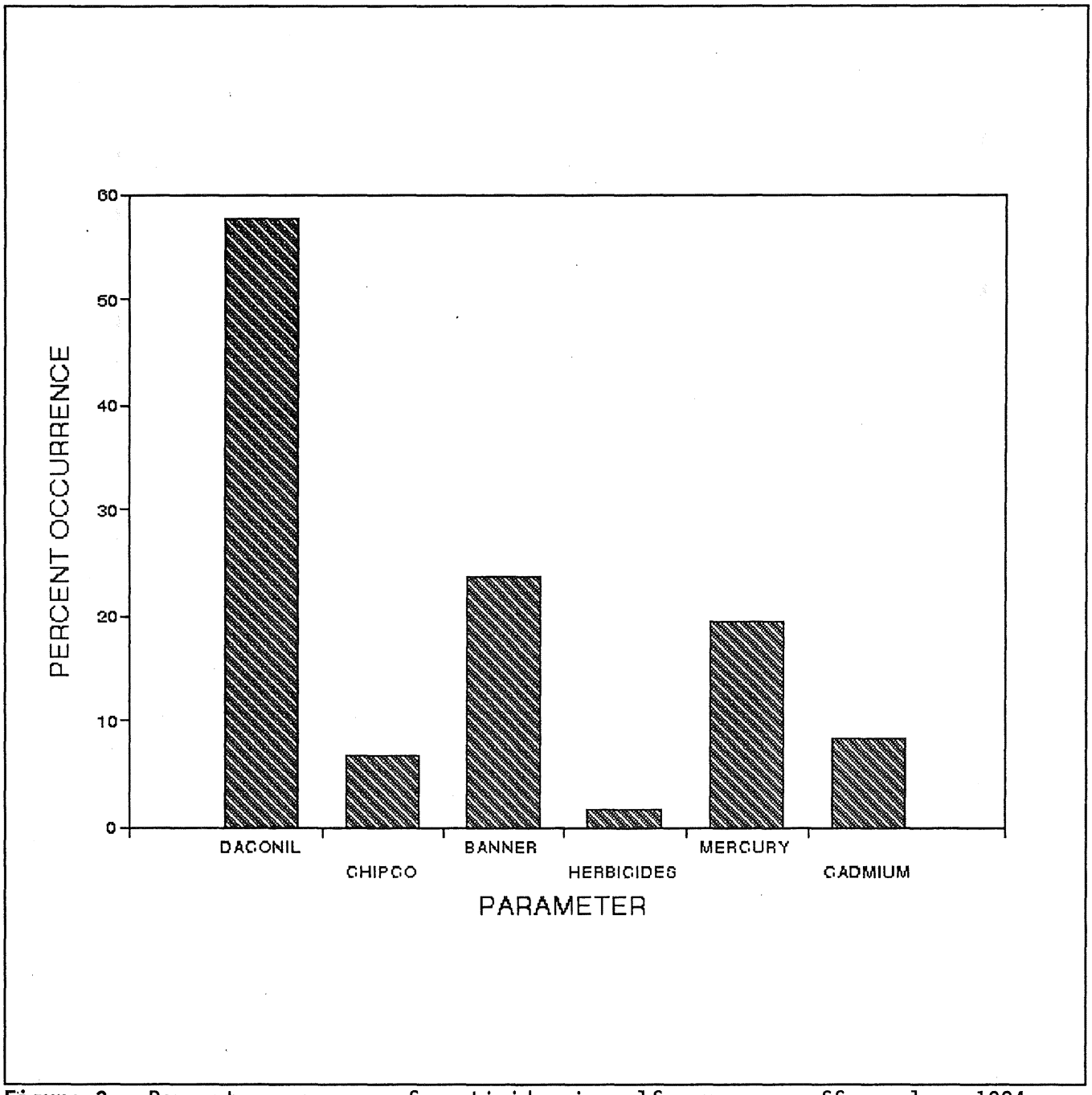

Figure 3. Percent occurrence of pesticides in golf course runoff samples, 1994.

SITE	TOTAL RUNOFF (Ac-Ft)	RUNOFF (%O RAINFALL	TOTAL PHOSPHORUS (LBS)	PHOSPHORUS EXPORT (LBS/ACRE)	TOTAL NITROGEN (LBS)	NITROGEN EXPORT (LBS/ACRE)
BAKER	5.4	0.058	4.1	0.09	22.5	0.48
MEADOWBROOK	16.4	0.078	44.5	0.33	74.4	0.79
WOODHILL	3.3	0.05	3	0.1	18.5	0.6
MINIKAHDA	16.6	0.052	19.4	0.014	587.1	4.28
MEAN		**0.060**		**0.13**		**1.54**
MINIKAHDA IN	548.4	0.208	315.3	0.27	1667.5	1.42
RESIDENTIAL*				0.94		4.8
OPEN*				0.16		0.92

* VALUES FROM BRACH, 1992

Table 9. Total runoff and nutrient export from four golf courses in the TCMA, 1994

FUNGICIDE	BAKER	MEADOWBROOK	WOODHILL	MINIKAHDA	MEAN
CHIPCO (Iprodione)					
APPLIED TO COURSE (LBS)	2.3	16.7	20.55	62.2	25.4
STUDY AREA (ACRES)	47.6	93.7	30.9	137	77.3
TOTAL EXPORTED (LBS)	0.00035	0.002	0.0023	0	0.00116
PERCENT EXPORTED	0.015	0.012	0.011	0	0.0095
EXPORT RATE (LBS/ACRE)	0.00001	0.00002	0.00007	0.00000	0.00003
DACONIL (Chlorothalonil)					
APPLIED TO COURSE (LBS)	9.9	13.9	106.8	574.2	176.2
STUDY AREA (ACRES)	47.6	93.7	30.9	137	77.3
TOTAL EXPORTED (LBS)	0.0041	0.0012	0.0041	0.068	0.0194
PERCENT EXPORTED	0.004	0.01	0.004	0.012	0.0075
EXPORT RATE (LBS/ACRE)	0.00001	0.00002	0.00013	0.00050	0.00017
BANNER (Propiconazole)					
APPLIED TO COURSE (LBS)	0.31	0	6.3	31	9.4
STUDY AREA (ACRES)	47.6	93.7	30.9	137	77.3
TOTAL EXPORTED (LBS)	0.0013	0	0.0039	0	0.0013
PERCENT EXPORTED	0.44	0	0.062	0	0.1255
EXPORT RATE (LBS/ACRE)	0.00003	0.00000	0.00010	0.00000	0.00003

Table 10. Fungicide export from four golf courses in the TCMA, 1994.

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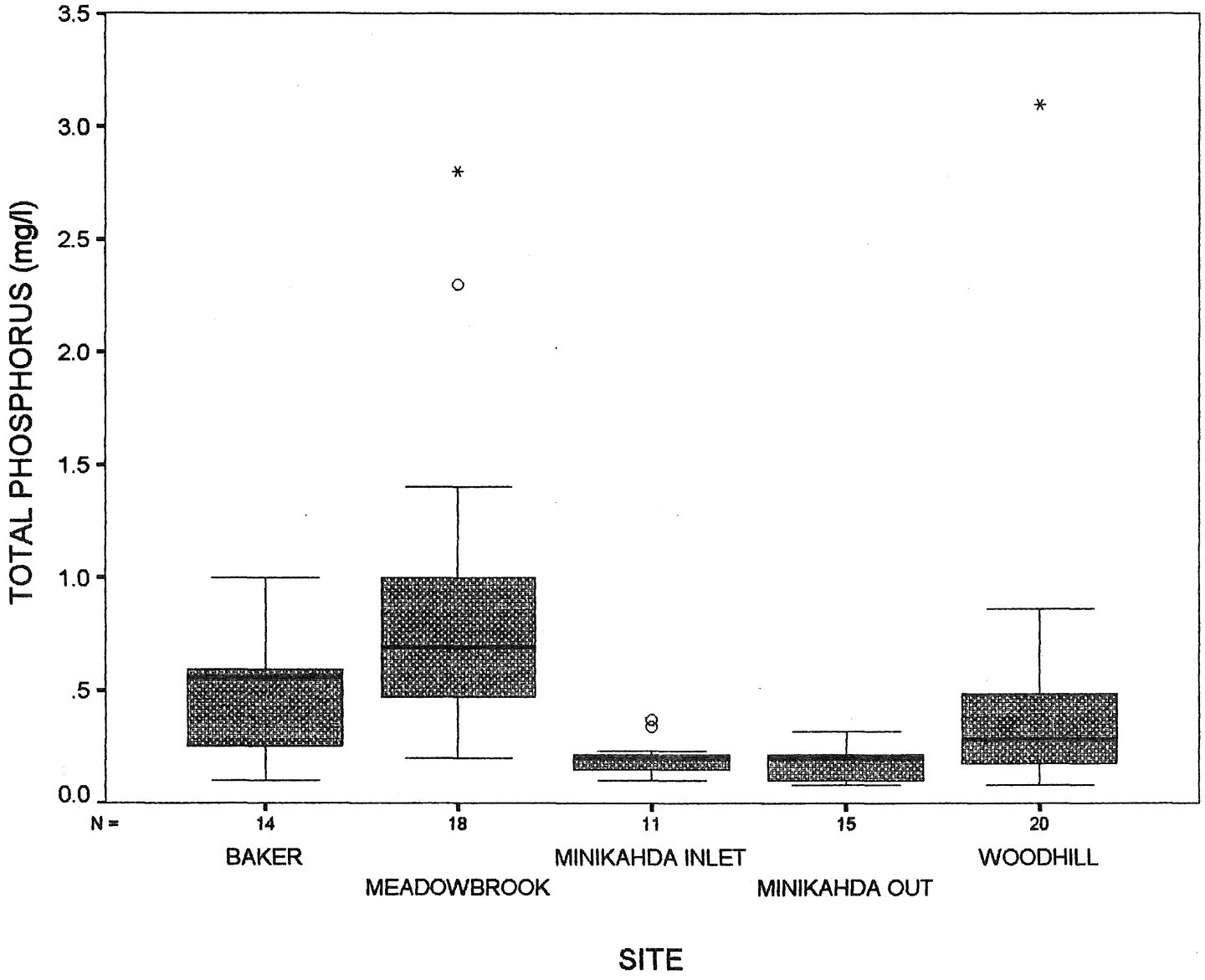
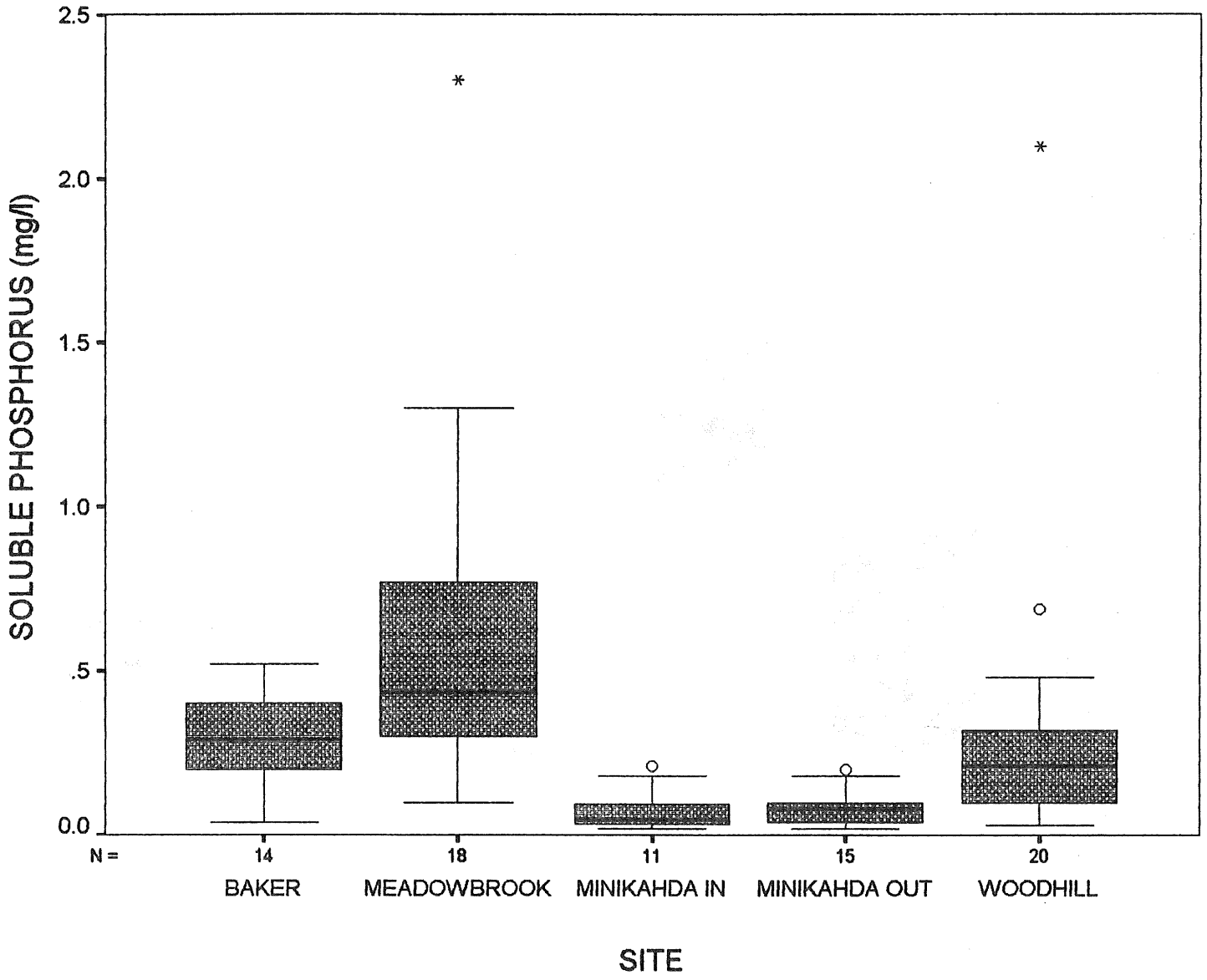
APPENDICES

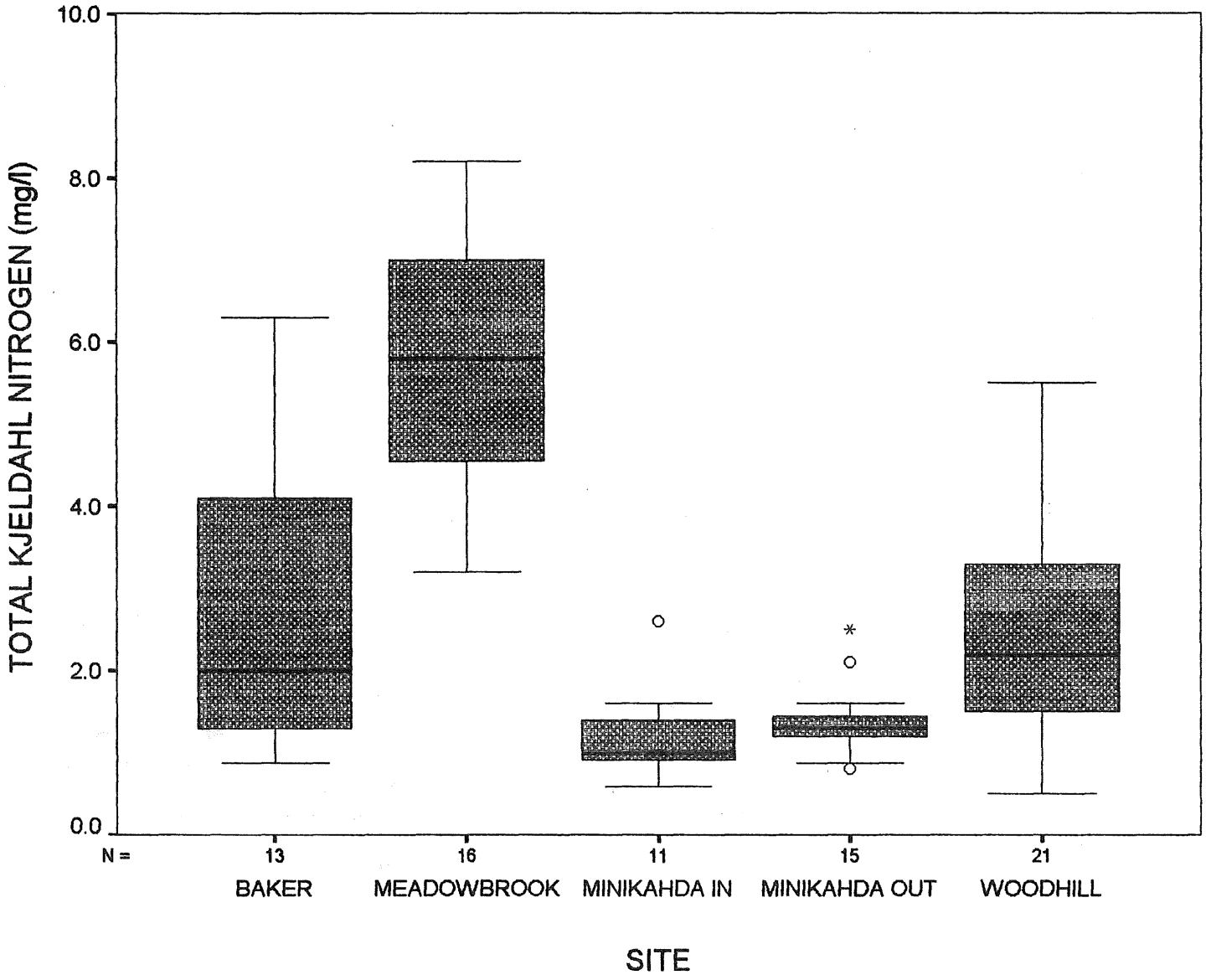
Appendix A. Interquartile boxplots for means of parameters measured in golf course runoff from four sites in 1994.



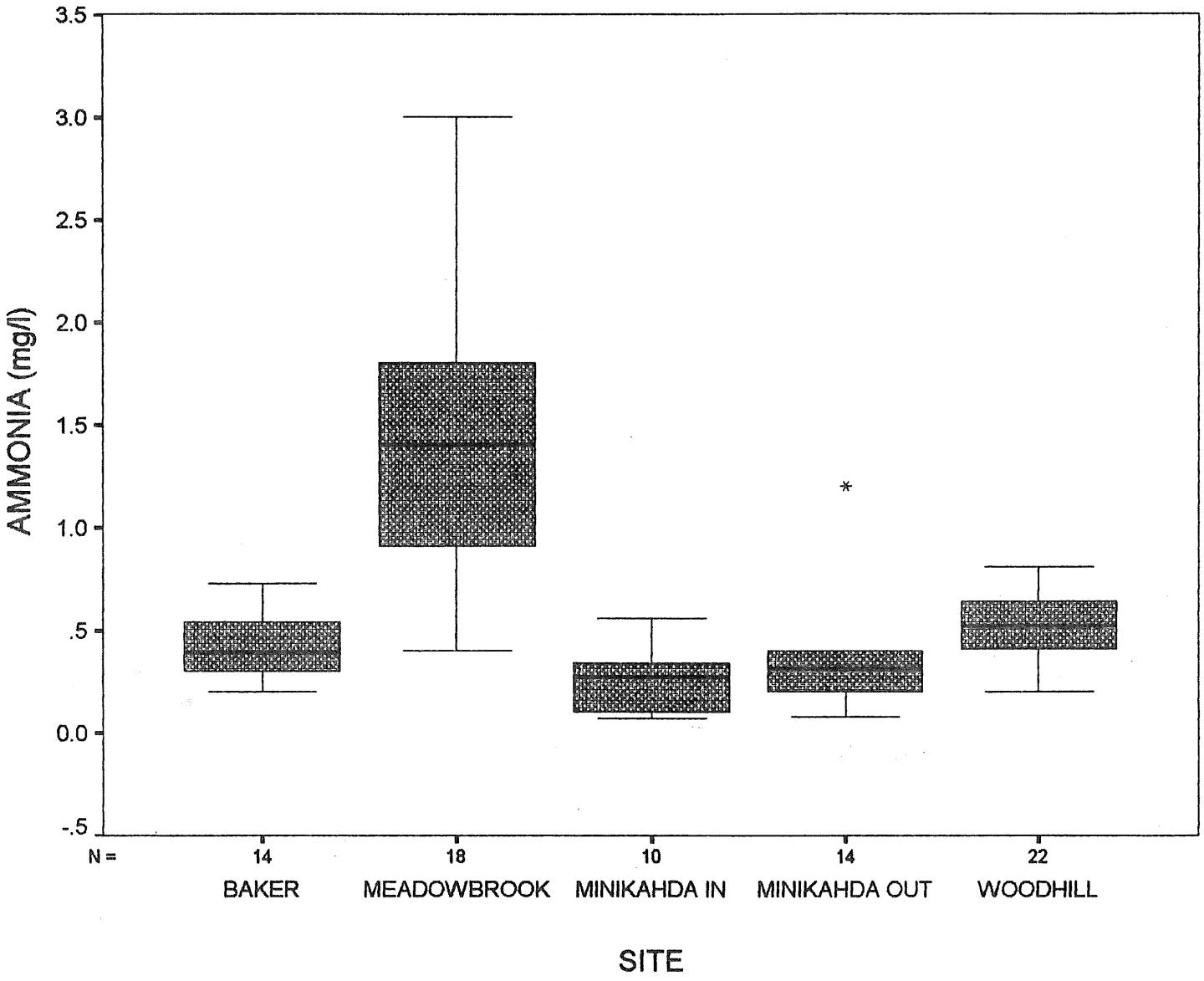
Appendix A1. Total phosphorus interquartile boxplots showing median, 25th and 75th percentiles, and range of data from five sites in the Twin Cities Metropolitan Area, 1994. Asterisks represent data outliers.



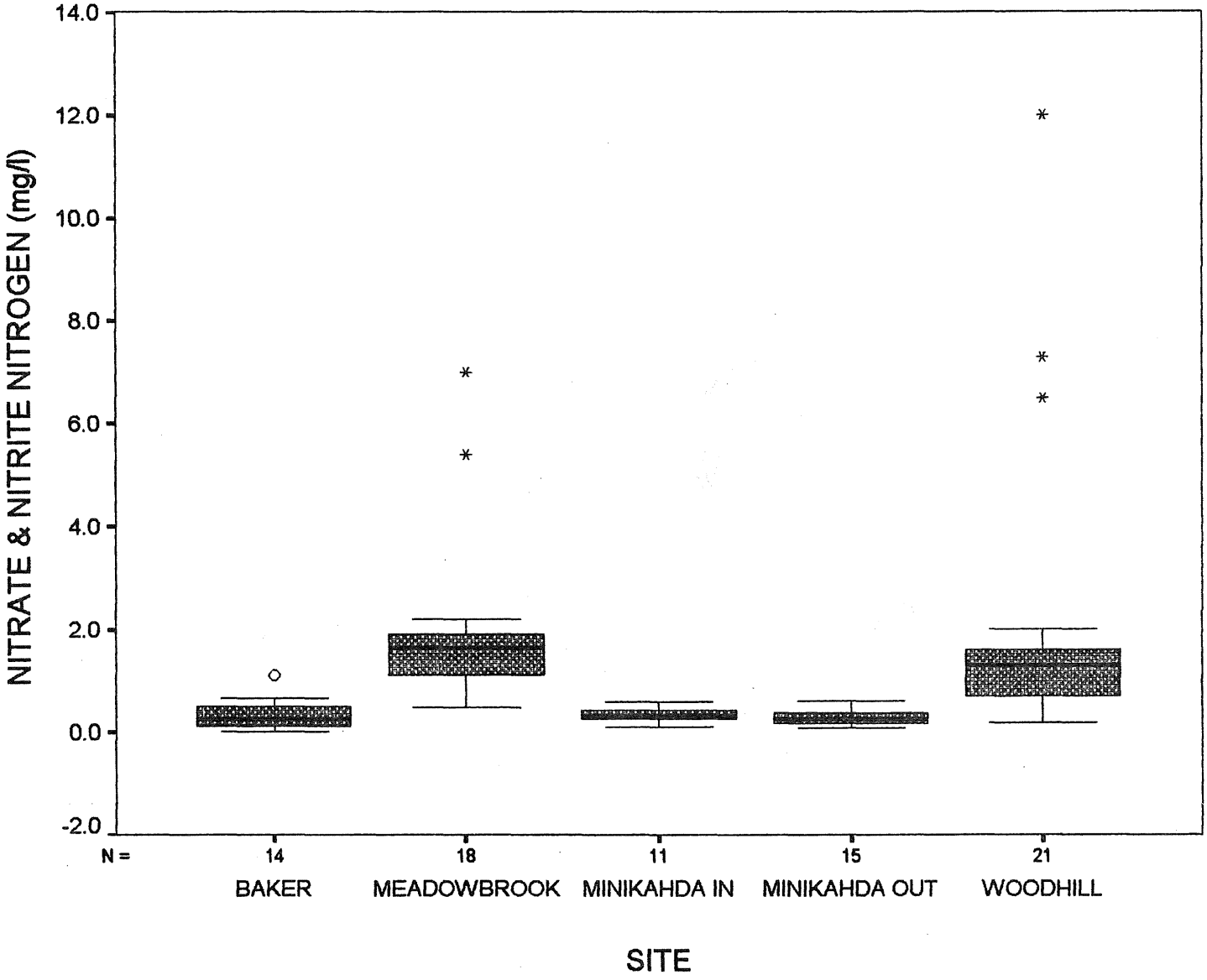
Appendix A2. Soluble reactive phosphorus interquartile boxplots showing median, 25th and 75th percentiles, and range of data from five sites in the Twin Cities Metropolitan Area, 1994. Asterisks represent data outliers.



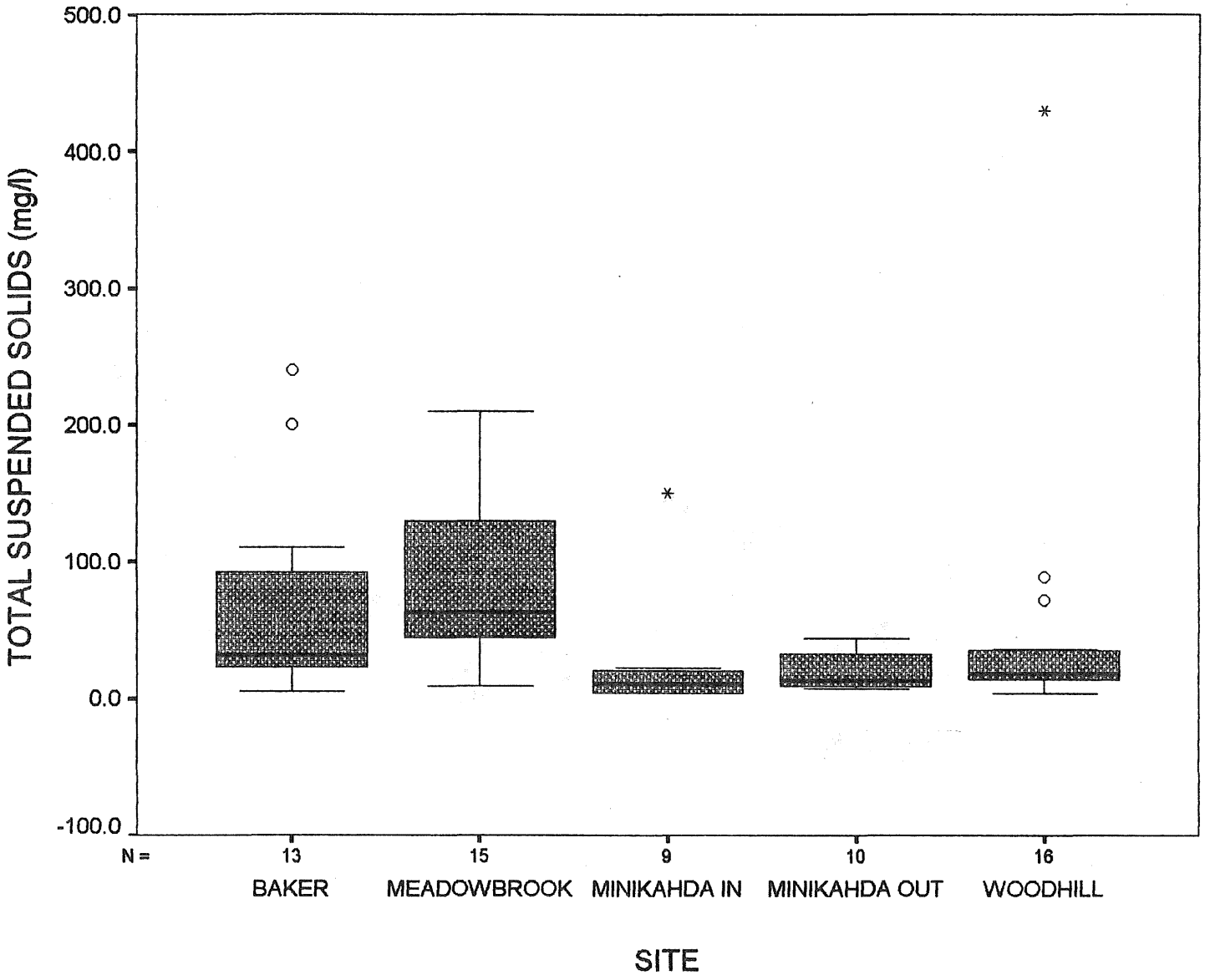
Appendix A3. Total Kjeldahl nitrogen interquartile boxplots showing median, 25th and 75th percentiles, and range of data from five sites in the Twin Cities Metropolitan Area, 1994. Asterisks represent data outliers.



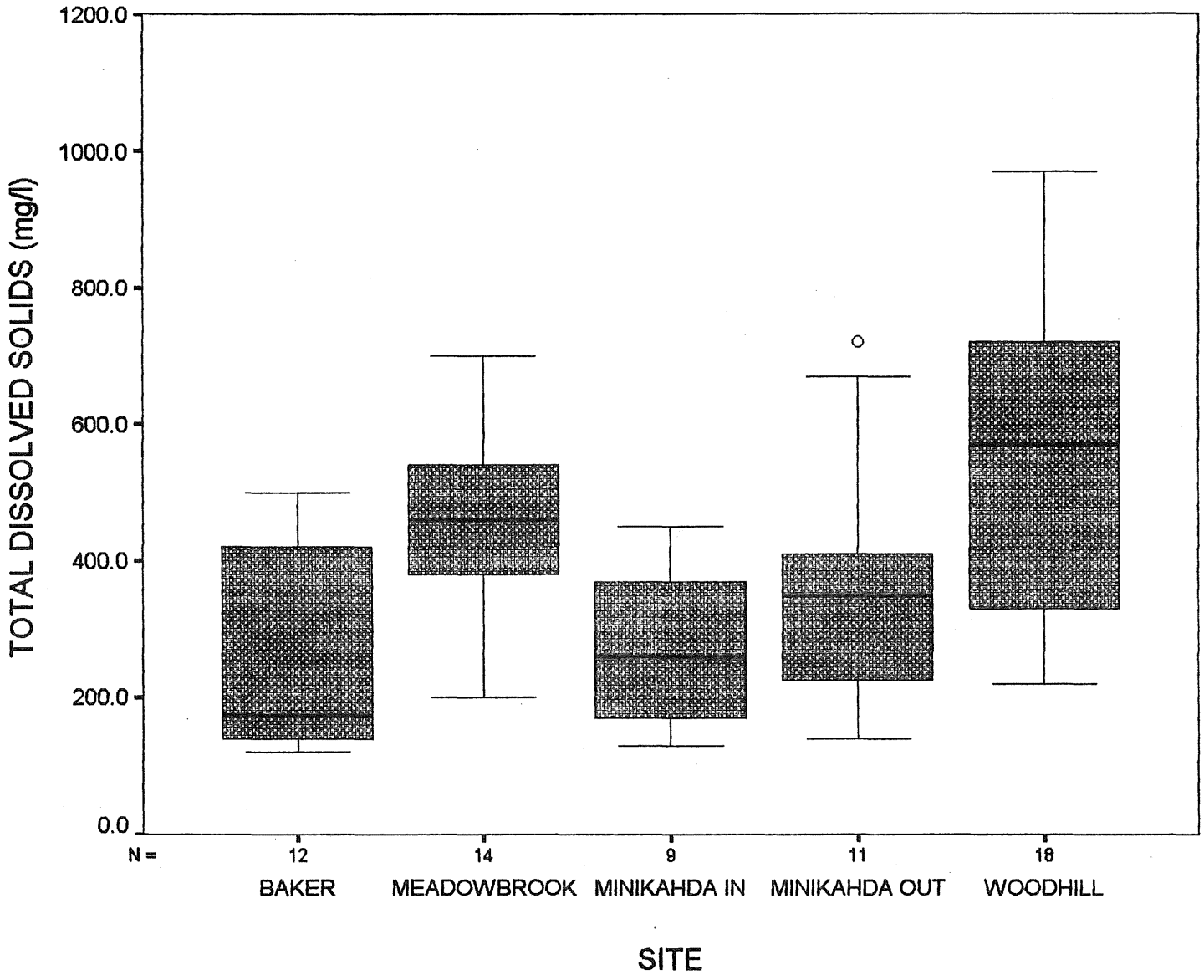
Appendix A4. Ammonia nitrogen interquartile boxplots showing median, 25th and 75th percentiles, and range of data from five sites in the Twin Cities Metropolitan Area, 1994. Asterisks represent data outliers.



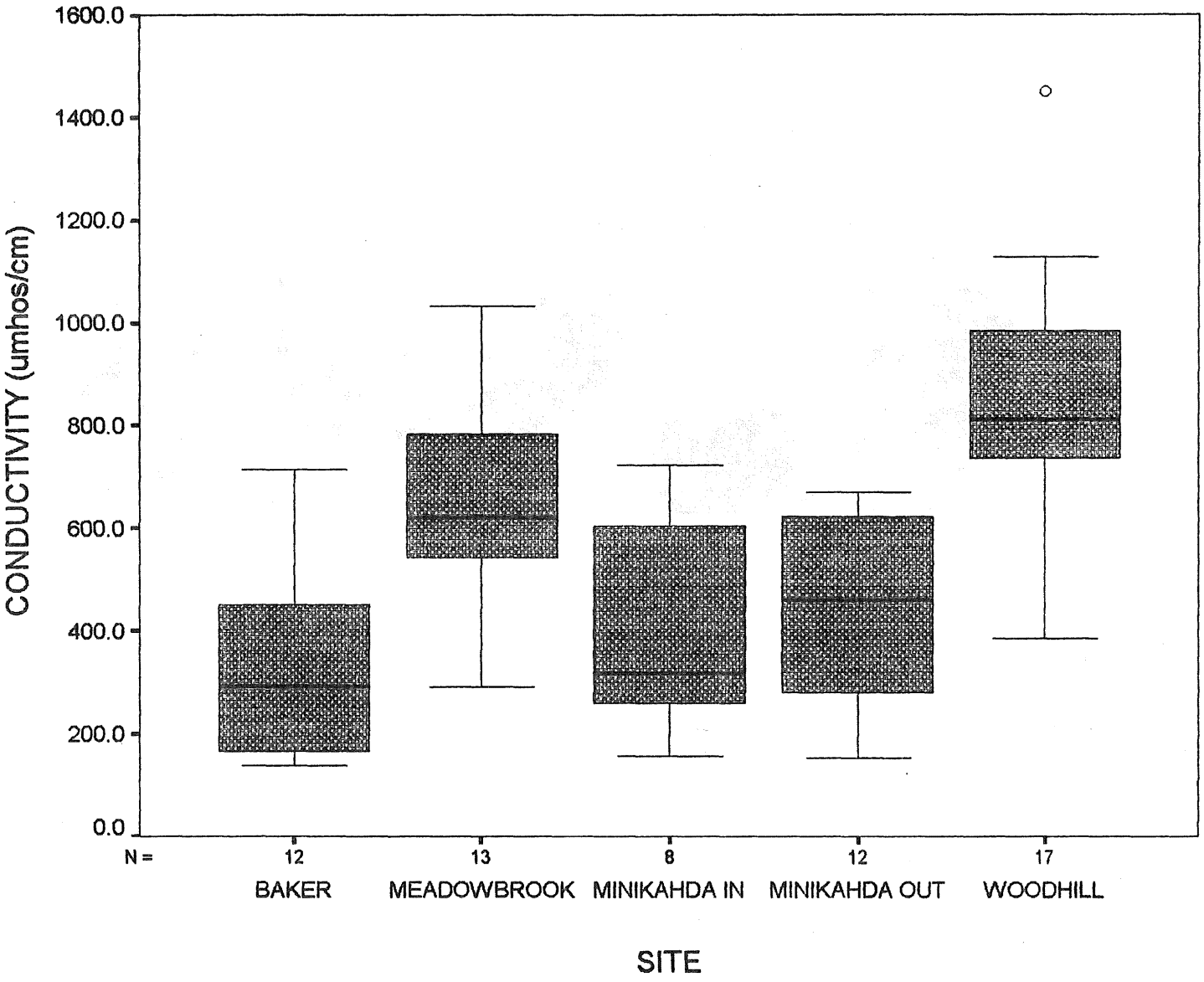
Appendix A5. Nitrate and nitrite nitrogen interquartile boxplots showing median, 25th and 75th percentiles, and range of data from five sites in the Twin Cities Metropolitan Area, 1994. Asterisks represent data outliers.



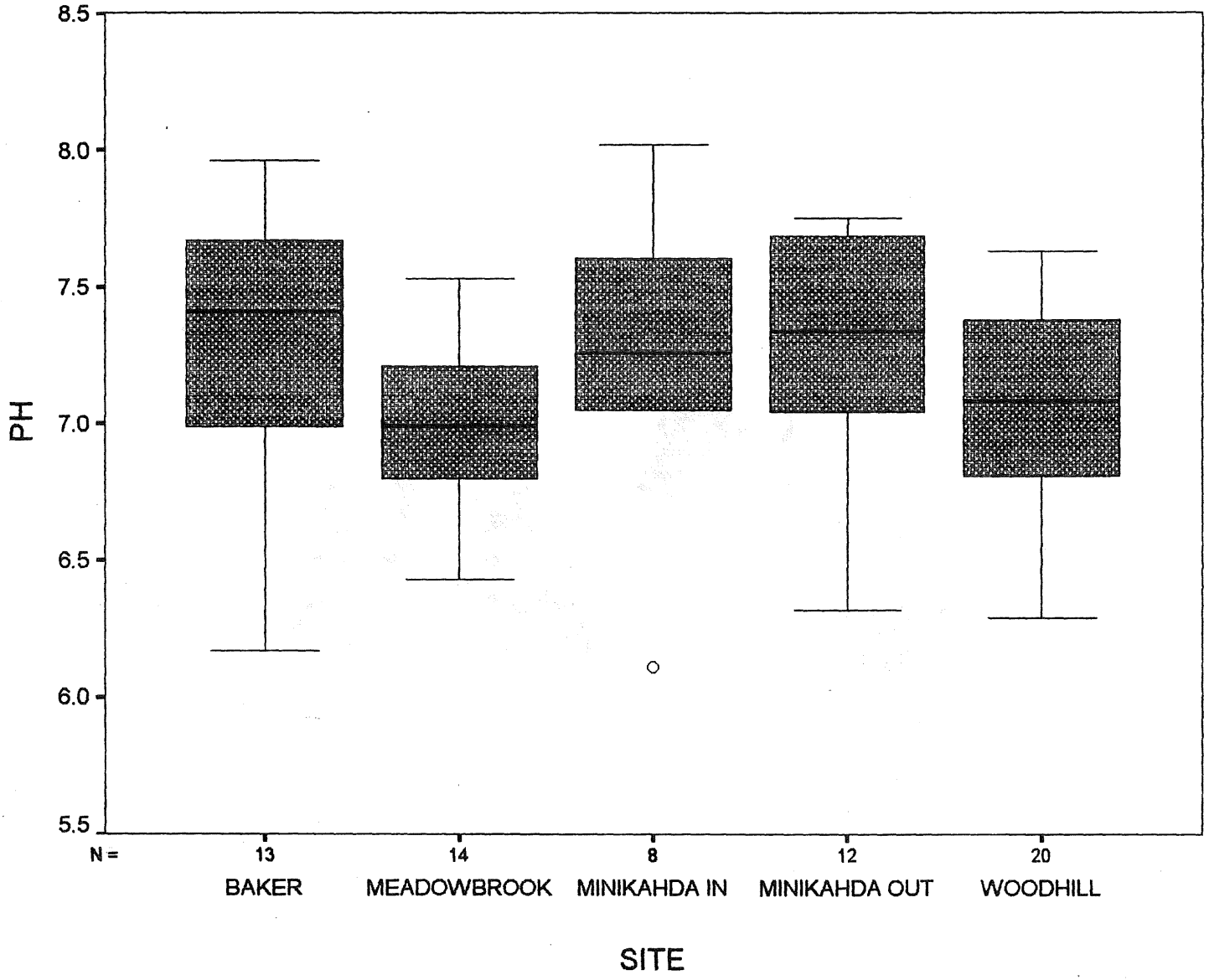
Appendix A6. Total suspended solids interquartile boxplots showing median, 25th and 75th percentiles, and range of data from five sites in the Twin Cities Metropolitan Area, 1994. Asterisks represent data outliers.



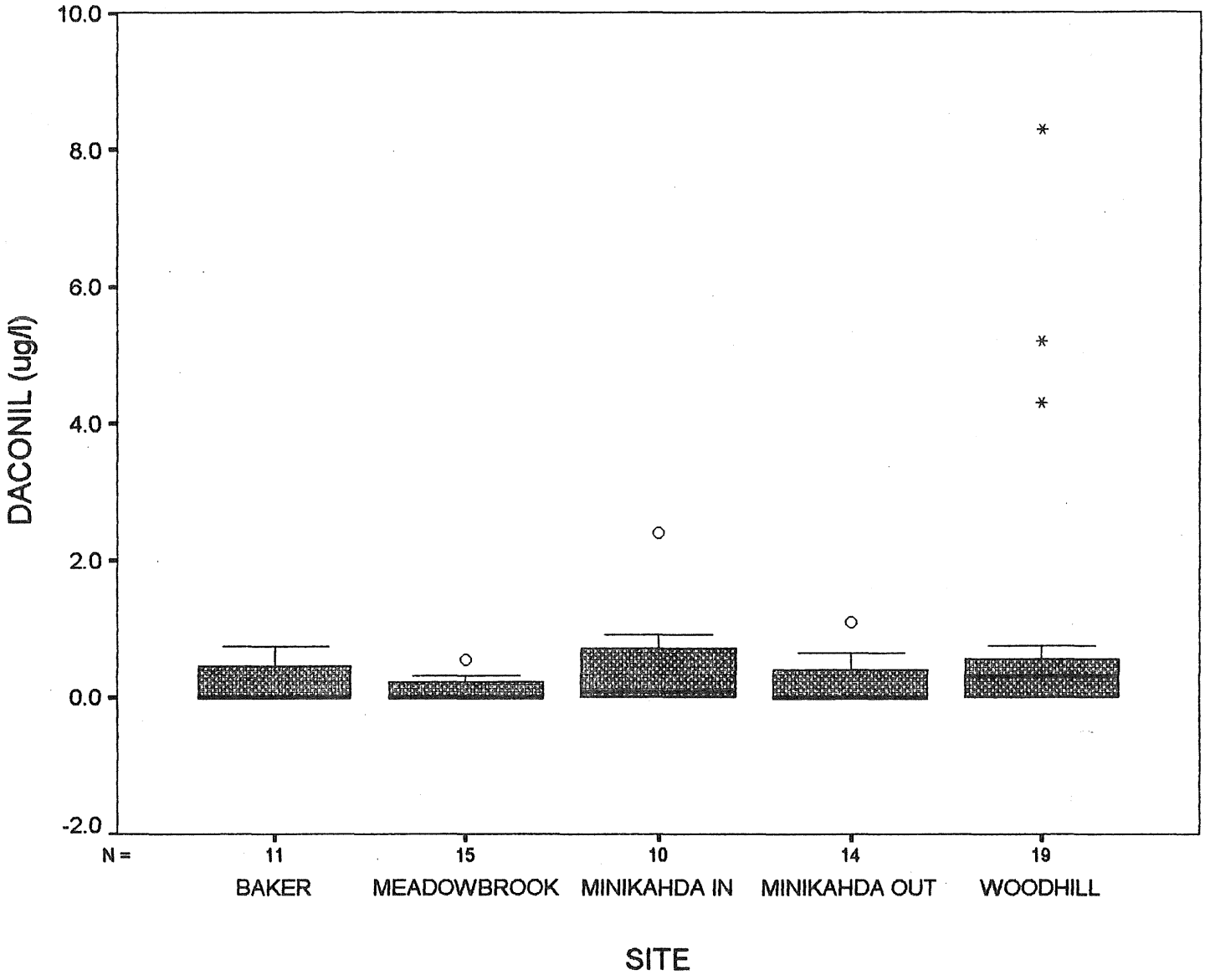
Appendix A7. Total dissolved solids interquartile boxplots showing median, 25th and 75th percentiles, and range of data from five sites in the Twin Cities Metropolitan Area, 1994. Asterisks represent data outliers.



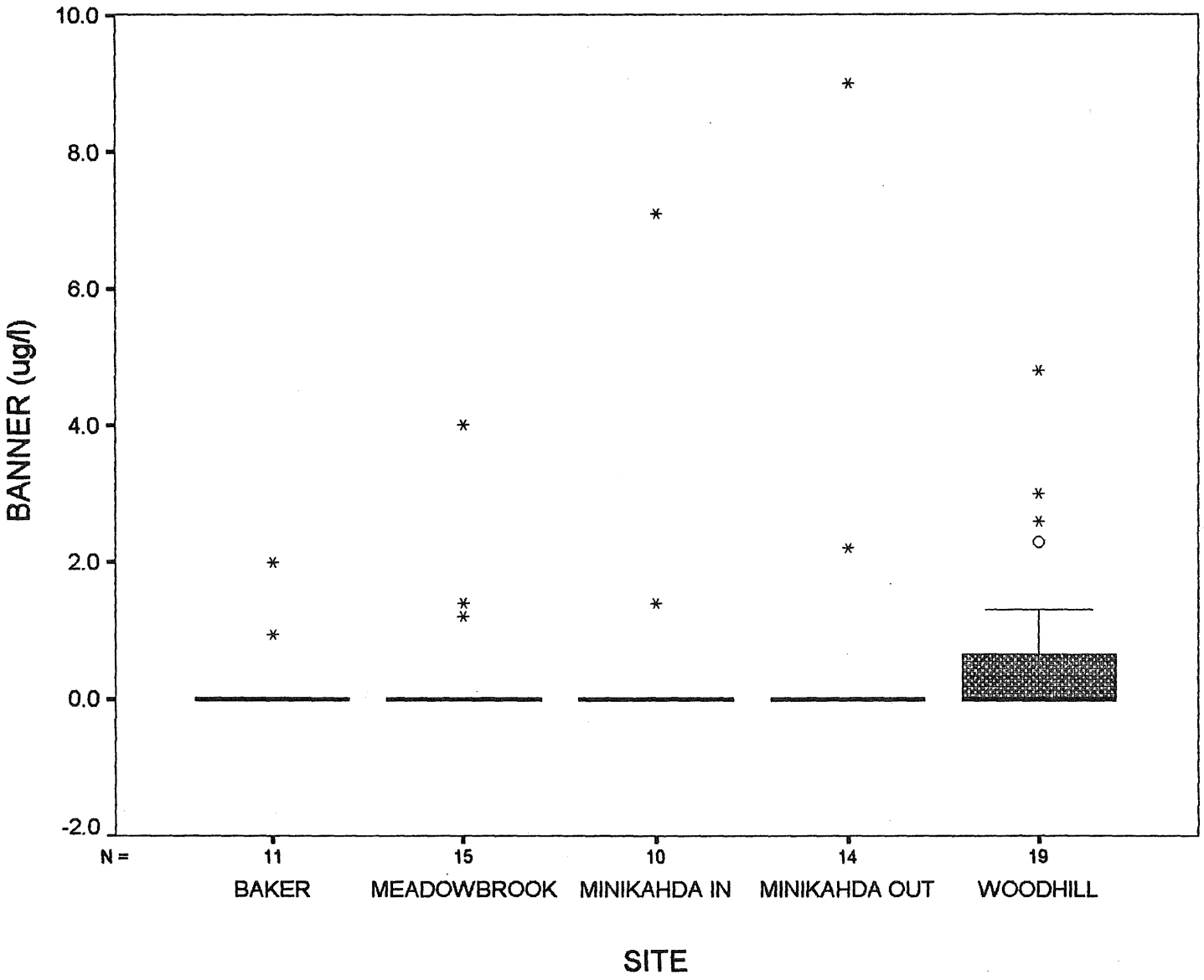
Appendix A8. Conductivity interquartile boxplots showing median, 25th and 75th percentiles, and range of data from five sites in the Twin Cities Metropolitan Area, 1994. Asterisks represent data outliers.



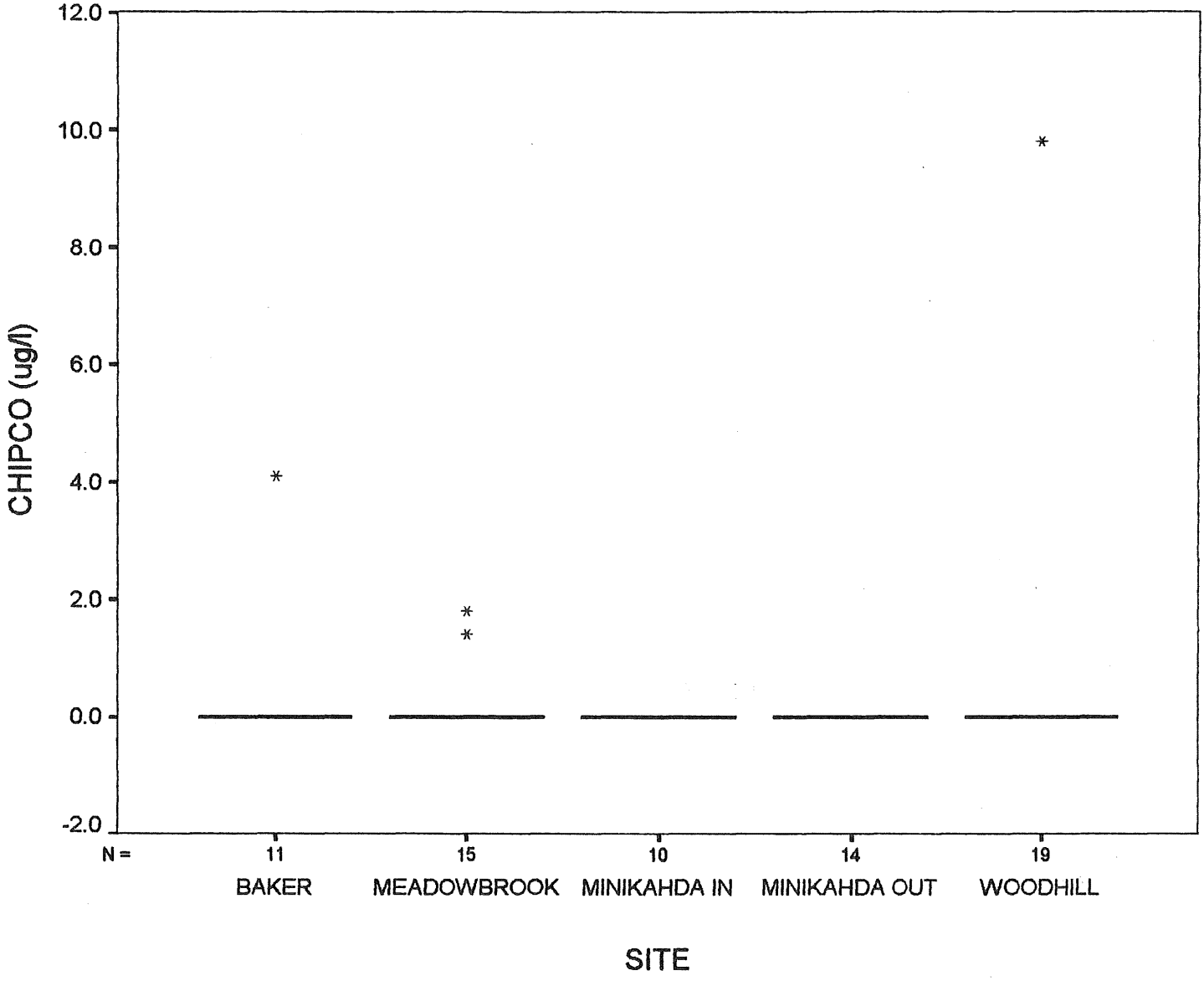
Appendix A9. pH interquartile boxplots showing median, 25th and 75th percentiles, and range of data from five sites in the Twin Cities Metropolitan Area, 1994. Asterisks represent data outliers.



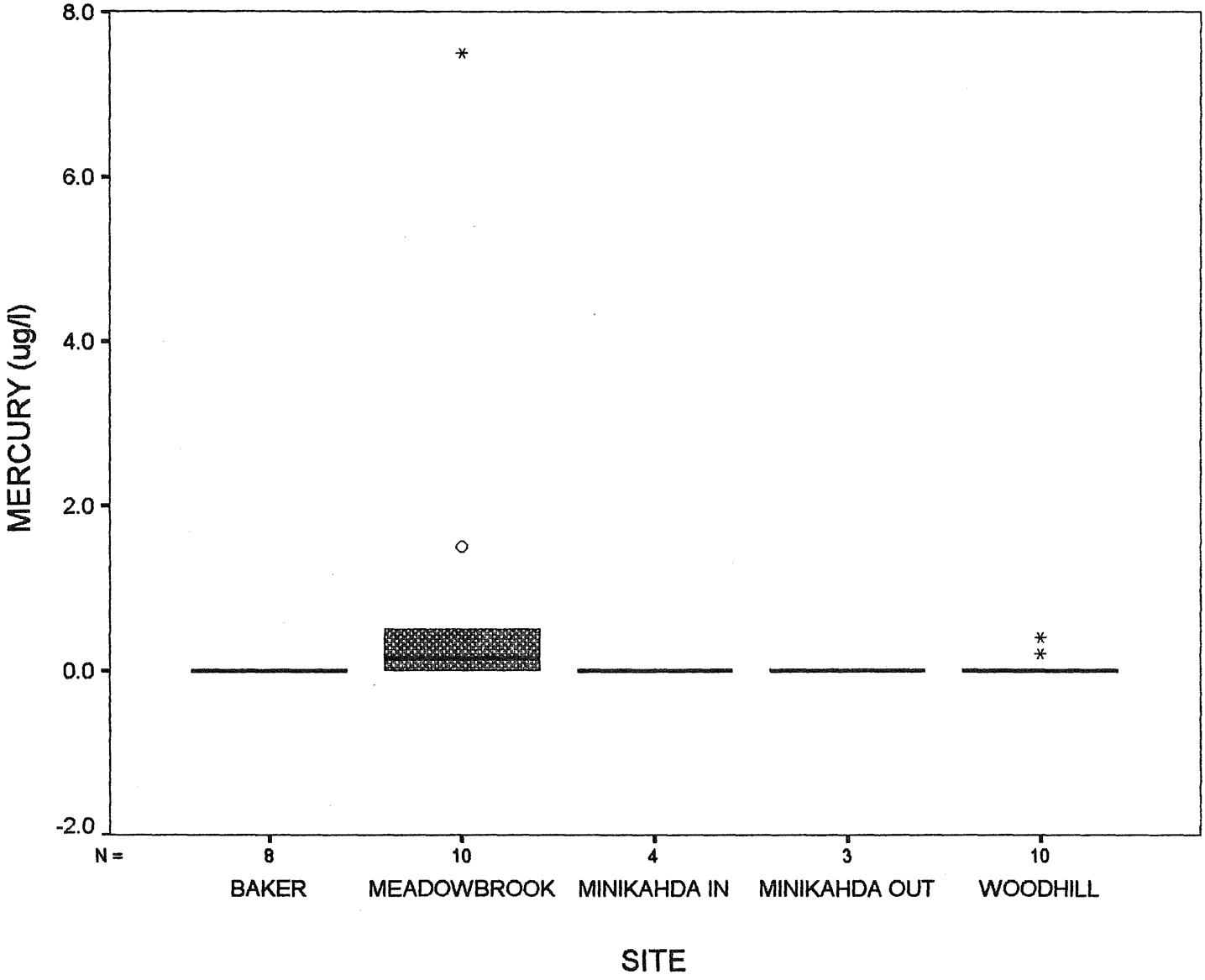
Appendix A10. DACONIL® interquartile boxplots showing median, 25th and 75th percentiles, and range of data from five sites in the Twin Cities Metropolitan Area, 1994. Asterisks represent data outliers.



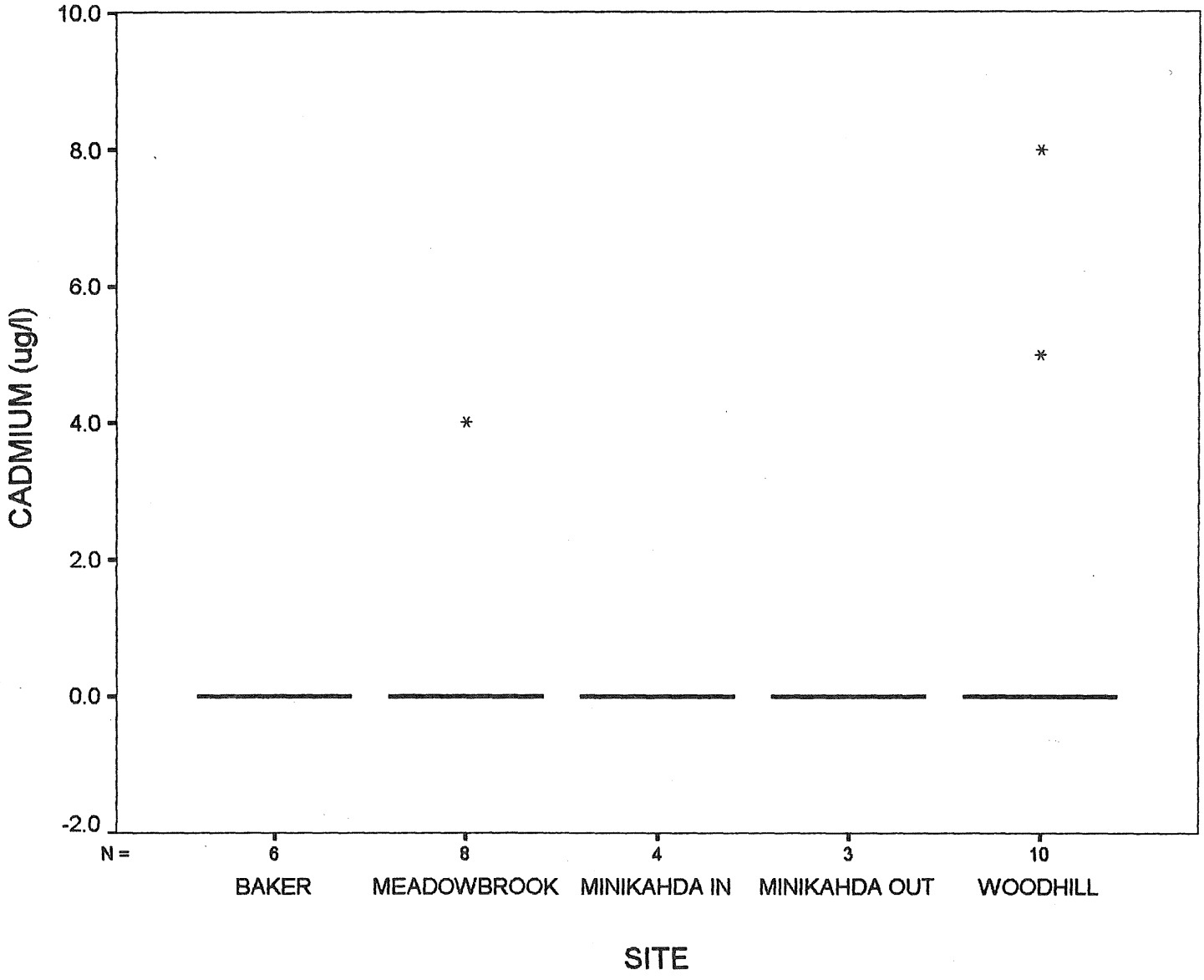
Appendix A11. BANNER® interquartile boxplots showing median, 25th and 75th percentiles, and range of data from five sites in the Twin Cities Metropolitan Area, 1994. Asterisks represent data outliers.



Appendix A12. CHIPCO® interquartile boxplots showing median, 25th and 75th percentiles, and range of data from five sites in the Twin Cities Metropolitan Area, 1994. Asterisks represent data outliers.



Appendix A13. Mercury interquartile boxplots showing median, 25th and 75th percentiles, and range of data from five sites in the Twin Cities Metropolitan Area, 1994. Asterisks represent data outliers.



Appendix A14. Cadmium interquartile boxplots showing median, 25th and 75th percentiles, and range of data from five sites in the Twin Cities Metropolitan Area, 1994. Asterisks represent data outliers.

Appendix B. Concentrations of selected parameters measured in runoff from four golf courses in the Twin Cities Metropolitan Area in 1994.

Appendix B1. Concentration of selected parameters measured in runoff from four golf courses in the Twin Cities Metropolitan Area in 1994.

Location	Date	NH3 (mg/l)	TKN (mg/l)	TP (mg/l)	SRP (mg/l)	NO2-NO3 (mg/L)	TSS (mg/l)	TDS (mg/l)	Dicamba (ug/l)	MCPP (ug/l)	2,4-D (ug/l	Chipco (ug/l)	Daconil (ug/l)	Banner (ug/l)	PCNB	PH	Cond.	Mercury	Cadmium
Baker	25-Apr-94	0.4	2	0.25	0.07	0.01	77	130								7.96	160	0	
Baker	27-Apr-94	0.2	1.3	0.1	0.04	0.01	5	180								7.93	290	0	
Baker	07-Jul-94	0.56	4.1	0.56	0.52	1.1	110	150								7.41	155		
Baker	20-Jul-94	0.64	17	0.73	0.41	0.25	23	160								6.99		0	0
Baker	05-Aug-94	0.49	0.87	0.2	0.02	0.04	5	500										0	0
Baker	05-Aug-94	0.49	0.87	0.24	0.2	0.04	5	500										0	0
Baker	07-Aug-94	0.73	1.3	0.3	0.28	0.21	26	410			12		0.41			7.67	341	0	0
Baker	10-Aug-94	0.32	1.9	0.59	0.32	0.49	200	170				4.1	0.5			7.7	263	0	0
Baker	29-Aug-94	0.39	0.88	0.3	0.3	0.11	60	450								6.17	689	0	0
Baker	14-Sep-94	0.5	4	0.56	0.3	0.65	29	120						0.94		7.63	138	0	0
Baker	22-Sep-94	0.2	6.3	1	0.4	0.56							0.43			7.28	329		
Baker	03-Oct-94	0.2	6	0.55	0.2	0.11	32						0.74			7.54	296		
Baker	07-Oct-94	0.54	5	0.7	0.2	0.24	92	120					0.49	2		6.98	172		
Baker	17-Oct-94	0.3	1.4	0.58	0.48	0.4	240	430								7.14	714		
Baker	18-Oct-94	0.3	2.6	0.24	0.1	0.3	8	370								6.73	562		
Meadowbrook	25-Apr-94	1	6	1.4	1.1	0.47	120	450								7.46		0.3	
Meadowbrook	27-Apr-94	0.91	4.5	0.71	0.44	0.95	87	380								7.21	621	0.4	
Meadowbrook	01-Jun-94	1.3	4	0.47	0.39	7	25	700											
Meadowbrook	21-Jun-94	1.4	4.2	0.4	0.31	0.72													
Meadowbrook	05-Jul-94	1.2	7.4	1	0.78	1.7													
Meadowbrook	07-Jul-94	1.4	6.4	0.72	0.5	2	58	470						4		7.13	622	0.5	0
Meadowbrook	18-Jul-94	1.6	5.8	0.42	0.25	1.1	37	620										0	4
Meadowbrook	22-Jul-94	1.8	4.6	0.2	0.2	1.4										7.53	1034	0	0
Meadowbrook	10-Aug-94	0.9	5.8	0.91	0.77	1.1	180	330								7.45	459	0	0
Meadowbrook	26-Aug-94	2.4	13	2.3	1.3	2.2	150	410								6.43	544	1.5	0
Meadowbrook	30-Aug-94	3	8.2	0.68	0.46	1.9	35	540				1.8	0.17			7.01	785	0	0
Meadowbrook	06-Sep-94	2.9	6.9	0.5	0.44	1.6	63	240				1.4	0.21			6.88	881	0	0
Meadowbrook	14-Sep-94	1.6	9.5	2.8	2.3	1.9	210	390								7.14	595	7.5	0
Meadowbrook	21-Sep-94	2.2	7.5	1.2	0.1	1.7	52	470					0.55	1.4		6.79	732		
Meadowbrook	22-Sep-94	1.6	5.8	0.4	0.25	1.1	9	560					0.23			6.73	826		
Meadowbrook	03-Oct-94	0.81	5.6	0.7	0.43	1	56	8								6.93	466		
Meadowbrook	07-Oct-94	0.65	7.1	0.61	0.3	5.4	140	500					0.31			6.8	739		
Meadowbrook	19-Oct-94	0.4	3.2	0.63	0.41	1.8	84	200					0.28	1.2		6.97	292		
Minikahda in	01-Jun-94	0.07	0.98	0.2	0.1	0.45	4	340											
Minikahda in	21-Jun-94	0.3	1.6	0.34	0.21	0.13								7.1					
Minikahda in	08-Aug-94	0.56	0.85	0.1	0.05	0.09	10	420					0.28			8.02	721	0	0
Minikahda in	10-Aug-94	0.34	2.6	0.37	0.18	0.27	150	210								7.64	353	0	0
Minikahda in	26-Aug-94	0.2	1.1	0.23	0.09	0.31	20	170					0.17	1.4		6.11	240	0	0
Minikahda in	12-Sep-94		1.5	0.2	0.03	0.59	4	260			4.5		0.72			7.57	489	0	0
Minikahda in	21-Sep-94	0.1	0.68	0.1	0.05	0.31	8	130					2.4						
Minikahda in	30-Sep-94	0.5	1.3	0.1	0.02	0.24	4	450					0.91			7.05	724		
Minikahda in	03-Oct-94	0.24	0.98	0.2	0.03	0.46										7.43	284		
Minikahda in	07-Oct-94	0.3	1	0.2	0.04	0.28	22	130								7.09	281		
Minikahda in	18-Oct-94	0.1	0.59	0.2	0.04	0.4	16	370								7.05	158		
Minikahda out	01-Jun-94	0.08	1.2	0.29	0.18	0.24	9	320											
Minikahda out	21-Jun-94	0.4	1.4	0.32	0.2	0.08								9					
Minikahda out	07-Jul-94	0.2	1.5	0.23	0.2	0.46								2.2		7.68	349		
Minikahda out	08-Aug-94	1.2	2.1	0.08	0.06	0.17	740	400								6.79	672	0	0
Minikahda out	10-Aug-94	0.33	1.6	0.1	0.08	0.32	44	350								7.71	593	0	0
Minikahda out	26-Aug-94	0.2	0.92	0.2	0.08	0.37	11	140								6.32	199	0	0
Minikahda out	06-Sep-94	0.4	1.2	0.22	0.1	0.09	10	670					0.4			7.49	388		
Minikahda out	12-Sep-94		2.5	0.21	0.1	0.16	7	300					0.66			7.75	536		
Minikahda out	14-Sep-94	0.3	1.3	0.2	0.1	0.39	17	140								7.69	255		
Minikahda out	21-Sep-94	0.2	0.87	0.2	0.06	0.55	15	720					1.1						
Minikahda out	02-Oct-94	0.4	1.4	0.1	0.02	0.24	8	420								7.19	668		
Minikahda out	03-Oct-94	0.4	1.2	0.1	0.02	0.24										7.58	592		
Minikahda out	07-Oct-94	0.3	1.2	0.1	0.04	0.2	33	150								7.11	308		
Minikahda out	17-Oct-94	0.4	1.4	0.2	0.04	0.1	35	350								6.98	655		
Minikahda out	18-Oct-94	0.1	0.81	0.1	0.03	0.6							0.46			7.13	154		
Woodhill	25-Apr-94	0.66	16	12	9.3	0.47	1300	300								7.55	385		
Woodhill	27-Apr-94	0.5	1.8	0.34	0.29	1.3	34	470								7.52	768		
Woodhill	01-Jun-94	0.5	5.5	6.6	6.6	1.6	430	950											
Woodhill	21-Jun-94	0.4	2.3	0.29	0.2	1.1													
Woodhill	05-Jul-94	0.63	3.5	0.24	0.2	7.3													
Woodhill	07-Jul-94	0.61	0.5	0.15	0.1	6.5	4	600								7.06	813	0.4	0
Woodhill	20-Jul-94	0.5	3.9	0.79	0.48	1.4	21	220					4.3	3		7.11	784	0.2	0
Woodhill	22-Jul-94	0.64	1.5	0.1	0.07	1.3						9.8		4.8		7.34		0	8
Woodhill	08-Aug-94	0.73	1.4	0.1	0.1	0.37	13	690								7.56		0	0
Woodhill	10-Aug-94	0.78	2.2	0.27	0.22	0.7	14	720					0.31			7.63	529	0	0
Woodhill	24-Aug-94	0.81	1.2	0.08	0.03	0.18	8	970								7.23	985	0	0
Woodhill	26-Aug-94	0.41	3.3	0.5	0.3	1.1	18	550					0.2			6.29	1129	0	0
Woodhill	30-Aug-94	0.5	2.8	0.42	0.27	1.1	26	580			0		0.38			6.74	738		
Woodhill	06-Sep-94	0.64	1.6	0.2	0.1	0.59	18	230					0.43			7.42	799	0	5
Woodhill	14-Sep-94	0.54	1.5	0.1	0.1	0.73	8	720					0.28			6.8	1014	0	0
Woodhill	21-Sep-94	0.57	3.4	0.47	0.34	2	18	560					0.35			7.1	1038	0	0
Woodhill	22-Sep-94	0.5	2.3	0.28	0.2	1.6							8.3	2.3		6.94	822		
Woodhill	02-Oct-94	0.68	1.4	0.22	0.2	0.48	15	760					0.76			7.2	823		
Woodhill	03-Oct-94	0.2	2.2	0.56	0.23	1.9	36	330					5.2			6.8			
Woodhill	07-Oct-94	0.2	4.5	3.1	2.1	12	1800	300								7.01	625		
Woodhill	17-Oct-94	0.3	1.2	0.44	0.36		72	850					0.37	1.3		6.83	453		
Woodhill	18-Oct-94	0.2	2.5	0.86	0.69	1.4	89	510								6.57	1452		
													0.7	2.6		6.82	814		

Appendix B1. Concentration of selected parameters measured in runoff from four golf courses in the Twin Cities Metropolitan Area in 1994.

Location	Date	NH3 (mg/l)	TKN (mg/l)	TP (mg/l)	SRP (mg/l)	NO2-NO3 (mg/L)	TSS (mg/l)	TDS (mg/l)	Dicamba (ug/l)	MCPP (ug/l)	2,4-D (ug/l	Chipco (ug/l)	Daconil (ug/l)	Banner (ug/l)	PCNB	PH	Cond.	Mercury	Cadmium
Baker	25-Apr-94	0.4	2	0.25	0.07	0.01	77	130								7.96	160	0	
Baker	27-Apr-94	0.2	1.3	0.1	0.04	0.01	5	180								7.93	290	0	
Baker	07-Jul-94	0.56	4.1	0.56	0.52	1.1	110	150								7.41	155		
Baker	20-Jul-94	0.64	17	0.73	0.41	0.25	23	160								6.99		0	0
Baker	05-Aug-94	0.49	0.87	0.2	0.02	0.04	5	500										0	0
Baker	05-Aug-94	0.49	0.87	0.24	0.2	0.04	5	500										0	0
Baker	07-Aug-94	0.73	1.3	0.3	0.28	0.21	26	410			12		0.41			7.67	341	0	0
Baker	10-Aug-94	0.32	1.9	0.59	0.32	0.49	200	170				4.1	0.5			7.7	263	0	0
Baker	29-Aug-94	0.39	0.88	0.3	0.3	0.11	60	450								6.17	689	0	0
Baker	14-Sep-94	0.5	4	0.56	0.3	0.65	29	120						0.94		7.63	138	0	0
Baker	22-Sep-94	0.2	6.3	1	0.4	0.56							0.43			7.28	329		
Baker	03-Oct-94	0.2	6	0.55	0.2	0.11	32						0.74			7.54	296		
Baker	07-Oct-94	0.54	5	0.7	0.2	0.24	92	120					0.49	2		6.98	172		
Baker	17-Oct-94	0.3	1.4	0.58	0.48	0.4	240	430								7.14	714		
Baker	18-Oct-94	0.3	2.6	0.24	0.1	0.3	8	370								6.73	562		
Meadowbrook	25-Apr-94	1	6	1.4	1.1	0.47	120	450								7.46		0.3	
Meadowbrook	27-Apr-94	0.91	4.5	0.71	0.44	0.95	87	380								7.21	621	0.4	
Meadowbrook	01-Jun-94	1.3	4	0.47	0.39	7	25	700											
Meadowbrook	21-Jun-94	1.4	4.2	0.4	0.31	0.72													
Meadowbrook	05-Jul-94	1.2	7.4	1	0.78	1.7													
Meadowbrook	07-Jul-94	1.4	6.4	0.72	0.5	2	58	470						4		7.13	622	0.5	0
Meadowbrook	18-Jul-94	1.6	5.8	0.42	0.25	1.1	37	620										0	4
Meadowbrook	22-Jul-94	1.8	4.6	0.2	0.2	1.4										7.53	1034	0	0
Meadowbrook	10-Aug-94	0.9	5.8	0.91	0.77	1.1	180	330								7.45	459	0	0
Meadowbrook	26-Aug-94	2.4	13	2.3	1.3	2.2	150	410								6.43	544	1.5	0
Meadowbrook	30-Aug-94	3	8.2	0.68	0.46	1.9	35	540				1.8	0.17			7.01	785	0	0
Meadowbrook	06-Sep-94	2.9	6.9	0.5	0.44	1.6	63	240				1.4	0.21			6.88	881	0	0
Meadowbrook	14-Sep-94	1.6	9.5	2.8	2.3	1.9	210	390								7.14	595	7.5	0
Meadowbrook	21-Sep-94	2.2	7.5	1.2	0.1	1.7	52	470					0.55	1.4		6.79	732		
Meadowbrook	22-Sep-94	1.6	5.8	0.4	0.25	1.1	9	560					0.23			6.73	826		
Meadowbrook	03-Oct-94	0.81	5.6	0.7	0.43	1	56	8								6.93	466		
Meadowbrook	07-Oct-94	0.65	7.1	0.61	0.3	5.4	140	500					0.31			6.8	739		
Meadowbrook	19-Oct-94	0.4	3.2	0.63	0.41	1.8	84	200					0.28	1.2		6.97	292		
Minikahda in	01-Jun-94	0.07	0.98	0.2	0.1	0.45	4	340											
Minikahda in	21-Jun-94	0.3	1.6	0.34	0.21	0.13								7.1					
Minikahda in	08-Aug-94	0.56	0.85	0.1	0.05	0.09	10	420					0.28			8.02	721	0	0
Minikahda in	10-Aug-94	0.34	2.6	0.37	0.18	0.27	150	210								7.64	353	0	0
Minikahda in	26-Aug-94	0.2	1.1	0.23	0.09	0.31	20	170					0.17	1.4		6.11	240	0	0
Minikahda in	12-Sep-94		1.5	0.2	0.03	0.59	4	260			4.5		0.72			7.57	489	0	0
Minikahda in	21-Sep-94	0.1	0.68	0.1	0.05	0.31	8	130					2.4						
Minikahda in	30-Sep-94	0.5	1.3	0.1	0.02	0.24	4	450					0.91			7.05	724		
Minikahda in	03-Oct-94	0.24	0.98	0.2	0.03	0.46										7.43	284		
Minikahda in	07-Oct-94	0.3	1	0.2	0.04	0.28	22	130								7.09	281		
Minikahda in	18-Oct-94	0.1	0.59	0.2	0.04	0.4	16	370								7.05	158		
Minikahda out	01-Jun-94	0.08	1.2	0.29	0.18	0.24	9	320											
Minikahda out	21-Jun-94	0.4	1.4	0.32	0.2	0.08								9					
Minikahda out	07-Jul-94	0.2	1.5	0.23	0.2	0.46								2.2		7.68	349		
Minikahda out	08-Aug-94	1.2	2.1	0.08	0.06	0.17	740	400								6.79	672	0	0
Minikahda out	10-Aug-94	0.33	1.6	0.1	0.08	0.32	44	350								7.71	593	0	0
Minikahda out	26-Aug-94	0.2	0.92	0.2	0.08	0.37	11	140								6.32	199	0	0
Minikahda out	06-Sep-94	0.4	1.2	0.22	0.1	0.09	10	670					0.4			7.49	388		
Minikahda out	12-Sep-94		2.5	0.21	0.1	0.16	7	300					0.66			7.75	536		
Minikahda out	14-Sep-94	0.3	1.3	0.2	0.1	0.39	17	140								7.69	255		
Minikahda out	21-Sep-94	0.2	0.87	0.2	0.06	0.55	15	720					1.1						
Minikahda out	02-Oct-94	0.4	1.4	0.1	0.02	0.24	8	420								7.19	668		
Minikahda out	03-Oct-94	0.4	1.2	0.1	0.02	0.24										7.58	592		
Minikahda out	07-Oct-94	0.3	1.2	0.1	0.04	0.2	33	150								7.11	308		
Minikahda out	17-Oct-94	0.4	1.4	0.2	0.04	0.1	35	350								6.98	655		
Minikahda out	18-Oct-94	0.1	0.81	0.1	0.03	0.6							0.46			7.13	154		
Woodhill	25-Apr-94	0.66	16	12	9.3	0.47	1300	300								7.55	385		
Woodhill	27-Apr-94	0.5	1.8	0.34	0.29	1.3	34	470								7.52	768		
Woodhill	01-Jun-94	0.5	5.5	6.6	6.6	1.6	430	950											
Woodhill	21-Jun-94	0.4	2.3	0.29	0.2	1.1													
Woodhill	05-Jul-94	0.63	3.5	0.24	0.2	7.3													
Woodhill	07-Jul-94	0.61	0.5	0.15	0.1	6.5	4	600								7.06	813	0.4	0
Woodhill	20-Jul-94	0.5	3.9	0.79	0.48	1.4	21	220					4.3	3		7.11	784	0.2	0
Woodhill	22-Jul-94	0.64	1.5	0.1	0.07	1.3						9.8		4.8		7.34		0	8
Woodhill	08-Aug-94	0.73	1.4	0.1	0.1	0.37	13	690								7.56		0	0
Woodhill	10-Aug-94	0.78	2.2	0.27	0.22	0.7	14	720					0.31			7.63	529	0	0
Woodhill	24-Aug-94	0.81	1.2	0.08	0.03	0.18	8	970								7.23	985	0	0
Woodhill	26-Aug-94	0.41	3.3	0.5	0.3	1.1	18	550					0.2			6.29	1129	0	0
Woodhill	30-Aug-94	0.5	2.8	0.42	0.27	1.1	26	580			0		0.38			6.74	738		
Woodhill	06-Sep-94	0.64	1.6	0.2	0.1	0.59	18	230					0.43			7.42	799	0	5
Woodhill	14-Sep-94	0.54	1.5	0.1	0.1	0.73	8	720					0.28			6.8	1014	0	0
Woodhill	21-Sep-94	0.57	3.4	0.47	0.34	2	18	560					0.35			7.1	1038	0	0
Woodhill	22-Sep-94	0.5	2.3	0.28	0.2	1.6							8.3	2.3		6.94	822		
Woodhill	02-Oct-94	0.68	1.4	0.22	0.2	0.48	15	760					0.76			7.2	823		
Woodhill	03-Oct-94	0.2	2.2	0.56	0.23	1.9	36	330					5.2			6.8			
Woodhill	07-Oct-94	0.2	4.5	3.1	2.1	12	1800	300								7.01	625		
Woodhill	17-Oct-94	0.3	1.2	0.44	0.36		72	850					0.37	1.3		6.83	453		
Woodhill	18-Oct-94	0.2	2.5	0.86	0.69	1.4	89	510								6.57	1452		
													0.7	2.6		6.82	814		