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# A water quality evaluation of the Heron Haven Wetland in Omaha, Nebraska.

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# A WATER QUALITY EVALUATION OF THE HERON HAVEN WETLAND IN OMAHA, NEBRASKA

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by

Gabrielle C. Collins

May 8, 2003

THESIS ACCEPTANCE

Acceptance for the faculty of the Graduate College,
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Date April 16, 2003______________________

Abstract

A WATER QUALITY EVALUATION OF THE HERON HAVEN WETLAND IN OMAHA, NEBRASKA

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Wetlands are areas characterized by hydric soils and vegetation, and are saturated at least part of the year. They perform a variety of functions among which are breaking down organic and inorganic solids, groundwater recharge, providing habitat, and flood control. In urban areas, wetlands are often vital to migrating wildlife, and they may serve as environmental education sites. Heron Haven Wetland is a restored wetland in Omaha, Nebraska. Because it is in a completely urbanized area, various contaminants have the potential to decrease water quality, making it functionally less effective.

Water quality was sampled at five areas within Heron Haven Wetland to establish baseline data, analyze spatial and temporal variations in water quality, examine the effect of heavy precipitation on the water quality and characterize the flow of pollutants through the wetland. Testing was performed for pH, total dissolved solids, total suspended solids, nitrates, phosphates and sodium. Analysis was completed on a regular basis throughout the year and also after major precipitation events.

Five sites were evaluated in this study. With some exceptions, conditions within the wetland were found to be fairly consistent throughout the year for all tests. One site

(upland creek), which flows from a nearby housing development into Heron Haven, had consistently lower water quality than the other sites. A second site (Maple Street buffer) was also expected to have low water quality, as it receives runoff from West Maple Road. This site was frequently found to have the lowest concentrations of nitrates, phosphates and total dissolved solids. The only effect precipitation events appeared to have was to decrease the range of values between sites for all tests with the exception of nitrates. The hypothesis that urban runoff will have a negative effect on water quality of wetlands in urban areas was not conclusively indicated by this study.

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Lastly, I would like to thank my family for all of their love and understanding during this process. My parents, Len and Ellen Fischman; my three children Nathaniel, Timothy and Valkyrie; and of course Gary Gilkison who made it possible for me to complete my degree.

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# CHAPTER I

## Introduction

Wetlands are ubiquitous but extremely variable and important elements of the landscape that are characterized by water saturation for at least part of the year. They may receive water from groundwater sources but many are recharged only from rainfall and surface runoff. Wetlands are found in most climates and in widely varying sizes and topographic settings. The soil/substrate, water chemistry, vegetation, groundwater, and other factors also vary (Environmental Protection Agency, 1999). Cowardin et al. (1979) describe wetlands as transitional lands between terrestrial and aquatic systems where the water table is at or near the surface. They contain hydrophytes, or water-loving plants, at least part of the year (Cowardin, et al., 1979). Inland wetlands, such as those in Nebraska, are commonly found on river floodplains, playas, lake margins, and other low-lying areas where the water table intercepts the surface or soil permeability is diminished.

Both the U.S. Army Corps of Engineers (USACE) and the National Research Council (NRC) have definitions of wetlands that are very similar. The USACE Wetlands Delineation Manual (1987) uses three diagnostic characteristics to identify wetlands:

1. There should be a prevalence of hydrophytic plants of the variety that grow in saturated or inundated conditions.
2. Area soils are developed under saturated (anaerobic) conditions.
3. There must be water saturation during all or part of the year, especially during the growing season.

Similarly, the NRC (1995) has three criteria for determining wetlands. These are:

1. Biota – hydric vegetation, as well as certain algae and / or animals;
2. Substrate – hydric soils and course-textured floodplain substrates that are at least seasonally flooded;
3. Water – saturated for a minimum of 14 days during the growing season.

Wetlands provide a variety of important services, not all of which are valued or recognized by society. These may generally be grouped into six basic categories. The first involves breaking down both organic and inorganic solids and other compounds. Nitrates would be an example of a contaminant removed effectively by wetlands (UNL Water Center, 1999). Wetlands are also highly productive biological environments that provide habitat for a wide variety of plants and animals. Nine of Nebraska's eleven endangered species either live in or otherwise use wetlands (Audubon Society of Omaha (ASO), 1999). Wetlands are also useful in flood control, acting like a sponge to hold in excess water during periods of flooding and high precipitation. By holding precipitation and excess runoff for a period of time, wetlands may also serve to help recharge groundwater supplies (EPA, 1999). Riparian wetlands cause a velocity reduction in rivers and streams, thereby allowing sediment to settle out and prevent soil from washing away into streams and lakes (NRC, 1995). Finally, drained wetlands make productive cropland. When drained, the high organic content of wetland soils often make highly productive agricultural soils. Even when wetlands are not drained, they can be used to obtain various foods and fibers including hay, timber, peat, rice, and shellfish, among others (UNL Water Center, 1999).

There is much value in wetlands that is also intangible. This includes such activities as hunting, fishing, wildlife watching, photography and other forms of recreation. In addition, some wetlands are useful in archaeological and historical contexts, hazardous waste remediation, and environmental education. In urban areas, these can be very valuable functions, as they relate more directly to people and communities. In many places, wetlands may represent some of the last vestiges of a "natural" ecosystem within the city's limits.

**Nature of Problem**

Despite their value, wetlands are disappearing across the country (Wallace, 1998). Omaha has historically had wetlands, especially along the Missouri River and its smaller tributaries, but they have often been regarded as useless or wasted land – a source of mosquitoes, flies, disease, and unpleasant odors. Consequently, most of Omaha's wetlands have been destroyed in favor of flood control projects, stream channel improvements, housing, agriculture and waste sites. Some wetlands, while not completely destroyed, have been damaged by inputs of chemicals, fertilizer, and sediment.

In Omaha, attempts have been made not only to retain and rehabilitate some existing wetlands, but also to construct new wetlands. Some are built for sediment control purposes, others for aesthetic reasons. With the exception of wetlands along the

Missouri River, Heron Haven is one of the larger "natural" wetlands remaining in the Big Papillion drainage basin and the surrounding area.

Heron Haven Wetland is a restored natural wetland located at 120th and Maple Streets (Figure 1 and 2). It is bordered on three sides by paved streets. The east side abuts private homes in a large subdivision. It lies in a depression at the base of two hills and is susceptible to nonpoint source pollution that has the potential to degrade the quality of the wetland. Chemicals applied to lawns, street runoff, road salt, yard and pet waste, household wastes, non-biodegradable litter, motor oil, and sediment are all factors in water quality degradation in urban wetlands (EPA, 1999). Five springs, surface runoff, precipitation, and possibly subsurface flow related to the nearby Big Papillion Creek support Heron Haven (UNL Heron Haven, 1999).

**Research Objectives**

This study compares the water quality in five areas within Heron Haven Wetland to establish baseline data, analyze spatial and temporal variations in water quality, and characterize the flow of pollutants through the wetland. Several research questions were considered for this study. Does water quality within the wetland show spatial chemical variance? Do precipitation events have an impact on pollutant concentrations, and if so, what is that impact? Are there seasonal variations within the wetland?

**Hypothesis**

The hypothesis is that there should be spatial variation in water quality within the wetland, as well as seasonal variation. The filtering ability of the wetland, as well as distance to possible pollution sources should be factors in the spatial variations. The areas of relatively poor water quality should be in the buffer adjacent to Maple Street and in the creek runoff from the housing development. Essentially, the water should be cleansed of dissolved and suspended solids as it moves through the wetland. In addition, precipitation events should result in a temporary increase in pollutants, but over time should dilute the concentrations of many elements in all parts of the wetland. This should be indicated by water quality readings during seasonal wet periods.

# CHAPTER II

## Study Area

The study area for this project is Heron Haven Wetland (Figure 1). This wetland is located at the northeast corner of 120th and Maple Streets in Omaha, Nebraska (Figure 2). It lies at the base of a steep slope on the floodplain of the Big Papillion Creek, where the water table intersects the surface. The area receives approximately 75 cm annual precipitation, and has cold winters and hot summers. Soils are Kennebec silt loam that are subject to occasional flooding. These mollisols are part of the Marshall-Ponca Association, consisting of deep, well-drained, silty soils on loess uplands (United States Department of Agriculture, 1975).

The water sources for Heron Haven Wetland consist of direct precipitation, surface runoff from the surrounding neighborhood and West Maple Road, a small drainage creek from the northeast, and at least five on-site springs. Subsurface flow in the form of springs and seeps sustain the hydrology of the wetland year-round (ASO, 2001).

Heron Haven Wetland is a reconstructed wetland within a completely urbanized area. It is bordered to the northwest by the Knolls Golf Course, to the east and northeast by private homes and the Lake Forest Apartment complex, to the south by Maple Street (a major four-lane thoroughfare), and to the west by a section of Mulhall's Nursery which primarily grows shrubs and small trees. With the exception of the golf course, each of these surrounding areas has at least the potential for pollutant contribution to the wetland.

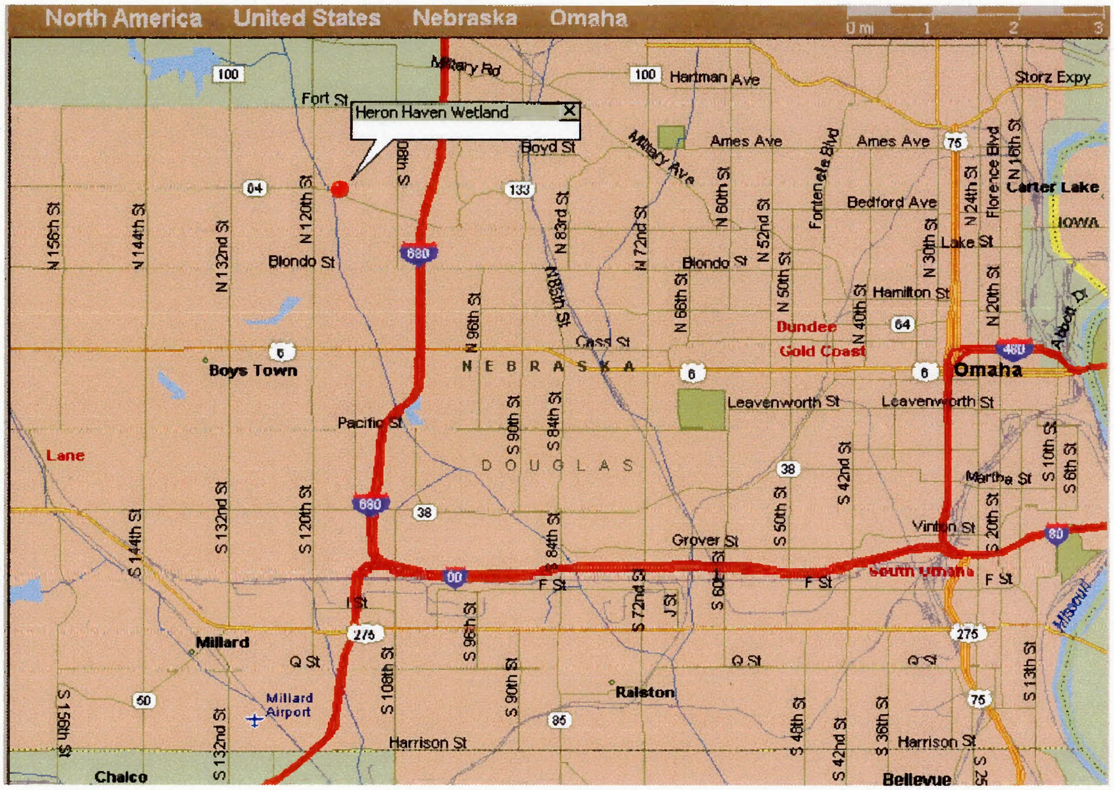



**Figure 1**: General location of Heron Haven Wetland in Omaha, NE (MapPoint, 2002)

**Figure 2**: Heron Haven Wetland as seen from West Maple Road (October, 2001)

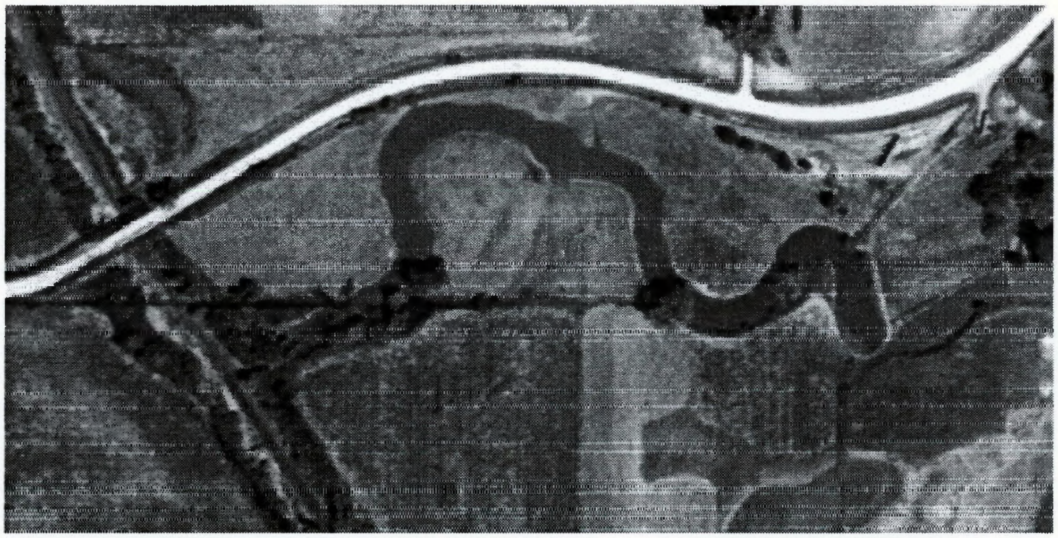


**Figure 3**: Aerial photo of Heron Haven Wetland in 1942

**Figure 4**: Aerial Photo of Heron Haven Wetland, USGS 1999

Originally, Heron Haven was a channel associated with the Big Papillion Creek to the west (Figures 3 and 4). When the Big Papillion was channelized sometime prior to 1940, the channel was further cut off and isolated from the creek, causing some sedimentation. As Omaha expanded westward, Heron Haven was utilized in places as an unofficial dump for asphalt, concrete, and accumulated roadside trash. There was little value given to the area as more than a drainage ditch and dump. In a joint effort to rehabilitate the wetland, to improve stormwater drainage and to promote environmental education, the Papio-Missouri Natural Resources District and the Omaha Chapter of the Audubon Society purchased the property in the 1980's (ASO, 2001).

There are several zones in this wetland as detailed by the Douglas County Extension Office in 1992 (Figures 5 and 6). The primary wetland is classified as a mostly palustrine, emergent wetland (Cowardin, et al., 1979) with organic soils and perennial hydrophytes. It is located in the southeast part of the current wetland. A "spoils" area acts as a zone of mixing between the primary and disturbed wetlands. The disturbed wetland just to the west of the primary wetland has been dredged within the last twenty years and acts as a buffer between the primary wetland and the fill area. The fill area is an area of mature trees planted in rows along the north side of the disturbed wetland, and it contains concrete and asphalt rubble covered by soil. An area designated as "upland forest" has a variety of mature native and exotic trees along the gully walls of a small tributary creek that runs into the wetland from the northeast. This area also borders Manderson Street and Old Maple Road, which run along the north side of the wetland. A small service road within the upland forest itself has been removed and rehabilitated with native trees and grasses, though in places it still exists as part of the trail system.

In addition, a barrier of native trees and shrubs has been planted along Maple Street to act as a buffer to road pollutants. Mulhall's Nursery, mainly located across Maple Street to the south, retains a small area to the west of the disturbed wetland. This area has little value as wetland, as it has existing subsoil drainage tiles, and is seasonally tilled, planted, and fertilized.

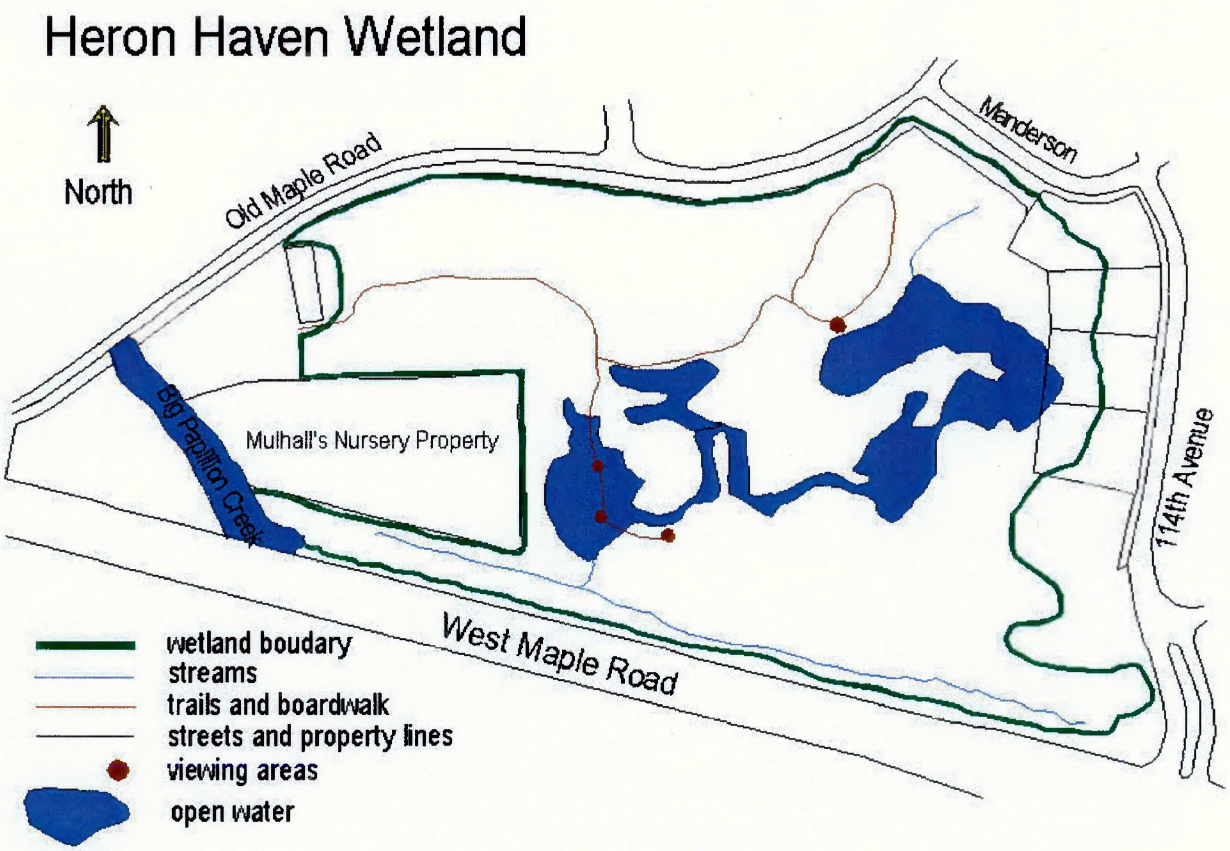



**Figure 5**: Heron Haven Wetland (modified from Douglas County Extension Office, 1992)

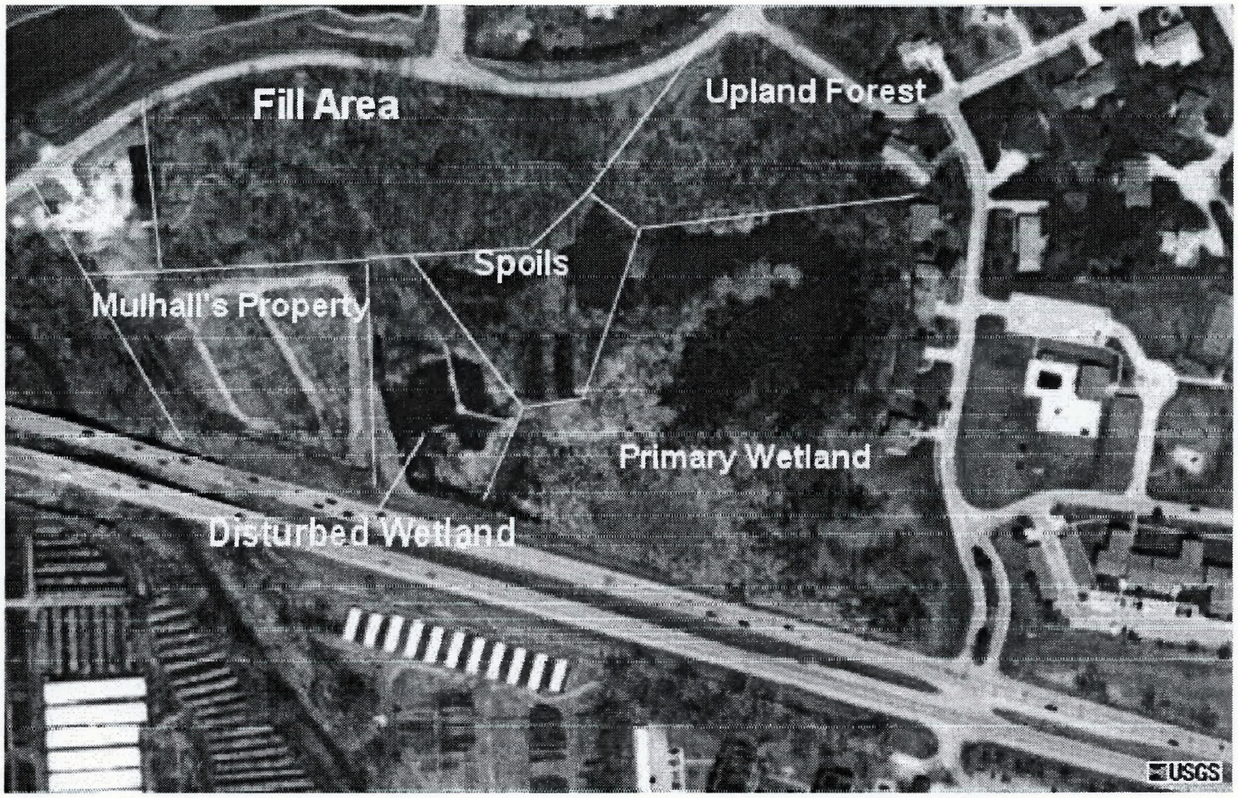



**Figure 6**: Zone map of Heron Haven Wetland area, modified from USGS 1999 aerial photo

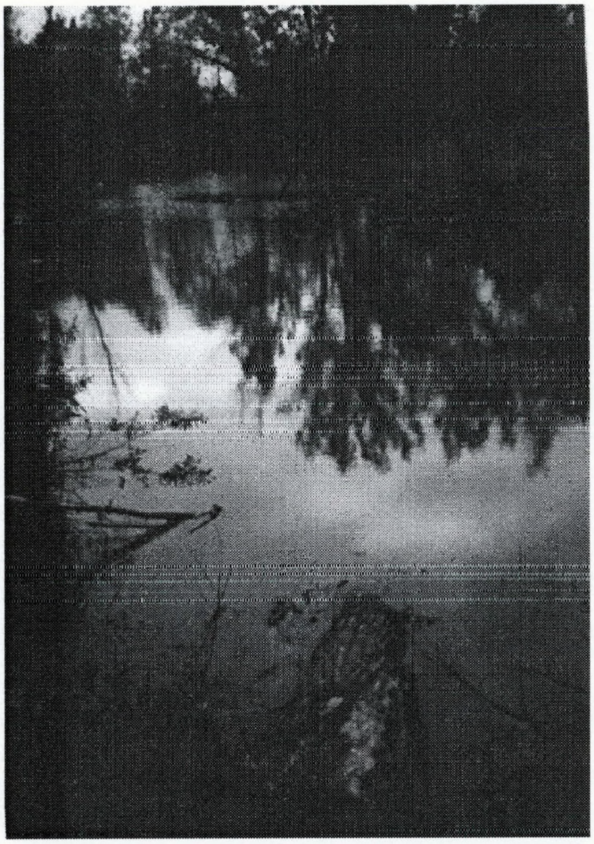
Dirt trails, viewing blinds, a large viewing deck overlooking the primary wetland, and a series of boardwalks provide minimal access to the public for viewing and educational purposes. Efforts have been made to remove exotic plant species and promote native plants in their place. Management of the wooded upland forest area is maintained to prevent non-native species from invading the wetland (ASO, 2001).

Five sample sites were established to characterize chemical variations within the wetland (Figure 7). The sampling locations include the primary wetland, the disturbed wetland, the spoils, the upland forest creek, and the Maple Street buffer. There is no surface water located in the fill area, so no samples were taken there. The first location

(Site 1) is within the primary wetland and has perennial emergent wetland plants and organic soils. The disturbed wetland (Site 2) is to the west of the primary wetland and consists of vegetation similar to that of the primary wetland. The “spoils” (Site 3) are a series of vegetated, interconnected pools along the boardwalks just to the north of the primary and disturbed wetlands. This area acts somewhat as a buffer between the public access trails and the wetland itself. The upland forest is a steep-sided, wooded area that drains runoff from the yards of private homes into a small ephemeral creek (Site 4) that runs into the primary wetland from the northeast. The final collection site is within the Maple Street buffer area (Site 5). This is an area that collects water runoff from both Maple Street and Mulhall’s Nursery and flows into the wetland. Each sample was collected in the same place each time a collection was made.

**7a.** Site 1: Primary wetland

**7b.** Site 2: Disturbed wetland



**7c.** Site 3: Spoils

**7d.** Site 4: Upland forest creek

**7e.** Site 5: Maple Street buffer

**Figure 7**: Specific testing sites in Heron Haven Wetland. 7a. primary wetland, 7b. disturbed wetland, 7c. spoils, 7d. upland forest creek, 7e. Maple Street buffer

# CHAPTER III

## Literature Review

Urban wetlands are sometimes used as stormwater retention basins and for wastewater remediation. They operate by establishing feedback loops that promote self-organization and self-repair, support multifunctions by creating habitat for wildlife, create oxygen, and achieve high levels of water treatment with little maintenance (Wallace, 1998). Water entering wetlands is slowed, allowing suspended solids and contaminants to settle out. In addition, many wetland plants promote chemical transformations of contaminants such as nitrogen and phosphorus, both of which can be found within Heron Haven (Wallace, 1998, Mitsch and Wu, 1998).

Urban runoff has been studied as a primary cause for degraded water quality in non-point source pollution studies for wetlands. Some early studies emphasize sewer overflows as contributing to Total Suspended Solids (TSS) and total coliform counts (Palmer, 1963; Browne, 1978). Another study by Sartor et al. (1974) identified inorganic street surface materials such as metals as contributing to TSS in urban runoff.

The importance of temperature, pH, turbidity (through TSS) and conductivity (through Total Dissolved Solids (TDS)) are discussed by Mitsch and Wu (1998). These can be affected by water column and sediment content as well as macrophyte cover.

Characklis and Wiesner (1997) studied metal concentrations and particle size distribution from urban stormwater runoff in Galveston Bay near Houston, TX. Specifically, samples were analyzed for turbidity, pH, total suspended solids (TSS), total organic carbon (TOC), and metal analysis at four sites during two precipitation events.

The TOC and TSS were shown to increase during precipitation events, as were concentrations of metals such as iron and zinc.

Processes and factors regulating phosphorus retention in streams and wetlands were reported by Reddy et al. (1999). Phosphorus is often the key limiting factor in freshwater ecosystems. The primary retention mechanisms are uptake and release by vegetation and microorganisms, sorption and exchange reactions in soils, chemical precipitation in the water column, and sedimentation and entrainment.

Reed and Brown (1995) examined the removal performance of wetlands on nitrogen, phosphorus, and TSS. The removal of nitrogen is described as being an important factor in water quality and aquatic life. Nitrogen removal was reported at 80% in the Bear Creek, Alabama, subsurface flow wetland studied. Hydrophytic plants such as *Phragmites*, *Typha*, and *Scirpus* were the primary removers of nitrogen. Phosphorus removal was not significant. TSS input into the system was from 20 to 118 mg/L whereas the output was measured at no more than 20 mg/L, indicating an adequate removal rate.

A case study done in Maryland by Whigham et al. (1999) found that restored wetlands in urban areas in Maryland removed an average of 68% of inflowing nitrate-nitrogen, 23% total nitrogen, and 43% total phosphorus. This study was repeated for three years, and during wet years nutrient retention was much lower than in drier years.

Adler et al. (1996) investigated the phosphorus removal in wetlands primarily by plant uptake. A wetland was constructed and maintained by harvesting biomass to regenerate the nutrient removal capacity of the wetland. It was found that the plant treatments removed approximately 40% of influent nitrate, and 80% of phosphorus. No harvesting is currently done at Heron Haven.

# CHAPTER IV

## Methodology

An initial study was conducted in 1999 to determine the extent of wetlands in the Omaha area. The Wetlands Interactive Mapper (Geotract Spatial Data Query (GSDQ), 1999) made it possible to locate many small wetlands within the designated areas of Omaha, Ralston, LaVista, Papillion, Bellevue, Irvington, and Carter Lake. Altogether, there were twenty-two separate locations indicated for this area (Appendix 1). Of these, all but three were visually verified. Most of these are very small and in danger of urban contamination or even total destruction.

Heron Haven was chosen for this study partly because of its accessibility, large size, and spatial variations within the wetland. In addition, it receives both urban runoff and groundwater flow as recharge. Water was collected from five locations within the wetland using a convenience sampling design within each "location" (Figure 8). Specific information regarding the sampling locations are detailed in the "Study Area" section. Samples were taken twice each month from September 2001 until the wetland froze for the winter in December, and again twice each month after the spring thaw (April) until August 2002. In addition, samples were taken after each precipitation event of at least one inch. These data provided an overview of water quality over an entire year's growing season, and it also allowed for the evaluation of stormwater effects compared to standard flow. Topography, distance from sources, and the types of possible pollutants from potential sources were evaluated.

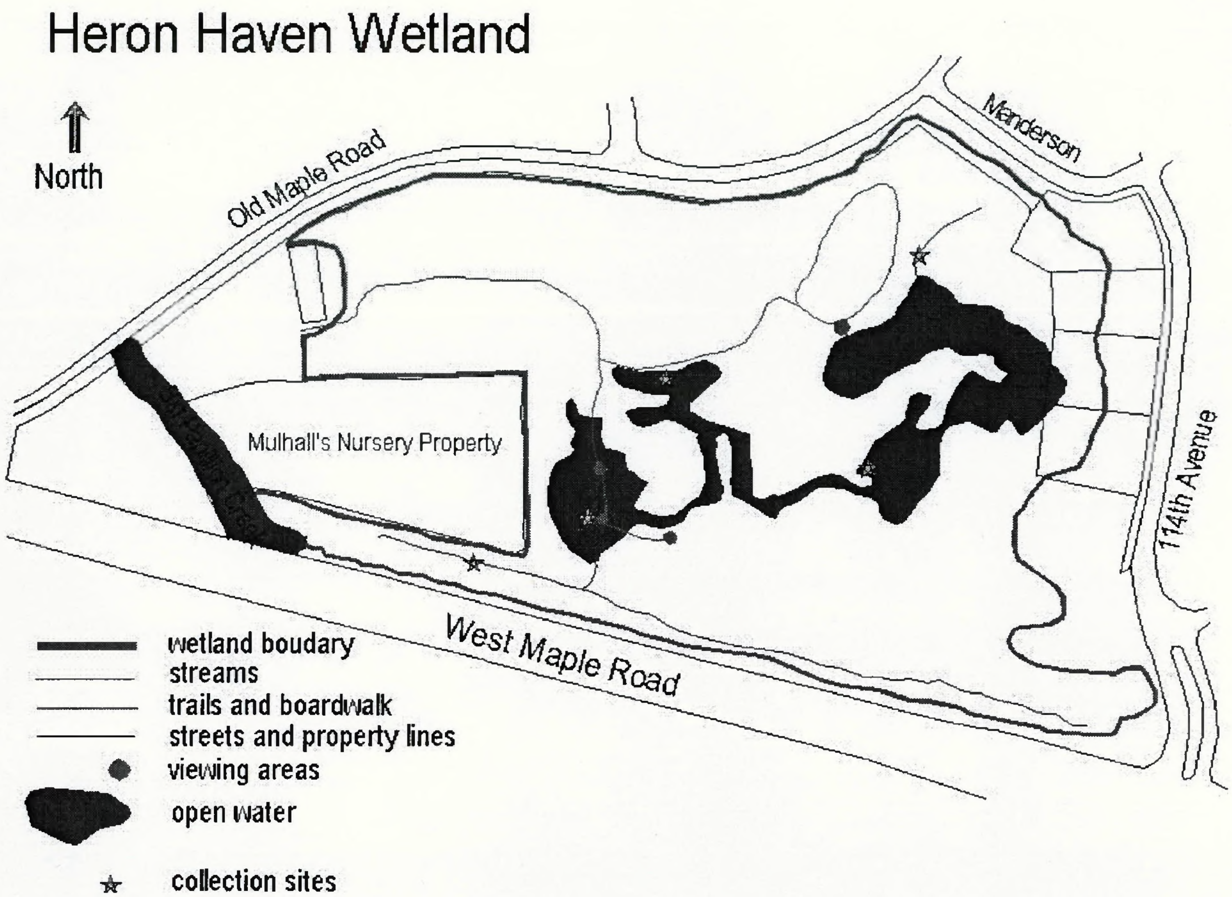



**Figure 8**: Sampling locations (modified from Douglas County Extension Office, 1992)

Samples were collected from areas within the primary wetland, disturbed wetland, spoils, upland forest and the Maple Street buffer. These five areas were chosen to highlight possible spatial variations within the wetland. (See Appendix 6 for detailed photographs of the wetland and surrounding areas.)

Upon collecting each sample, temperature was recorded using a digital thermometer. Temperature can affect the solubility of minerals and provide information about how the hydrologic system is operating with regard to how long the water has been in the system. Total dissolved solids (TDS) and pH were measured at the sample sites using calibrated solid-state meters. The pH represents the measure of acidity or alkalinity in the water sample. TDS is the measure of the total amount of material dissolved in the water sample.

Upon completing the collection and field-testing of the five samples, they were analyzed at the University of Nebraska at Omaha's water quality testing lab for sodium (Na) using a solid state Hariba Ion-Selective meter, and total suspended solids (TSS) by the filtration method. Sodium would likely be an indicator of road salt. TSS measures the total amount of solid-sediment in the water sample. Phosphates (P) and nitrates ($NO_3$) were tested using reagent test strips and a Reflectoquant Meter. This measures the chemical concentrations by measuring reflectance of ion specific test strips. Phosphate is found in many commercial fertilizers and nitrates may be derived from fertilizers, animal waste, or septic systems.

The results of each test were recorded and compared in tabular and graphic format, giving an overall measurement of general water quality at each site and an indication of pollutant movement through the wetland system. Data storage and graphing were done using Microsoft Excel spreadsheets. The construction of these graphs was undertaken in an attempt to identify chemical variations within the wetland, and possible pollution sources.

# CHAPTER V

## Results and Discussion

The pH throughout the wetland remained fairly consistent spatially throughout the year (Table 1). In general, the upland forest creek (site 4) and the buffer (site 5) had the most variation from 7.0, but it was negligible.

**Table 1:** pH readings

| **Date** | **Site 1** | **Site 2** | **Site 3** | **Site 4** | **Site 5** | **Precip. Event** |
|---|---|---|---|---|---|---|
| Sept 3 2001 | 7.4 | 7.3 | 7.5 | 7.4 | 7.5 | no |
| Sept 8 2001 | 7 | 7.1 | 7 | 7.1 | 7 | yes |
| Sept 24 2001 | 7 | 7 | 7 | 7.1 | 7.1 | no |
| Oct 8 2001 | 7 | 7.1 | 7.1 | 7 | 7 | no |
| Oct 13 2001 | 6.9 | 7 | 6.9 | 6.9 | 7 | yes |
| Oct 23 2001 | 6.6 | 6.7 | 6.7 | 6.7 | 7 | no |
| Nov 6 2001 | 6.7 | 6.9 | 6.7 | 6.7 | 7 | no |
| Nov 24 2001 | 7.2 | 7.3 | 7 | 7.1 | 7.1 | yes |
| Dec 6 2001 | 6.9 | 7 | 6.9 | 6.8 | 7 | no |
| Mar 30 2002 | 7.3 | 6.7 | 6.9 | 6.9 | 6.7 | no |
| Apr 18 2002 | 7 | 7.1 | 7.1 | 7.1 | 7.1 | no |
| Apr 25 2002 | 7.6 | 7.5 | 7.1 | 6.8 | 7 | no |
| Apr 29 2002 | 7 | 7.3 | 7.1 | 7.2 | 6.9 | yes |
| May 12 2002 | 7.1 | 7.1 | 7.1 | 7.2 | 7.2 | no |
| May 18 2002 | 7.3 | 7.2 | 7.2 | 7.2 | 7.2 | yes |
| May 22 2002 | 7 | 7.1 | 7 | 7.2 | 7 | no |
| June 3 2002 | 7 | 7 | 7.1 | 7.1 | 7 | no |
| June 23 2002 | 7 | 7.4 | 7 | 7.1 | 7 | no |
| July 10 2002 | 7.1 | 7.1 | 7.1 | 7.3 | 7.1 | no |
| July 19 2002 | 7.1 | 7.1 | 7.3 | 7.1 | 7.1 | no |
| Aug 1 2002 | 7 | 7.1 | 7.1 | 7.1 | 7.1 | no |

The overall mean TDS readings at each site ranged from 250ppm to 375ppm, with the upland creek (site 4) remaining consistently higher than the others (Table 2). The primary wetland (site 1) had three anomalously high readings on June 3, July 19 and August 1, of 401ppm, 444ppm and 449ppm, respectively. I am unable to account for these anomalies.

**Table 2:** TDS readings

| **Date** | **Site 1** | **Site 2** | **Site 3** | **Site 4** | **Site 5** | **Precip..Event** |
|---|---|---|---|---|---|---|
| Sept 3 2001 | 355 | 359 | 358 | 396 | 355 | no |
| Sept 8 2001 | 260 | 251 | 257 | 355 | 254 | yes |
| Sept 24 2001 | 296 | 294 | 366 | 387 | 354 | no |
| Oct 8 2001 | 262 | 253 | 259 | 283 | 256 | no |
| Oct 13 2001 | 257 | 250 | 258 | 263 | 248 | yes |
| Oct 23 2001 | 267 | 270 | 273 | 256 | 266 | no |
| Nov 6 2001 | 252 | 254 | 254 | 260 | 246 | no |
| Nov 24 2001 | 328 | 329 | 330 | 333 | 329 | yes |
| Dec 6 2001 | 325 | 330 | 300 | 330 | 326 | no |
| Mar 30 2002 | 252 | 259 | 302 | 312 | 272 | no |
| Apr 18 2002 | 356 | 324 | 330 | 400 | 336 | no |
| Apr 25 2002 | 370 | 326 | 309 | 398 | 305 | no |
| Apr 29 2002 | 336 | 260 | 274 | 367 | 255 | yes |
| May 12 2002 | 296 | 254 | 282 | 377 | 259 | no |
| May 18 2002 | 190 | 193 | 268 | 386 | 200 | yes |
| May 22 2002 | 326 | 264 | 288 | 324 | 245 | no |
| June 3 2002 | 401 | 257 | 233 | 306 | 226 | no |
| June 23 2002 | 307 | 337 | 365 | 406 | 313 | no |
| July 10 2002 | 319 | 309 | 289 | 367 | 346 | no |
| July 19 2002 | 444 | 286 | 304 | 378 | 325 | no |
| Aug 1 2002 | 499 | 322 | 339 | 379 | 350 | no |

The TSS readings were consistent both spatially and temporally, with two exceptions (Table 3). On Oct 23, the disturbed wetland (site 2) and the spoils (site 3) had readings of over 0.15 mg/L. In addition, the primary wetland (site 1) had a reading of 0.29 mg/L on April 25, and of 0.145 mg/L on April 29.

**Table 3:** TSS readings

| **Date** | **Site 1** | **Site 2** | **Site 3** | **Site 4** | **Site 5** | **Precip. Event** |
|---|---|---|---|---|---|---|
| Sept 3 2001 | 0.035 | 0.02 | 0.01 | 0.02 | 0.02 | no |
| Sept 8 2001 | 0.05 | 0.03 | 0.04 | 0.01 | 0.03 | yes |
| Sept 24 2001 | 0.055 | 0.03 | 0.045 | 0.01 | 0.035 | no |
| Oct 8 2001 | 0.055 | 0.065 | 0.06 | 0.005 | 0.03 | no |
| Oct 13 2001 | 0.055 | 0.055 | 0.015 | 0.025 | 0.075 | yes |
| Oct 23 2001 | 0.02 | 0.16 | 0.15 | 0.05 | 0.075 | no |
| Nov 6 2001 | 0.05 | 0.025 | 0.04 | 0.01 | 0.035 | no |
| Nov 24 2001 | 0.0012 | 0.0002 | 0.0004 | 0.0027 | 0.0001 | yes |
| Dec 6 2001 | 0.01 | 0.015 | 0.02 | 0.02 | 0.035 | no |
| Mar 30 2002 | 0.085 | 0.035 | 0.02 | 0.025 | 0.005 | no |
| Apr 18 2002 | 0.05 | 0.07 | 0.01 | 0.005 | 0.075 | no |
| Apr 25 2002 | 0.29 | 0.085 | 0.06 | 0.025 | 0.1 | no |
| Apr 29 2002 | 0.145 | 0.055 | 0.04 | 0.025 | 0.035 | yes |
| May 12 2002 | 0.051 | 0.002 | 0.0015 | 0.0025 | 0.0005 | no |
| May 18 2002 | 0.037 | 0.002 | 0.0075 | 0.006 | 0.0453 | yes |
| May 22 2002 | 0.045 | 0.003 | 0.007 | 0.01 | 0.005 | no |
| June 3 2002 | 0.0515 | 0.006 | 0.007 | 0.013 | 0.04 | no |
| June 23 2002 | 0.0505 | 0.0035 | 0.0085 | 0.0065 | 0.0015 | no |
| July 10 2002 | 0.0345 | 0.001 | 0.009 | 0.004 | 0.003 | no |
| July 19 2002 | 0.037 | 0.002 | 0.007 | 0.003 | 0.003 | no |
| Aug 1 2002 | 0.05 | 0.002 | 0.01 | 0.025 | 0.02 | no |

Nitrates at Heron Haven proved to be the most variable (Table 4). The upland creek (site 4) was consistently the highest in nitrate concentration levels, and the buffer (site 5) was consistently the lowest. The disturbed wetland (site 2) closely paralleled the buffer, with only slightly higher concentrations. The primary wetland (site 1) and the spoils (site 3) had the second highest levels interchangeably throughout the year. There was one anomalous peak in the nitrate levels of the sample taken at site one on April 29, of 30ppm.

**Table 4:** Nitrate readings

| **Date** | **Site 1** | **Site 2** | **Site 3** | **Site 4** | **Site 5** | **Precip. Event** |
|---|---|---|---|---|---|---|
| Sept 3 2001 | 0 | 0 | 5 | 9 | 0 | no |
| Sept 8 2001 | 16 | 6 | 11 | 25 | 0 | yes |
| Sept 24 2001 | 20 | 7 | 13 | 25 | 8 | no |
| Oct 8 2001 | 13 | 8 | 9 | 19 | 0 | no |
| Oct 13 2001 | 7 | 7 | 11 | 26 | 0 | yes |
| Oct 23 2001 | 5 | 6 | 8 | 22 | 5 | no |
| Nov 6 2001 | 6 | 8 | 10 | 21 | 6 | no |
| Nov 24 2001 | 5 | 7 | 13 | 24 | 7 | yes |
| Dec 6 2001 | 18 | 15 | 19 | 26 | 12 | no |
| Mar 30 2002 | 10 | 0 | 0 | 21 | 0 | no |
| Apr 18 2002 | 0 | 0 | 0 | 24 | 0 | no |
| Apr 25 2002 | 0 | 0 | 0 | 22 | 0 | no |
| Apr 29 2002 | 30 | 0 | 0 | 14 | 0 | yes |
| May 12 2002 | 0 | 0 | 0 | 14 | 0 | no |
| May 18 2002 | 0 | 0 | 0 | 17 | 0 | yes |
| May 22 2002 | 1 | 2 | 1 | 20 | 0 | no |
| June 3 2002 | 0 | 7 | 8 | 29 | 5 | no |
| June 23 2002 | 11 | 0 | 8 | 26 | 0 | no |
| July 10 2002 | 16 | 0 | 10 | 24 | 0 | no |
| July 19 2002 | 0 | 0 | 0 | 21 | 0 | no |
| Aug 1 2002 | 0 | 0 | 0 | 20 | 0 | no |

Phosphates remained consistent through the year, although the upland creek (site 4) had generally the highest reading of the five sites (Table 5). The exception to this was during June and July, when all or most of the other sites showed higher phosphate levels.

**Table 5:** Phosphate readings

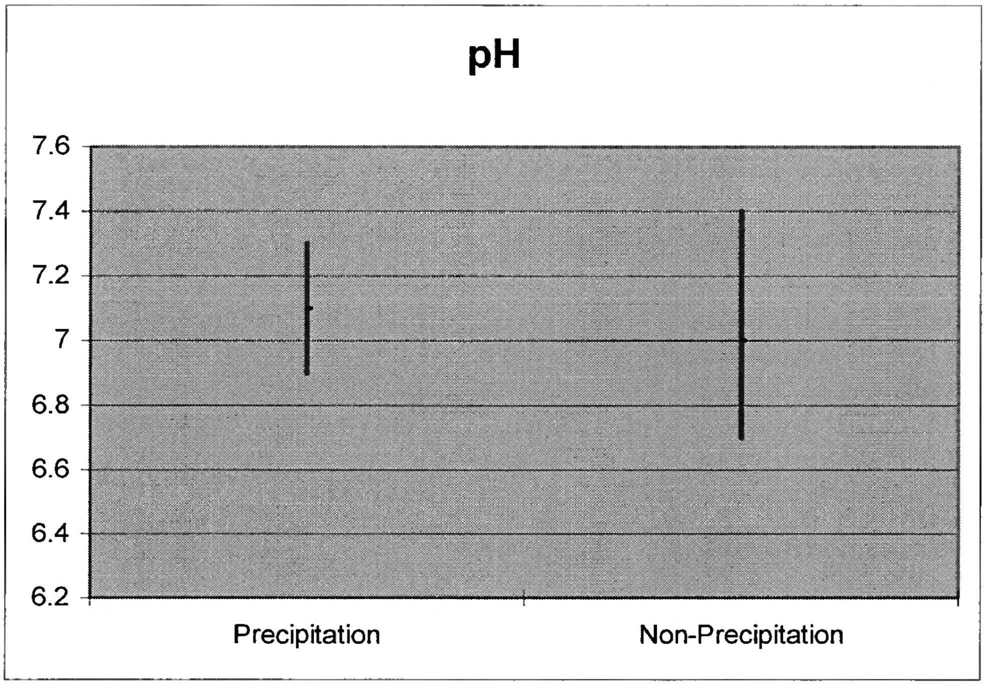
| Date | Site 1 | Site 2 | Site 3 | Site 4 | Site 5 | Precip. Event |
|---|---|---|---|---|---|---|
| Sept 3 2001 | 20 | 5 | 6 | 0 | 5 | no |
| Sept 8 2001 | 2 | 5 | 3 | 8 | 4 | yes |
| Sept 24 2001 | 4 | 7 | 13 | 25 | 8 | no |
| Oct 8 2001 | 13 | 8 | 4 | 15 | 9 | no |
| Oct 13 2001 | 2 | 9 | 9 | 14 | 3 | yes |
| Oct 23 2001 | 1 | 1 | 5 | 4 | 6 | no |
| Nov 6 2001 | 3 | 1 | 7 | 13 | 9 | no |
| Nov 24 2001 | 1 | 9 | 7 | 18 | 9 | yes |
| Dec 6 2001 | 0 | 1 | 4 | 4 | 7 | no |
| Mar 30 2002 | 1 | 0 | 0 | 2 | 0 | no |
| Apr 18 2002 | 8 | 2 | 2 | 7 | 3 | no |
| Apr 25 2002 | 0 | 1 | 0 | 2 | 1 | no |
| Apr 29 2002 | 4 | 0 | 4 | 4 | 2 | yes |
| May 12 2002 | 0 | 4 | 2 | 6 | 0 | no |
| May 18 2002 | 0 | 2 | 7 | 7 | 2 | yes |
| May 22 2002 | 5 | 6 | 6 | 7 | 1 | no |
| June 3 2002 | 12 | 4 | 4 | 9 | 3 | no |
| June 23 2002 | 14 | 19 | 18 | 9 | 6 | no |
| July 10 2002 | 36 | 22 | 8 | 5 | 26 | no |
| July 19 2002 | 4 | 0 | 8 | 10 | 5 | no |
| Aug 1 2002 | 21 | 7 | 3 | 11 | 3 | no |

In September and the beginning of October sodium readings were under 15ppm at all of the sites (Table 6). A rainfall of 4.5 cm occurred on October 13, and elevated readings at all sites, especially in the upland creek (site 4), were recorded. From this date through mid-May readings remained consistently between 15 and 25ppm for all sites. On May 18 there was a large precipitation event of 6.6 cm that caused immediate increased sodium readings at the spoils (site 3) and upland creek sites. From this point, sodium readings for all five sites rose dramatically throughout May, June, and the first part of July, at which time they slowly fell to nearly the same levels experienced in September of the previous year. While the rainfalls in October and May seemed to trigger a rise in sodium levels, rainfalls in September, November, and April had no appreciable effect.

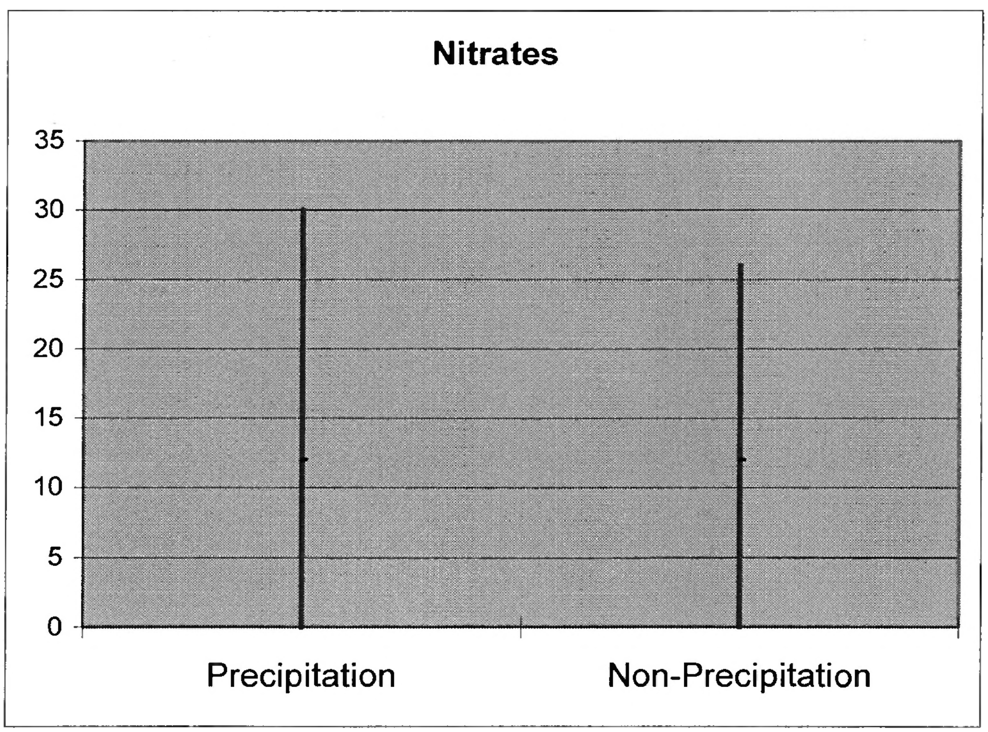
**Table 6:** Sodium readings

| Date | Site 1 | Site 2 | Site 3 | Site 4 | Site 5 | Precip. Event |
|---|---|---|---|---|---|---|
| Sept 3 2001 | 5 | 12 | 6 | 0 | 1 | no |
| Sept 8 2001 | 11 | 15 | 11 | 2 | 3 | yes |
| Sept 24 2001 | 12 | 13 | 14 | 12 | 14 | no |
| Oct 8 2001 | 9 | 9 | 8 | 8 | 9 | no |
| Oct 13 2001 | 27 | 25 | 24 | 42 | 28 | yes |
| Oct 23 2001 | 15 | 16 | 17 | 15 | 17 | no |
| Nov 6 2001 | 21 | 19 | 18 | 18 | 21 | no |
| Nov 24 2001 | 17 | 20 | 18 | 20 | 22 | yes |
| Dec 6 2001 | 16 | 16 | 15 | 16 | 16 | no |
| Mar 30 2002 | 15 | 14 | 17 | 14 | 21 | no |
| Apr 18 2002 | 23 | 26 | 22 | 23 | 26 | no |
| Apr 25 2002 | 15 | 15 | 14 | 15 | 14 | no |
| Apr 29 2002 | 17 | 15 | 16 | 15 | 20 | yes |
| May 12 2002 | 26 | 25 | 26 | 28 | 25 | no |
| May 18 2002 | 14 | 15 | 26 | 26 | 18 | yes |
| May 22 2002 | 22 | 26 | 24 | 29 | 23 | no |
| June 3 2002 | 41 | 28 | 34 | 33 | 32 | no |
| June 23 2002 | 34 | 36 | 36 | 33 | 34 | no |
| July 10 2002 | 35 | 27 | 21 | 22 | 31 | no |
| July 19 2002 | 26 | 15 | 10 | 7 | 12 | no |
| Aug 1 2002 | 11 | 13 | 5 | 1 | 5 | no |

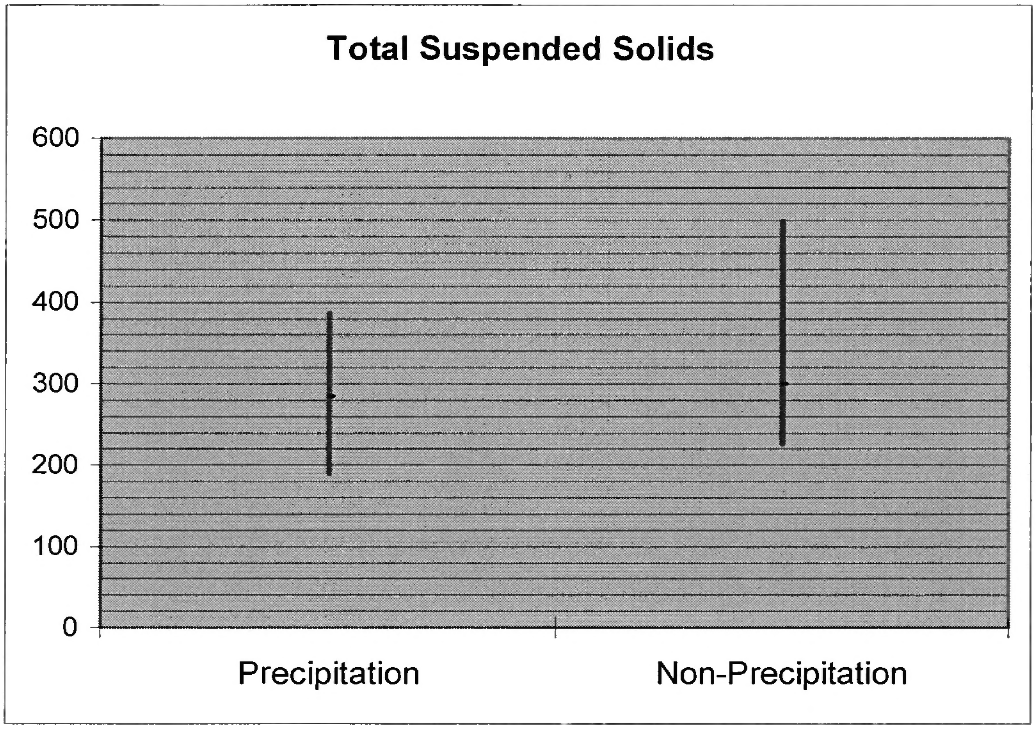
The range plots (Figures 9a – 9f) are intended strictly to indicate ranges of readings for precipitation vs. non-precipitation events for all sites combined. Maximum, minimum and mean values are indicated on each graph. Graphic representations of these readings are located in Appendix 3. Additionally, results by each site are located in Appendices 4 and 5.



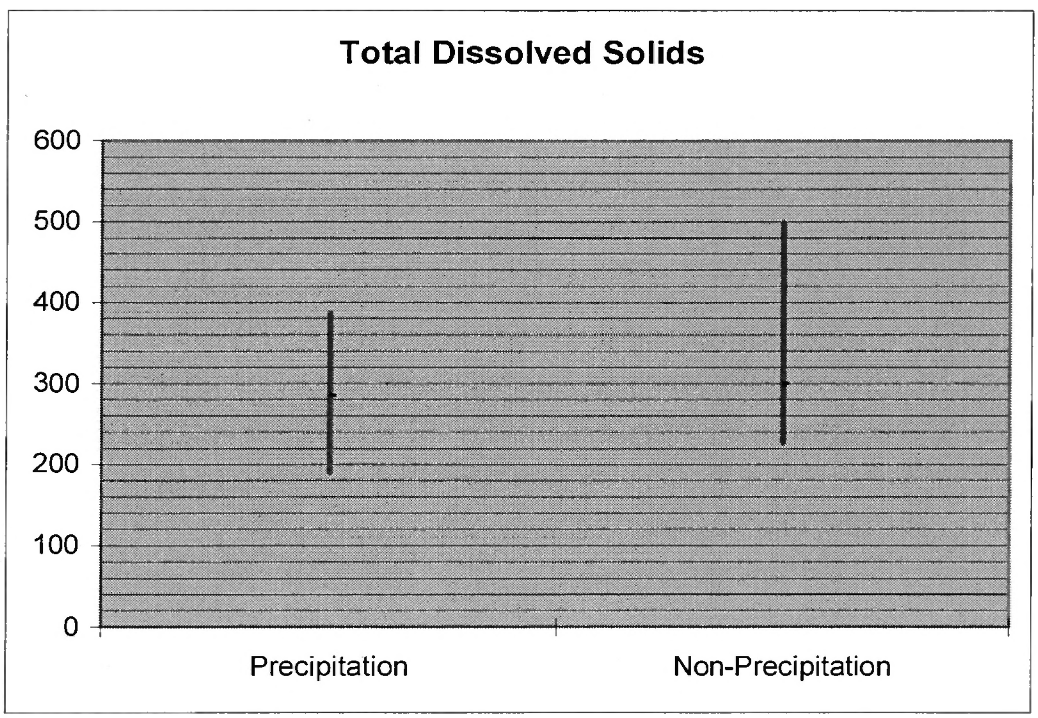

**9a.** Range of values for pH.



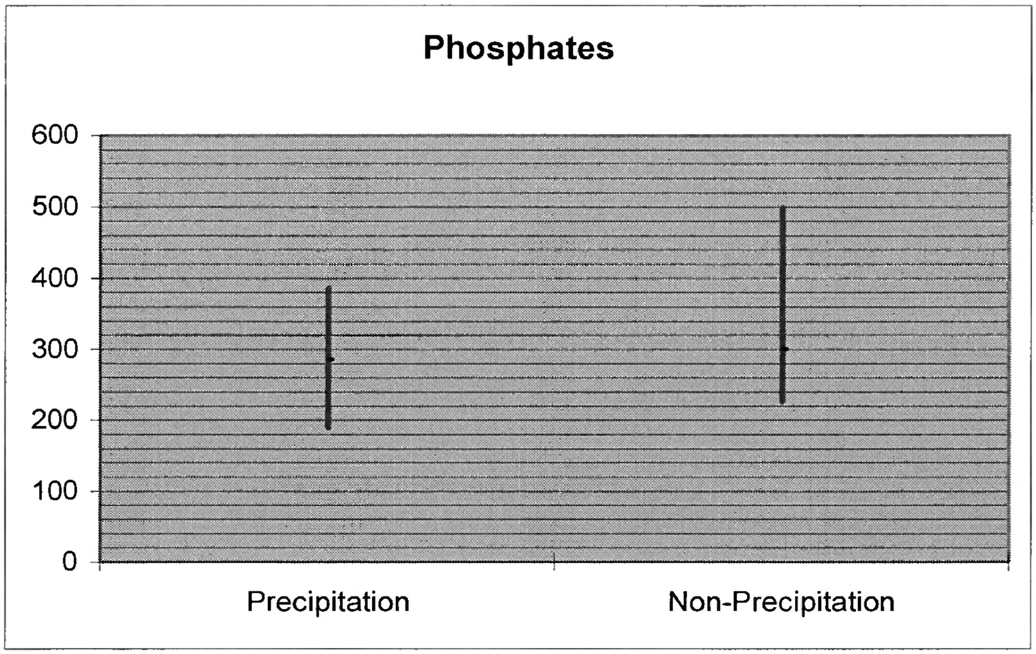

**9b.** Range of values for nitrates in ppm.



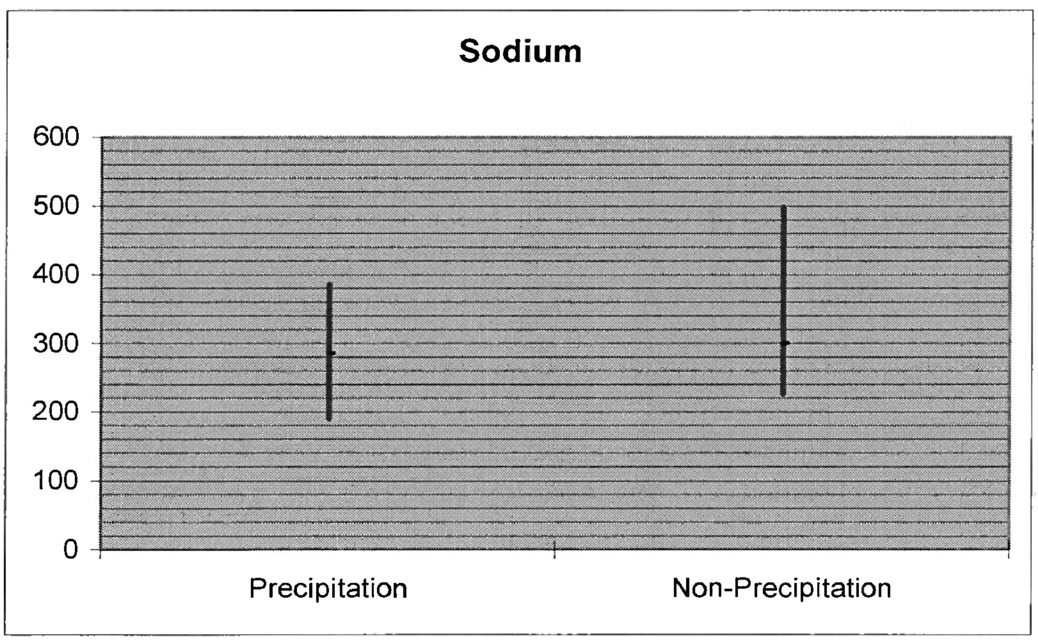

**9c.** Range of values for TSS in mg/L.




**9d.** Range of values for TDS in ppm.




**9c.** Range of values for phosphates in ppm.




**9f.** Range of values for sodium in ppm.

**Figure 9**: Range plots for readings at Heron Haven Wetland

In analyzing precipitation events vs. non-precipitation events, pH tended to be closer to 7.0 during rainfall. This most likely indicates dilution due to the rain. The other tests indicate little or no appreciable difference in precipitation vs. non-precipitation testing periods (see Appendix 5 for site results by rainfall events).

There appears to be very little yearly variation within the wetland. There were elevations of both sodium and phosphates in the summer months, and a marked decrease of nitrates in the spring. In analyzing the different sites in Heron Haven Wetland, the creek consistently had the highest readings of the elements tested. This site receives runoff from the housing development to the northeast of Heron Haven. It is interesting to note that this water was of lower quality than even the water from the runoff of Mulhall's Nursery and Maple Street. The most likely cause of these elevated levels is because of fertilizer from lawns and general household waste being washed into the storm drains, which in turn drain into the wetland.

# CHAPTER VI

## Conclusions

One of the original hypotheses of this study was that precipitation events might trigger a temporary increase of pollutants as they are washed in from surrounding areas, but should eventually create an overall diluting effect. From September 2001 through August 2002, Omaha suffered moderate to severe drought, and there were only five storm events with 2.5 cm or greater precipitation. Some preliminary connections might be made between rainfall and possible dilution of the variables tested, but further study in a wetter year would be necessary to validate any overall trends.

There was little spatial variation within the wetland, with the exception of the upland creek. It was hypothesized that the upland creek (characterized by site four) and the Maple Street buffer (characterized by site five) would have the highest chemical concentrations, as they are directly connected to the most likely pollution sources. As expected, nitrates and phosphates were consistently higher. The most likely cause of this degraded water quality is the use of fertilizers on area lawns and general household waste getting washed into the stream throughout the year. The buffer, however, consistently showed the lowest concentrations of phosphate, nitrate, TSS and TDS.

Of the three areas of actual wetland (disturbed wetland, primary wetland and spoils), the disturbed wetland had the best quality. The fact that the exceptional water quality coming from the Maple Street buffer runs into the disturbed wetland may account for it's lower levels of pollutants. Because the upland creek flows directly into the primary wetland, this part of Heron Haven tends to have slightly worse lower quality than that of the rest of the wetland.

Nitrates were subject to the most temporal variation in Heron Haven. Additionally, this study expected to show increased sodium in the winter and spring months because of the washing of street salts from surrounding roads during rainstorms and snowmelt. The results clearly show that increased sodium levels occurred in the middle of the summer, contrary to the expected results. As there were only two days during the winter months in which the streets were salted, an increase of sodium could not be verified. It is possible that during a winter with more snow, a sodium increase could be documented.

While runoff from the housing areas into the creek did show regularly degraded quality, this was rarely transferred to the wetland as a whole. The presence of natural springs no doubt has some effect on the overall water quality, perhaps much more than was previously credited. In addition, this wetland may experience a great deal of through-flow to the Big Papillion Creek, which has not been documented thus far. More study in this area, particularly during wetter years, would be valuable. Comparisons to urban wetlands that are not spring fed might also show contrasting results.

The hypothesis that runoff will have a negative effect on water quality of wetlands in urban areas was not conclusively indicated in this study.

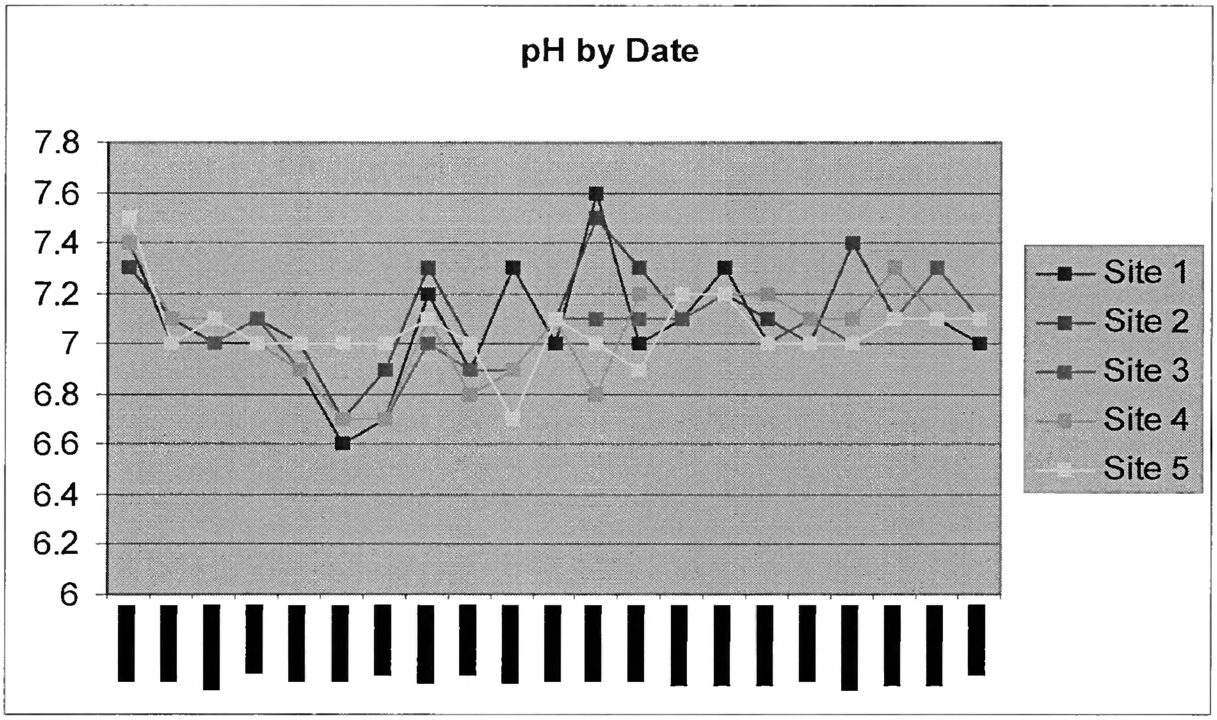
**Appendix 1**: Wetlands in the Omaha Area

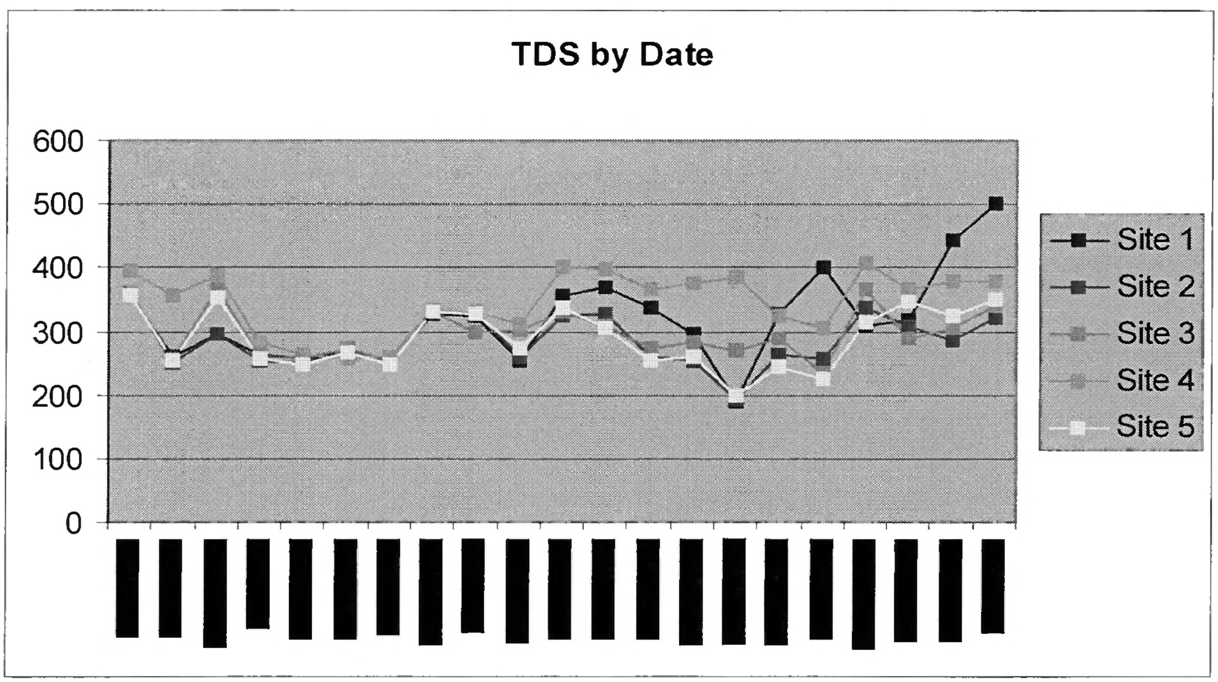
| **Name and / or Location of Wetland** | **Visually Verified** |
|---|---|
| Eagle Run Golf Course – 144th & Maple | Yes |
| Heron Haven Wetlands – 120th & Maple | Yes |
| Hefflinger Park – 117th & Maple | Yes |
| Linden Estates (private lake) – 142nd & Dodge | Yes |
| 180th & Pacific | Yes |
| Standing Bear Lake – west end, approx. 144th & Ida | Yes |
| Zorinsky Lake – northwest end, approx. 180th & Spring | Yes |
| Towl Park – 93rd & Center | Yes |
| 72nd & Cornhusker | Yes |
| 88th & Giles | Yes |
| 77th & Hwy 370 | *No* |
| Rumsey Station – 66th & Cornhusker | Yes |
| Hidden Lake – Fontenelle Forest | Yes |
| The Great Marsh – Fontenelle Forest | Yes |
| 16th & Locust | *No* |
| Carter Lake, inside south of east arm | Yes |
| Carter Lake, inside middle of east arm | Yes |
| Carter Lake, inside north of east arm | Yes |
| Miller Park – 24th & Kansas | Yes |
| 28th & State | *No* |
| Fontenelle Park – 50th & Ames | Yes |
| Benson Park – 70th & Military | Yes |

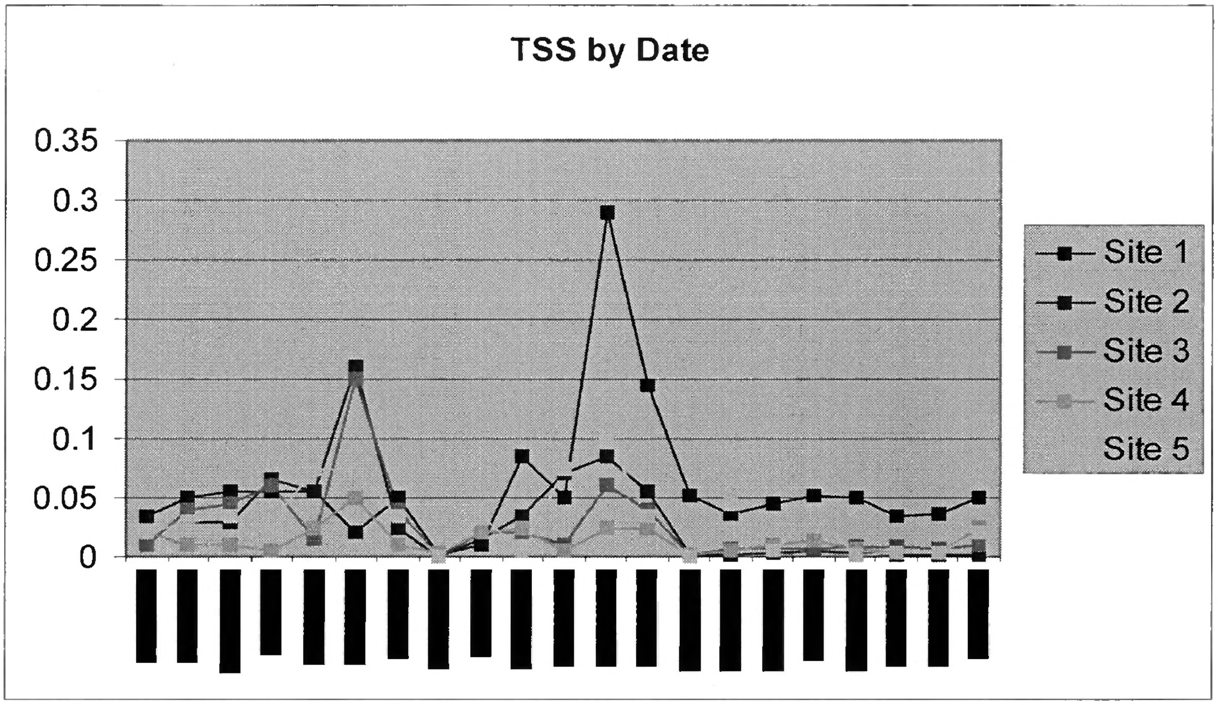
**Appendix 2**: Precipitation Events

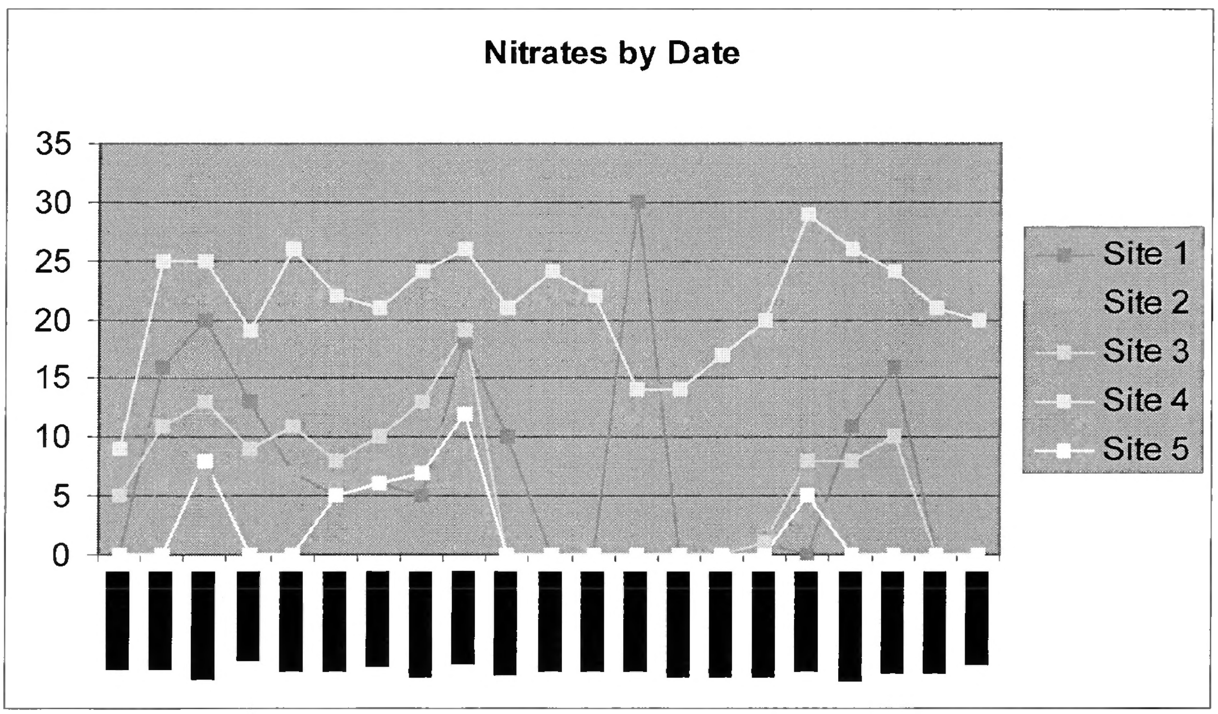
| **Date** | **Centimeters of Precipitation** |
|---|---|
| Sept 8 2001 | 3.2 |
| Oct 13 2001 | 4.5 |
| Nov 24 2001 | 3.5 |
| Apr 29 2002 | 4.6 |
| May 18 2002 | 6.6 |

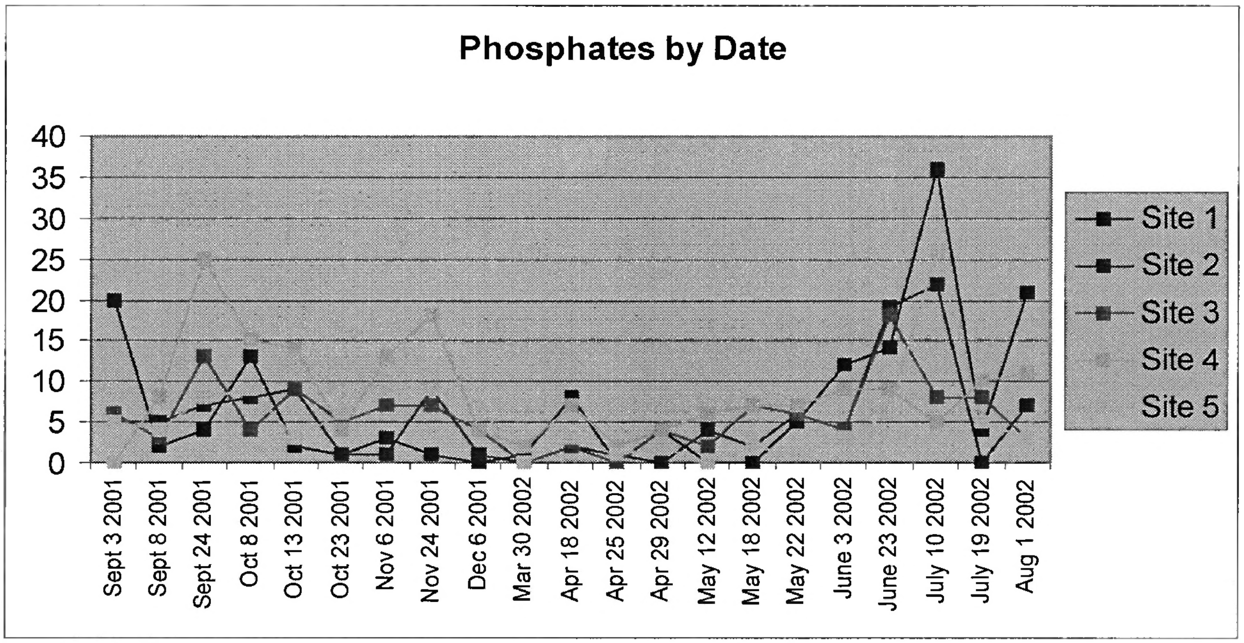
**Appendix 3**: Results by Date

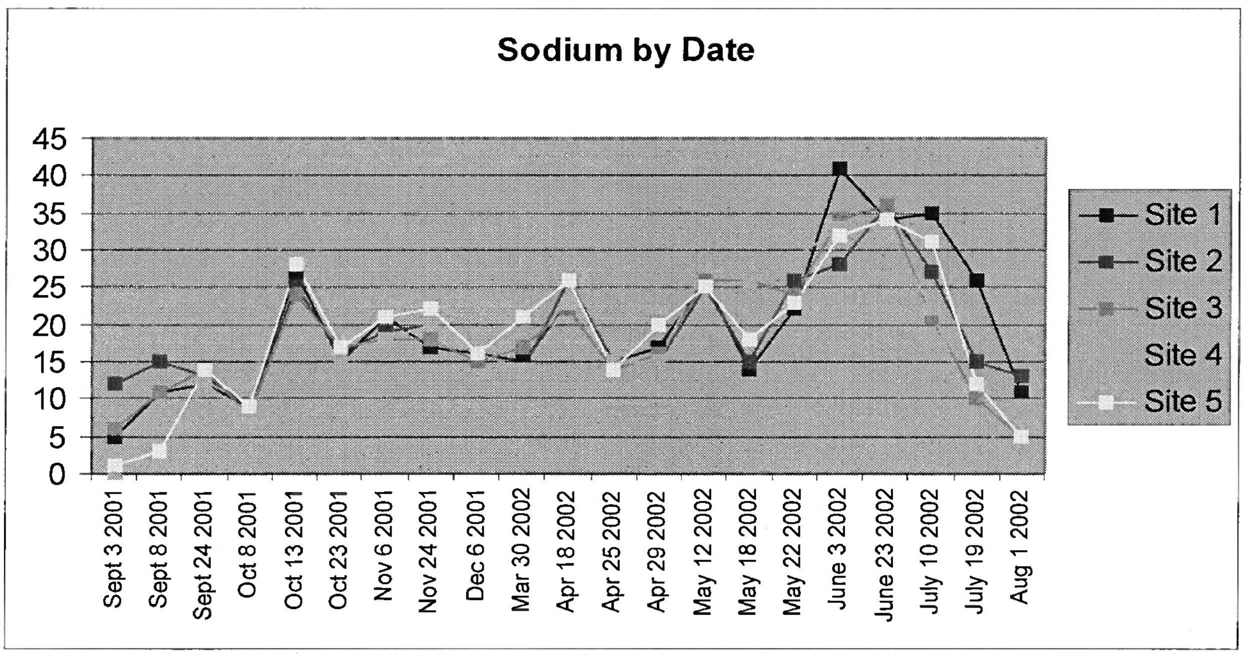



TSS by Date
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Site 1
Site 2
Site 3
Site 4
Site 5


Nitrates by Date
35
30
25
20
15
10
5
0
Site 1
Site 2
Site 3
Site 4
Site 5

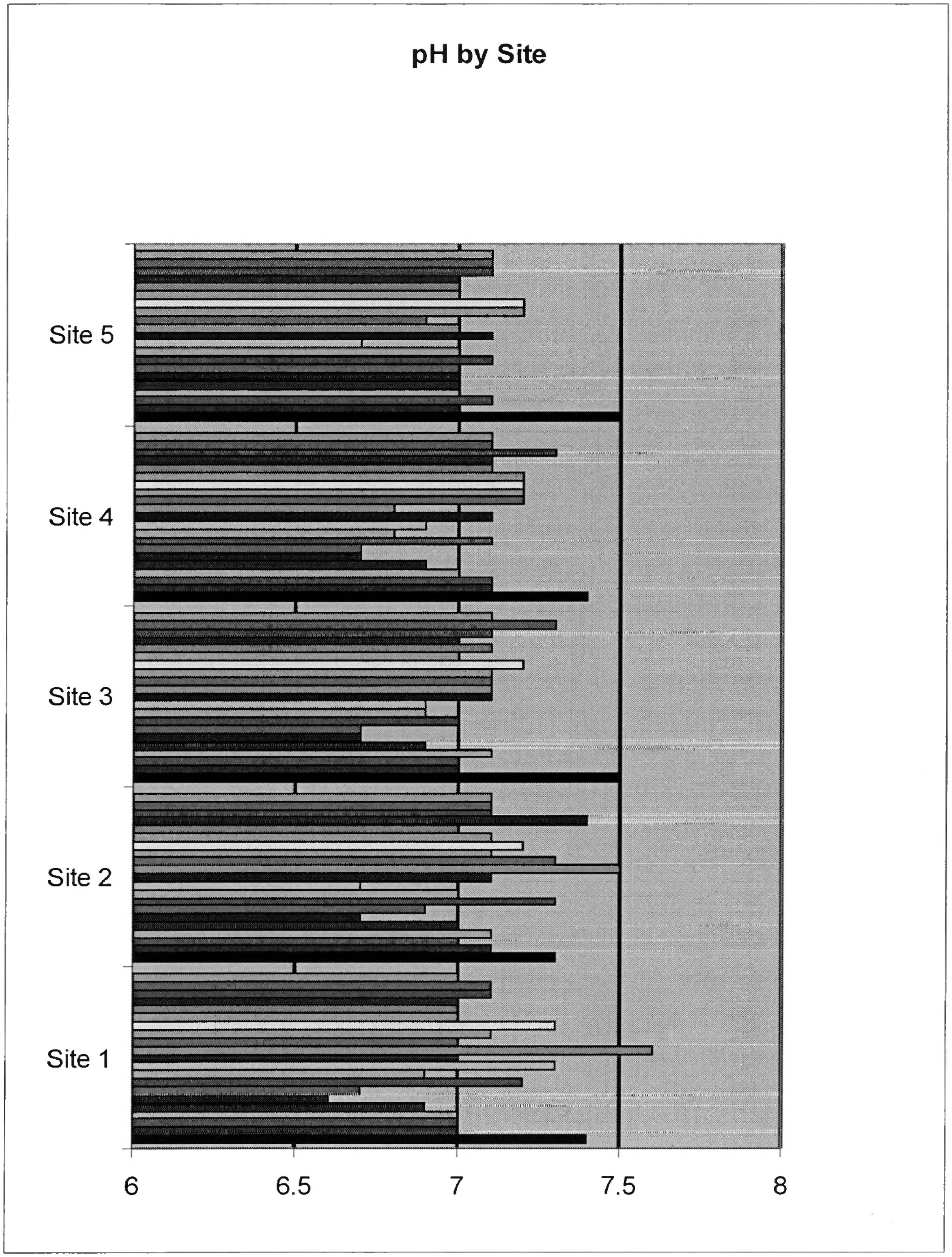

Phosphates by Date
40
35
30
25
20
15
10
5
0
Sept 3 2001
Sept 8 2001
Sept 24 2001
Oct 8 2001
Oct 13 2001
Oct 23 2001
Nov 6 2001
Nov 24 2001
Dec 6 2001
Mar 30 2002
Apr 18 2002
Apr 25 2002
Apr 29 2002
May 12 2002
May 18 2002
May 22 2002
June 3 2002
June 23 2002
July 10 2002
July 19 2002
Aug 1 2002
Site 1
Site 2
Site 3
Site 4
Site 5

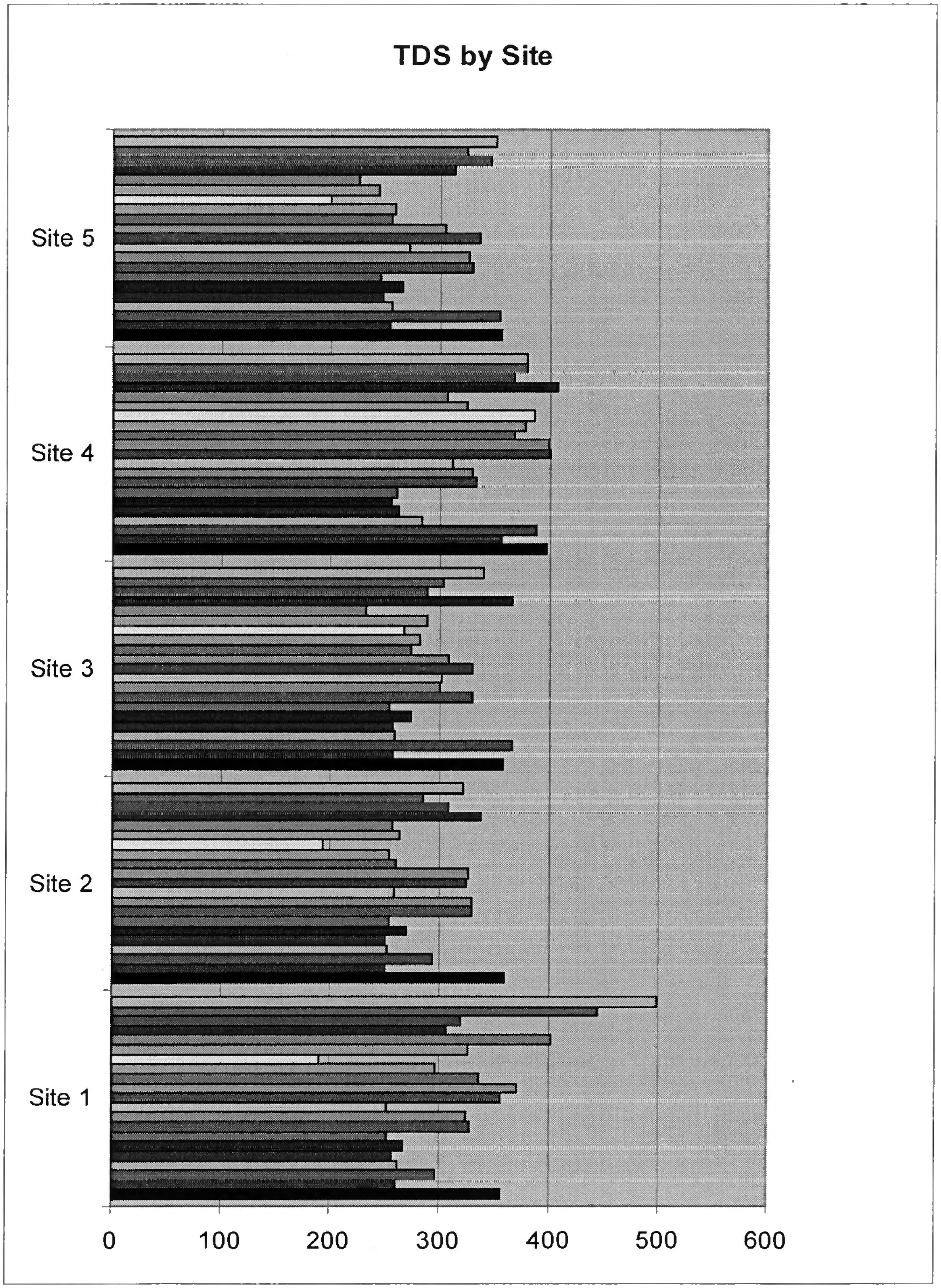

Sodium by Date
45
40
35
30
25
20
15
10
5
0
Sept 3 2001
Sept 8 2001
Sept 24 2001
Oct 8 2001
Oct 13 2001
Oct 23 2001
Nov 6 2001
Nov 24 2001
Dec 6 2001
Mar 30 2002
Apr 18 2002
Apr 25 2002
Apr 29 2002
May 12 2002
May 18 2002
May 22 2002
June 3 2002
June 23 2002
July 10 2002
July 19 2002
Aug 1 2002
Site 1
Site 2
Site 3
Site 4
Site 5

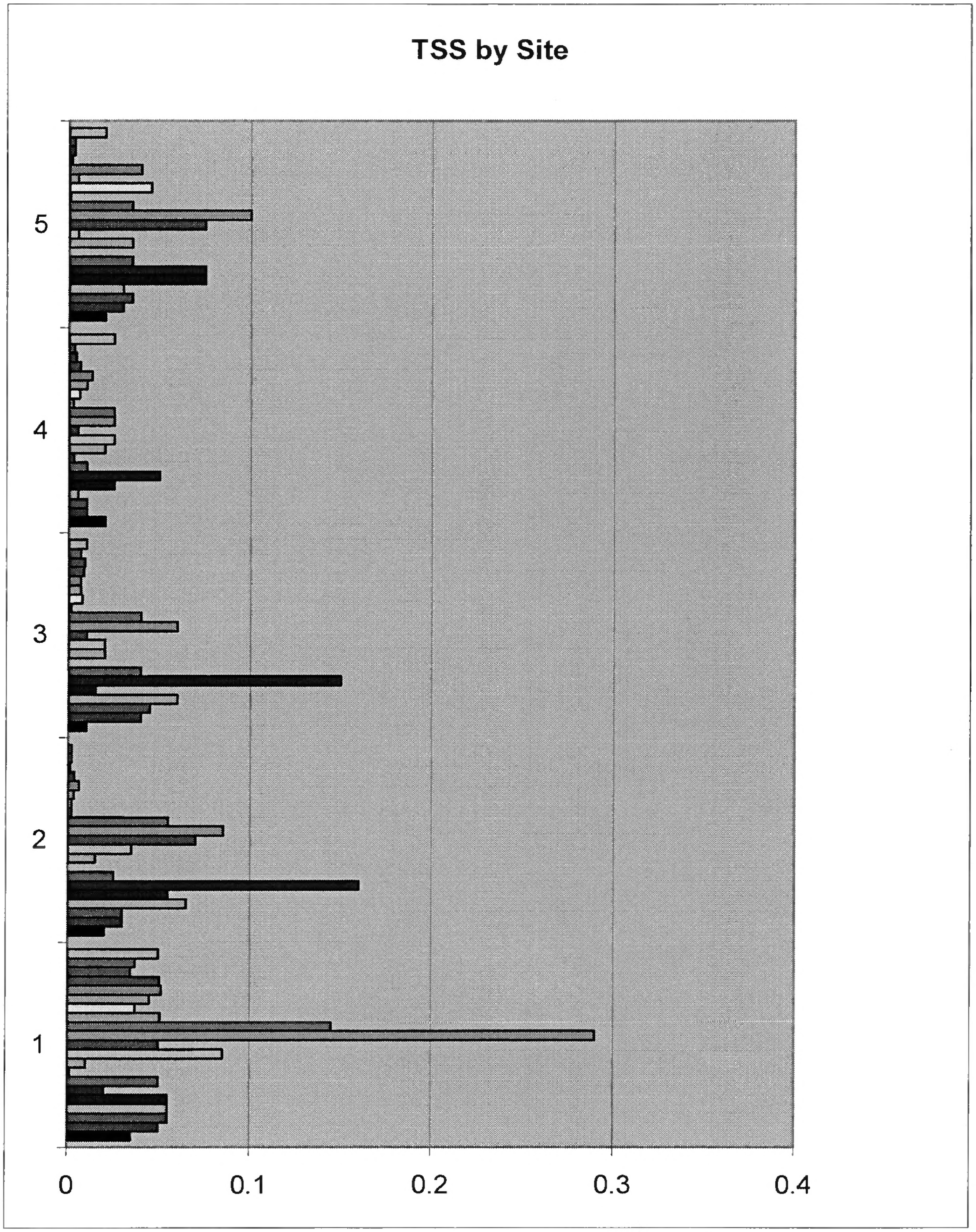
**Appendix 4**: Results by Site

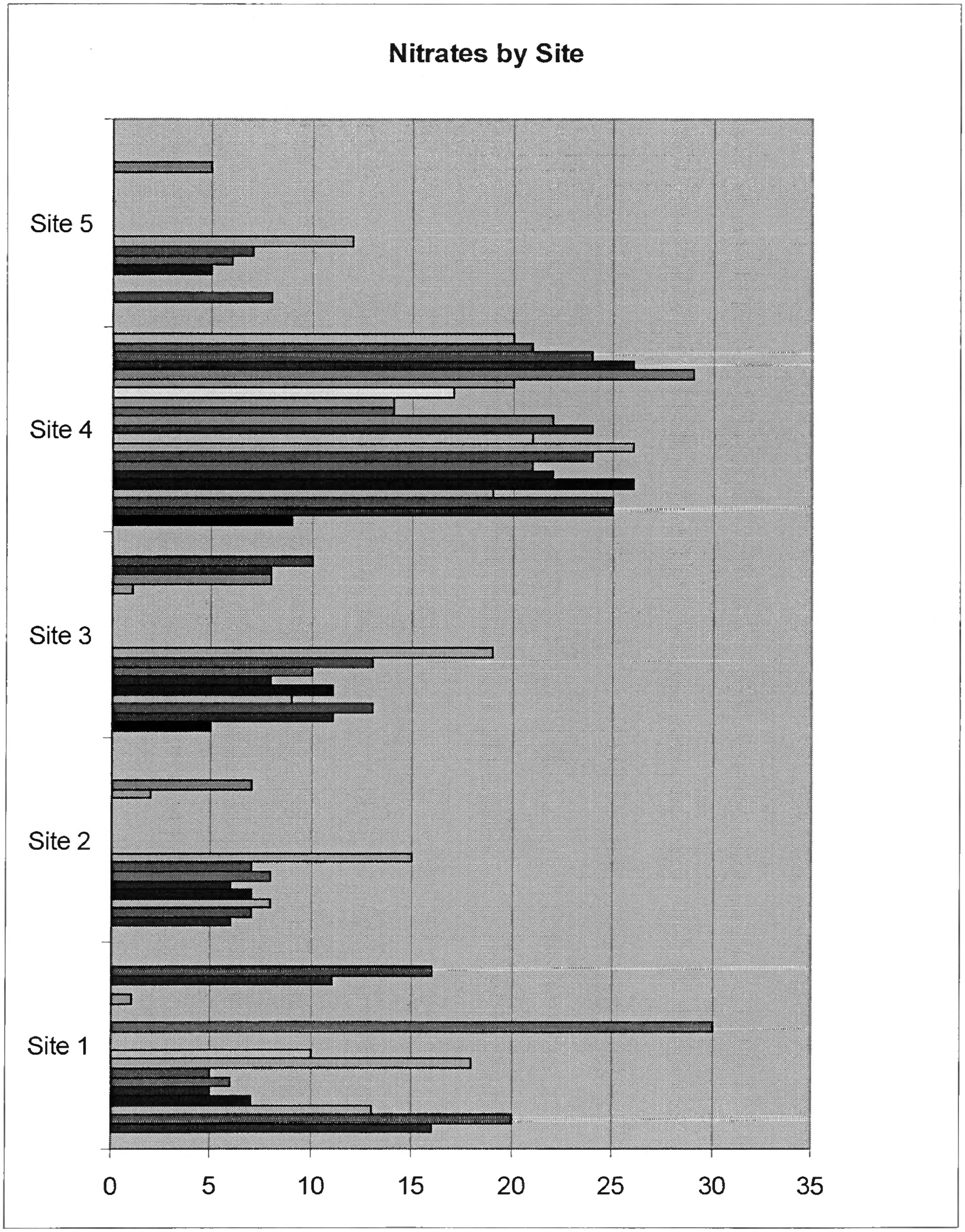
Key

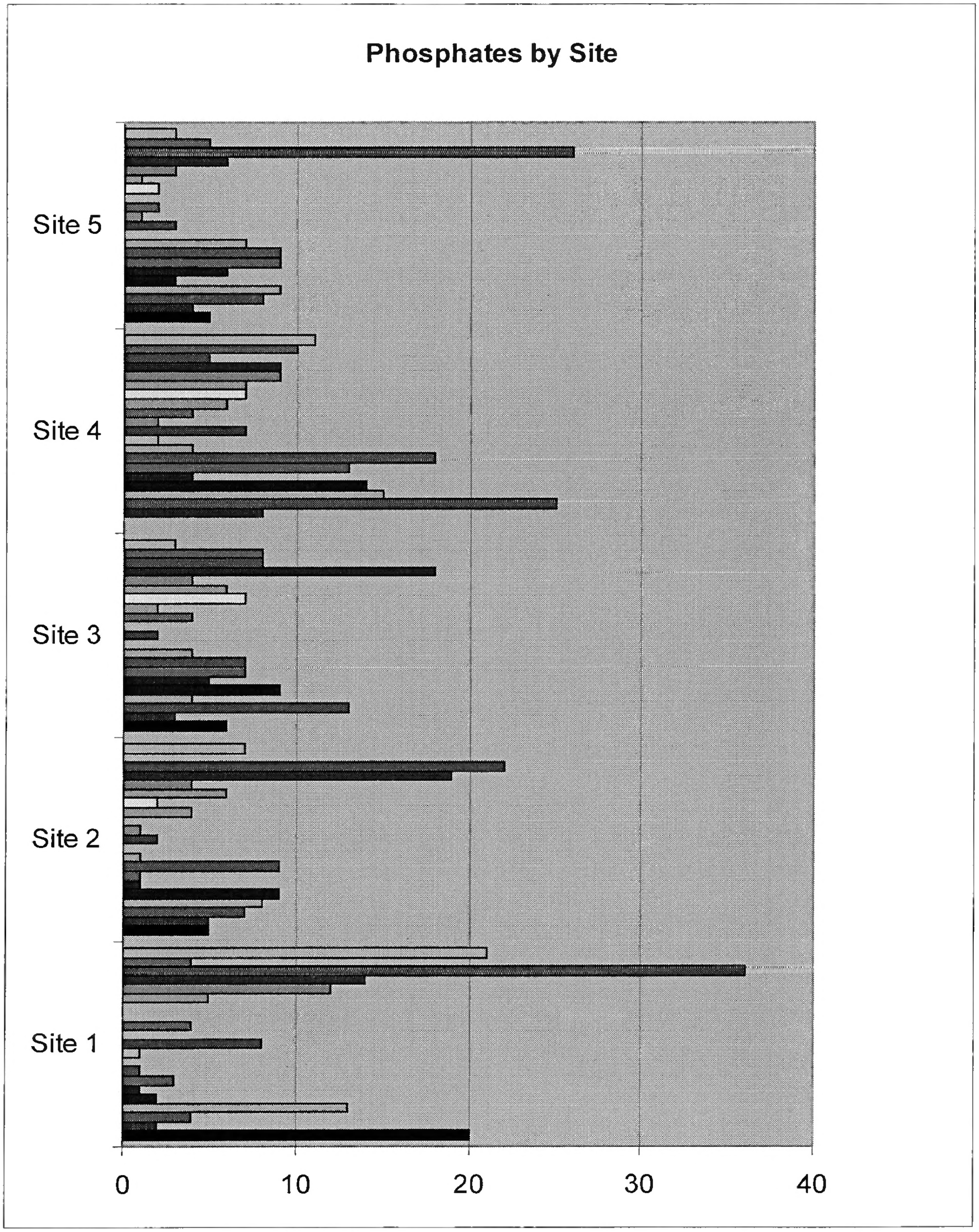
| | | | | |
|---|---|---|---|---|
| Sept 3 2001 | Oct 23 2001 | Apr 18 2002 | May 22 2002 | Aug 1 2002 |
| Sept 8 2001 | Nov 6 2001 | Apr 25 2002 | Jun 3 2002 | |
| Sept 24 2001 | Nov 24 2001 | Apr 29 2002 | Jun 23 2002 | |
| Oct 8 2001 | Dec 6 2001 | May 12 2002 | Jul 10 2002 | |
| Oct 13 2001 | Mar 30 2002 | May 18 2002 | Jul 19 2002 | |


pH by Site
Site 5
Site 4
Site 3
Site 2
Site 1
6
6.5
7
7.5
8

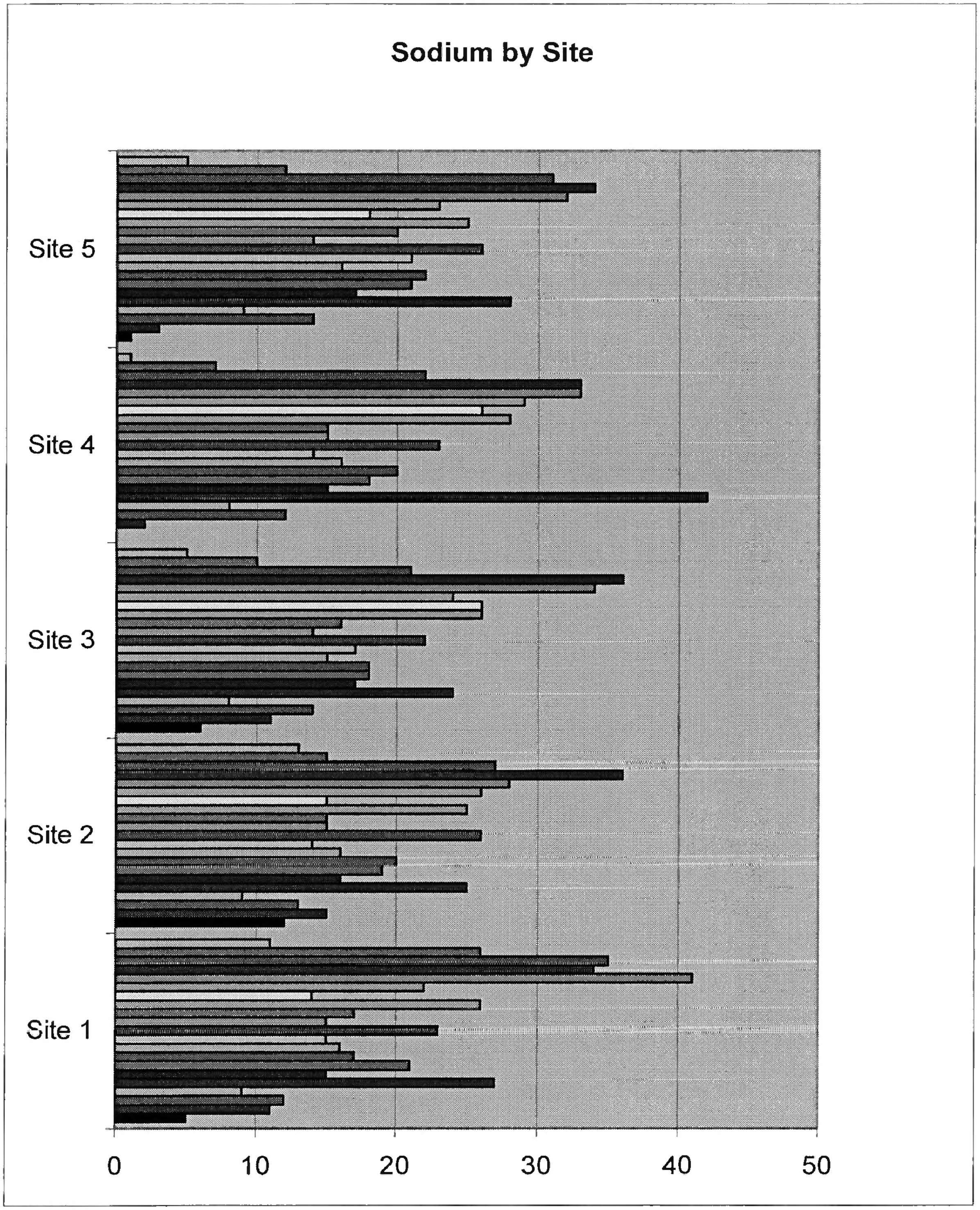

TDS by Site
Site 5
Site 4
Site 3
Site 2
Site 1
0
100
200
300
400
500
600


TSS by Site
5
4
3
2
1
0
0.1
0.2
0.3
0.4


Nitrates by Site
Site 5
Site 4
Site 3
Site 2
Site 1
0
5
10
15
20
25
30
35



Phosphates by Site
Site 5
Site 4
Site 3
Site 2
Site 1
0
10
20
30
40


Sodium by Site
Site 5
Site 4
Site 3
Site 2
Site 1
0
10
20
30
40
50

**Appendix 5**: Tables of Results by Site

**Table 8a**: Precipitation Events

| | Date | Temp | TDS | P | Na | N | pH | TSS |
|---|---|---|---|---|---|---|---|---|
| Site 1 | Sept 8 2001 | 20 | 260 | 16 | 11 | 2 | 7 | 0.05 |
| | Oct 13 2001 | 14.2 | 257 | 7 | 27 | 2 | 6.9 | 0.055 |
| | Nov 24 2001 | 7.7 | 328 | 5 | 17 | 1 | 7.2 | 0.0012 |
| | Apr 29 2002 | 19.6 | 336 | 30 | 17 | 4 | 7 | 0.145 |
| | May 18 2002 | 22.3 | 190 | 0 | 14 | 0 | 7.3 | 0.037 |
| Site 2 | Sept 8 2001 | 18.7 | 251 | 5 | 15 | 6 | 7.1 | 0.03 |
| | Oct 13 2001 | 15.3 | 250 | 9 | 25 | 7 | 7 | 0.055 |
| | Nov 24 2001 | 8 | 329 | 9 | 20 | 7 | 7.3 | 0.0002 |
| | Apr 29 2002 | 16.5 | 260 | 0 | 15 | 0 | 7.3 | 0.055 |
| | May 18 2002 | 24.9 | 193 | 2 | 15 | 0 | 7.2 | 0.002 |
| Site 3 | Sept 8 2001 | 20.1 | 257 | 3 | 11 | 11 | 7 | 0.04 |
| | Oct 13 2001 | 15.9 | 258 | 9 | 24 | 11 | 6.9 | 0.015 |
| | Nov 24 2001 | 8.6 | 330 | 7 | 18 | 13 | 7 | 0.0004 |
| | Apr 29 2002 | 17.2 | 274 | 4 | 16 | 0 | 7.1 | 0.04 |
| | May 18 2002 | 25.3 | 268 | 7 | 26 | 0 | 7.2 | 0.0075 |
| Site 4 | Sept 8 2001 | 18.3 | 355 | 8 | 2 | 25 | 7.1 | 0.01 |
| | Oct 13 2001 | 13 | 263 | 14 | 42 | 26 | 6.9 | 0.025 |
| | Nov 24 2001 | 10.2 | 333 | 18 | 20 | 24 | 7.1 | 0.0027 |
| | Apr 29 2002 | 16.4 | 367 | 4 | 15 | 14 | 7.2 | 0.025 |
| | May 18 2002 | 15.4 | 386 | 7 | 26 | 17 | 7.2 | 0.006 |
| Site 5 | Sept 8 2001 | 17.9 | 254 | 4 | 3 | 0 | 7 | 0.03 |
| | Oct 13 2001 | 14.6 | 248 | 3 | 28 | 0 | 7 | 0.075 |
| | Nov 24 2001 | 8.1 | 329 | 9 | 22 | 7 | 7.1 | 0.0001 |
| | Apr 29 2002 | 13.2 | 255 | 2 | 20 | 0 | 6.9 | 0.035 |
| | May 18 2002 | 21.4 | 200 | 2 | 18 | 0 | 7.2 | 0.0453 |

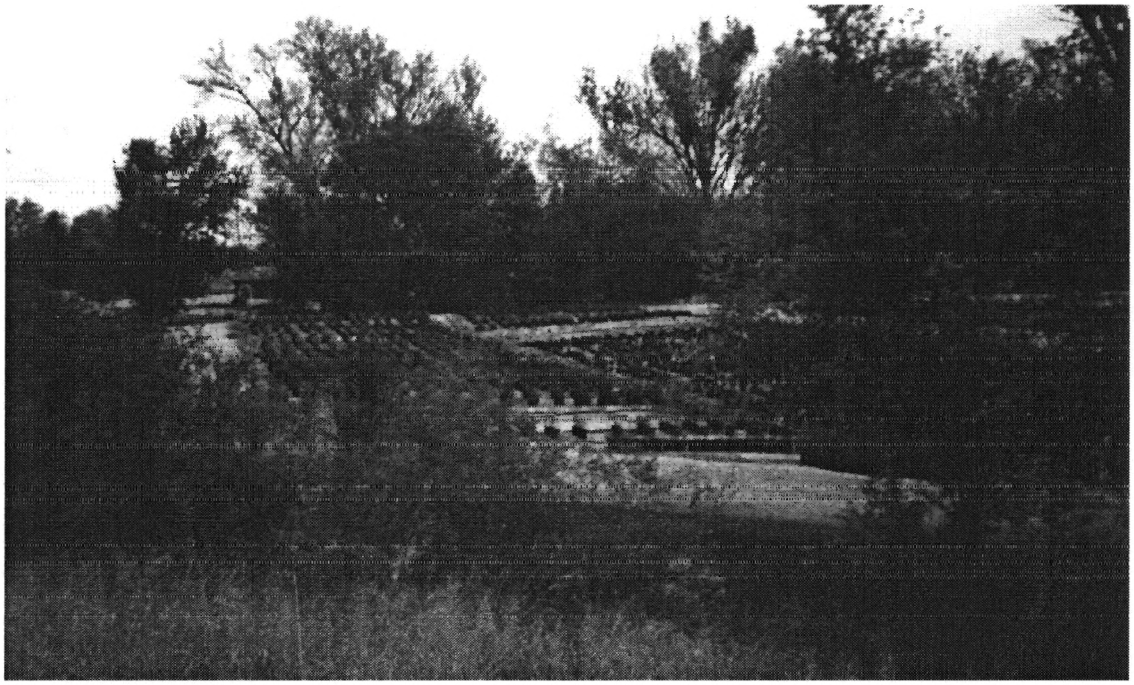
**Table 8b**: Non-Precipitation Events

| | Date | Temp | TDS | P | Na | N | pH | TSS |
|---|---|---|---|---|---|---|---|---|
| Site 1 | Sept 3 2001 | 26.7 | 355 | 0 | 5 | 20 | 7.4 | 0.035 |
| | Sept 24 2001 | 20.1 | 296 | 20 | 12 | 4 | 7 | 0.055 |
| | Oct 8 2001 | 17 | 262 | 13 | 9 | 13 | 7 | 0.055 |
| | Oct 23 2001 | 11.2 | 267 | 5 | 15 | 1 | 6.6 | 0.02 |
| | Nov 6 2001 | 11 | 252 | 6 | 21 | 3 | 6.7 | 0.05 |
| | Dec 6 2001 | 0.8 | 325 | 18 | 16 | 0 | 6.9 | 0.01 |
| | Mar 30 2002 | 12.4 | 252 | 10 | 15 | 1 | 7.3 | 0.085 |
| | Apr 18 2002 | 20.5 | 356 | 0 | 23 | 8 | 7 | 0.05 |
| | Apr 25 2002 | 10.4 | 370 | 0 | 15 | 0 | 7.6 | 0.29 |

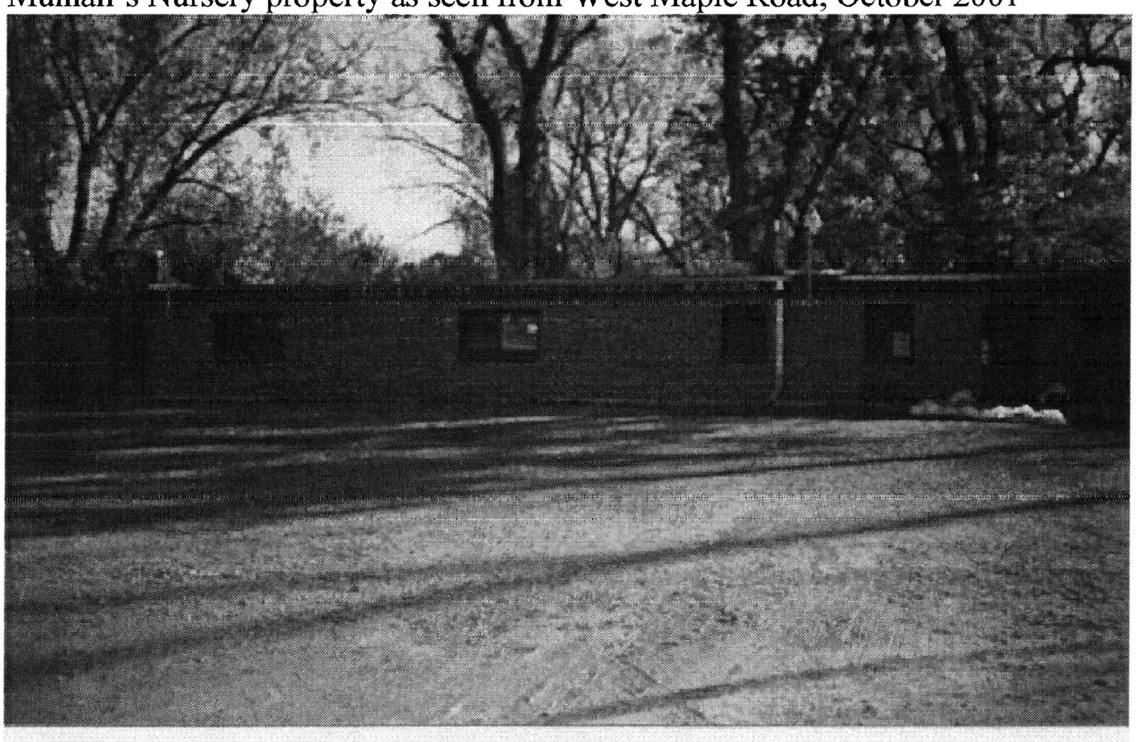
| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | May 12 2002 | 13.6 | 296 | 0 | 26 | 0 | 7.1 | 0.051 |
| | May 22 2002 | 21.9 | 326 | 1 | 22 | 5 | 7 | 0.045 |
| | June 3 2002 | 22.6 | 401 | 0 | 41 | 12 | 7 | 0.0515 |
| | June 23 2002 | 24.7 | 307 | 11 | 34 | 14 | 7 | 0.0505 |
| | July 10 2002 | 32.5 | 319 | 16 | 35 | 36 | 7.1 | 0.0345 |
| | July 19 2002 | 33.2 | 444 | 0 | 26 | 4 | 7.1 | 0.037 |
| | Aug 1 2002 | 29.9 | 499 | 0 | 11 | 21 | 7 | 0.05 |
| Site 2 | Sept 3 2001 | 26.4 | 359 | 5 | 12 | 0 | 7.3 | 0.02 |
| | Sept 24 2001 | 18.7 | 294 | 7 | 13 | 7 | 7 | 0.03 |
| | Oct 8 2001 | 16.8 | 253 | 8 | 9 | 8 | 7.1 | 0.065 |
| | Oct 23 2001 | 12.6 | 270 | 1 | 16 | 6 | 6.7 | 0.16 |
| | Nov 6 2001 | 12.4 | 254 | 1 | 19 | 8 | 6.9 | 0.025 |
| | Dec 6 2001 | 2.2 | 330 | 1 | 16 | 15 | 7 | 0.015 |
| | Mar 30 2002 | 11.6 | 259 | 0 | 14 | 0 | 6.7 | 0.035 |
| | Apr 18 2002 | 19.8 | 324 | 2 | 26 | 0 | 7.1 | 0.07 |
| | Apr 25 2002 | 13.3 | 326 | 1 | 15 | 0 | 7.5 | 0.085 |
| | May 12 2002 | 14.1 | 254 | 4 | 25 | 0 | 7.1 | 0.002 |
| | May 22 2002 | 25.9 | 264 | 6 | 26 | 2 | 7.1 | 0.003 |
| | June 3 2002 | 25.6 | 257 | 4 | 28 | 7 | 7 | 0.006 |
| | June 23 2002 | 27.5 | 337 | 19 | 36 | 0 | 7.4 | 0.0035 |
| | July 10 2002 | 32.9 | 309 | 22 | 27 | 0 | 7.1 | 0.001 |
| | July 19 2002 | 33.9 | 286 | 0 | 15 | 0 | 7.1 | 0.002 |
| | Aug 1 2002 | 31.3 | 322 | 7 | 13 | 0 | 7.1 | 0.002 |
| Site 3 | Sept 3 2001 | 24.3 | 358 | 6 | 6 | 5 | 7.5 | 0.01 |
| | Sept 24 2001 | 19.3 | 366 | 13 | 14 | 13 | 7 | 0.045 |
| | Oct 8 2001 | 17 | 259 | 4 | 8 | 9 | 7.1 | 0.06 |
| | Oct 23 2001 | 12.9 | 273 | 5 | 17 | 8 | 6.7 | 0.15 |
| | Nov 6 2001 | 12.5 | 254 | 7 | 18 | 10 | 6.7 | 0.04 |
| | Dec 6 2001 | 3.6 | 300 | 4 | 15 | 19 | 6.9 | 0.02 |
| | Mar 30 2002 | 11 | 302 | 0 | 17 | 0 | 6.9 | 0.02 |
| | Apr 18 2002 | 20.7 | 330 | 2 | 22 | 0 | 7.1 | 0.01 |
| | Apr 25 2002 | 13.1 | 309 | 0 | 14 | 0 | 7.1 | 0.06 |
| | May 12 2002 | 13.9 | 282 | 2 | 26 | 0 | 7.1 | 0.0015 |
| | May 22 2002 | 26.5 | 288 | 6 | 24 | 1 | 7 | 0.007 |
| | June 3 2002 | 26.1 | 233 | 4 | 34 | 8 | 7.1 | 0.007 |
| | June 23 2002 | 27.5 | 365 | 18 | 36 | 8 | 7 | 0.0085 |
| | July 10 2002 | 32.8 | 289 | 8 | 21 | 10 | 7.1 | 0.009 |
| | July 19 2002 | 32.9 | 304 | 8 | 10 | 0 | 7.3 | 0.007 |
| | Aug 1 2002 | 31.2 | 339 | 3 | 5 | 0 | 7.1 | 0.01 |
| Site 4 | Sept 3 2001 | 15 | 396 | 0 | 0 | 9 | 7.4 | 0.02 |
| | Sept 24 2001 | 17.5 | 387 | 25 | 12 | 25 | 7.1 | 0.01 |
| | Oct 8 2001 | 14.3 | 283 | 15 | 8 | 19 | 7 | 0.005 |
| | Oct 23 2001 | 11.8 | 256 | 4 | 15 | 22 | 6.7 | 0.05 |
| | Nov 6 2001 | 12.5 | 260 | 13 | 18 | 21 | 6.7 | 0.01 |
| | Dec 6 2001 | 8.4 | 330 | 4 | 16 | 26 | 6.8 | 0.02 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Mar 30 2002 | 11 | 312 | 2 | 14 | 21 | 6.9 | 0.025 |
| | Apr 18 2002 | 15.5 | 400 | 7 | 23 | 24 | 7.1 | 0.005 |
| | Apr 25 2002 | 10 | 398 | 2 | 15 | 22 | 6.8 | 0.025 |
| | May 12 2002 | 11.5 | 377 | 6 | 28 | 14 | 7.2 | 0.0025 |
| | May 22 2002 | 15 | 324 | 7 | 29 | 20 | 7.2 | 0.01 |
| | June 3 2002 | 15.5 | 306 | 9 | 33 | 29 | 7.1 | 0.013 |
| | June 23 2002 | 16.2 | 406 | 9 | 33 | 26 | 7.1 | 0.0065 |
| | July 10 2002 | 18.1 | 367 | 5 | 22 | 24 | 7.3 | 0.004 |
| | July 19 2002 | 19 | 378 | 10 | 7 | 21 | 7.1 | 0.003 |
| | Aug 1 2002 | 17.2 | 379 | 11 | 1 | 20 | 7.1 | 0.025 |
| Site 5 | Sept 3 2001 | 25.3 | 355 | 5 | 1 | 0 | 7.5 | 0.02 |
| | Sept 24 2001 | 17.7 | 354 | 8 | 14 | 8 | 7.1 | 0.035 |
| | Oct 8 2001 | 13.9 | 256 | 9 | 9 | 0 | 7 | 0.03 |
| | Oct 23 2001 | 12.3 | 266 | 6 | 17 | 5 | 7 | 0.075 |
| | Nov 6 2001 | 12 | 246 | 9 | 21 | 6 | 7 | 0.035 |
| | Dec 6 2001 | 4.4 | 326 | 7 | 16 | 12 | 7 | 0.035 |
| | Mar 30 2002 | 10.6 | 272 | 0 | 21 | 0 | 6.7 | 0.005 |
| | Apr 18 2002 | 19.8 | 336 | 3 | 26 | 0 | 7.1 | 0.075 |
| | Apr 25 2002 | 12.8 | 305 | 1 | 14 | 0 | 7 | 0.1 |
| | May 12 2002 | 13.8 | 259 | 0 | 25 | 0 | 7.2 | 0.0005 |
| | May 22 2002 | 21.6 | 245 | 1 | 23 | 0 | 7 | 0.005 |
| | June 3 2002 | 22 | 226 | 3 | 32 | 5 | 7 | 0.04 |
| | June 23 2002 | 25.2 | 313 | 6 | 34 | 0 | 7 | 0.0015 |
| | July 10 2002 | 20.5 | 346 | 26 | 31 | 0 | 7.1 | 0.003 |
| | July 19 2002 | 21.2 | 325 | 5 | 12 | 0 | 7.1 | 0.003 |
| | Aug 1 2002 | 18.6 | 350 | 3 | 5 | 0 | 7.1 | 00.2 |

**Appendix 6**: Photographs of Heron Haven Wetland and the Surrounding Area



Mulhall's Nursery property as seen from West Maple Road, October 2001



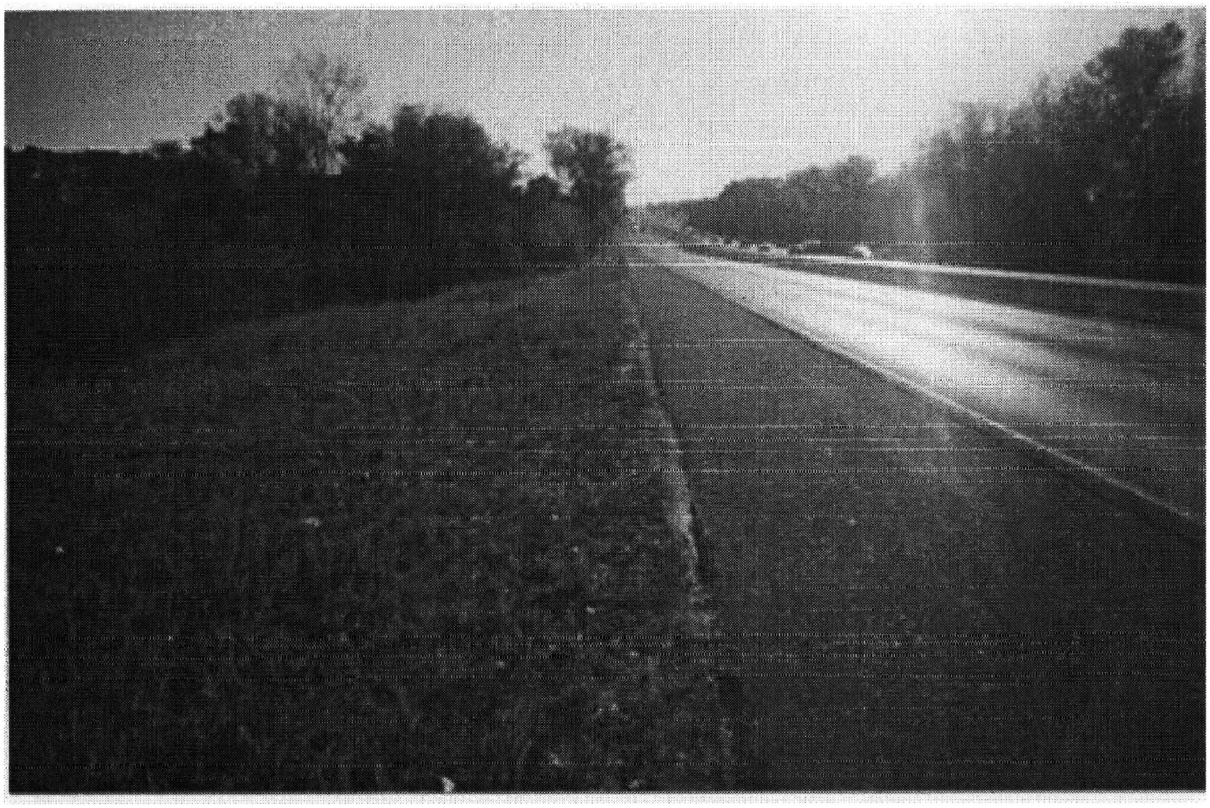
Heron Haven / Audubon Society building October, 2001

Wooded "uplands", October, 2001

Wooded "uplands", August 2002

Filled in dump area, August 2002

Trail in the fill area, August 2002



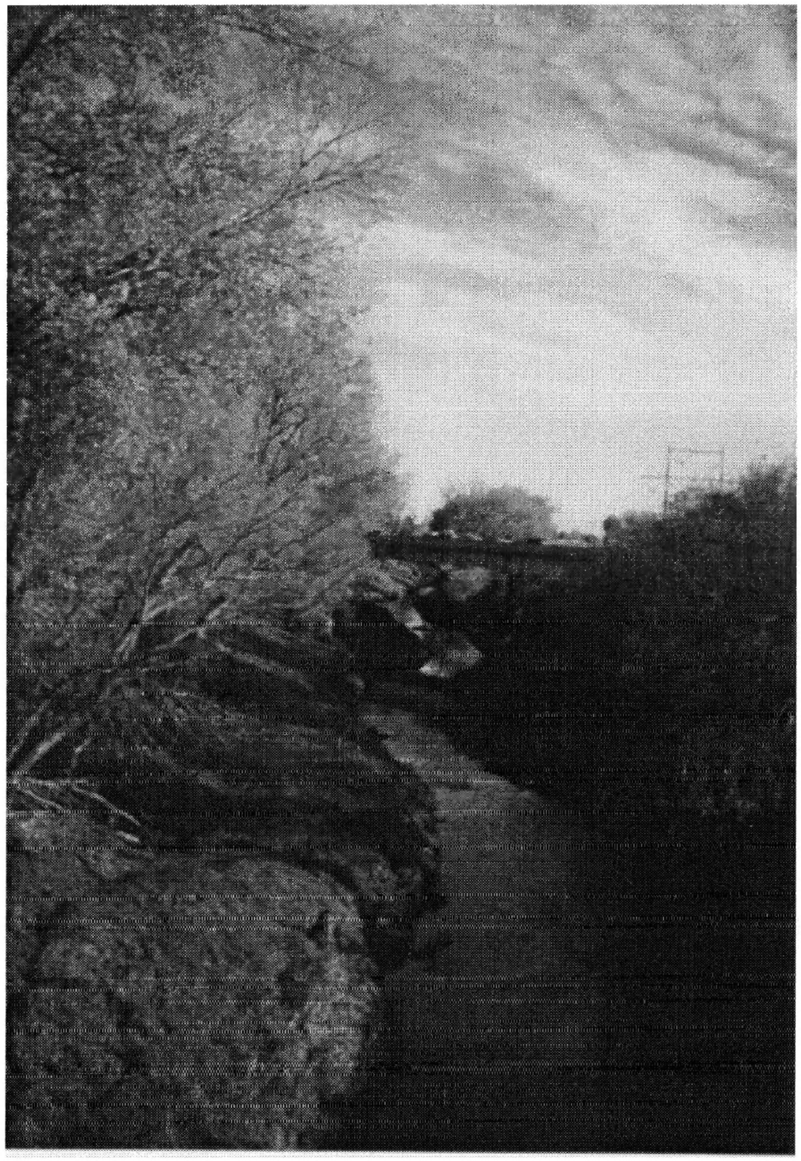
West Maple Road, Heron Haven to left, October 2001

The Knolls Golf Course, Heron Haven to right, October, 2001

Lake Forest Apartments' property, August 2002


Overlooking Heron Haven from the residences and Lake Forest Apartments, August 2002

Manderson Street, Heron Haven to right, October, 2001



Big Papillion River where it runs near Heron Haven. The bridge pictured is West Maple Road. October 2001

Site 1: Primary Wetland, October 2001

Site 1: Primary Wetland, August 2002

Site 1 – actual collection site, August 2002

Site 2 as seen from West Maple Road, October 2001

Site 2: Disturbed Wetland, October 2001

Site 2: Disturbed Wetland, August 2002

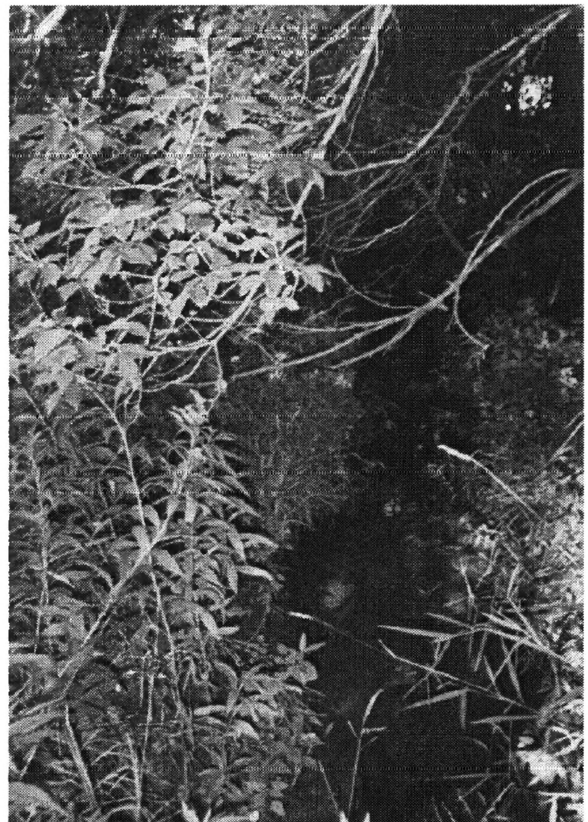
Site 3: Spoils, October 2001

Site 3: Spoils, August 2002

Site 4: Creek, October 2001

Site 4: Creek, August 2002

Site 5: Maple Street Buffer, October 2001



Site 5: Maple Street Buffer, August 2001

View of Mulhall's property, buffer and disturbed wetland from West Maple Road, October 2001

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** Heron Haven Wetland concept plans courtesy of Steve Oltmans, Nebraska Resources District (NRD), General Manager, October, 1999.