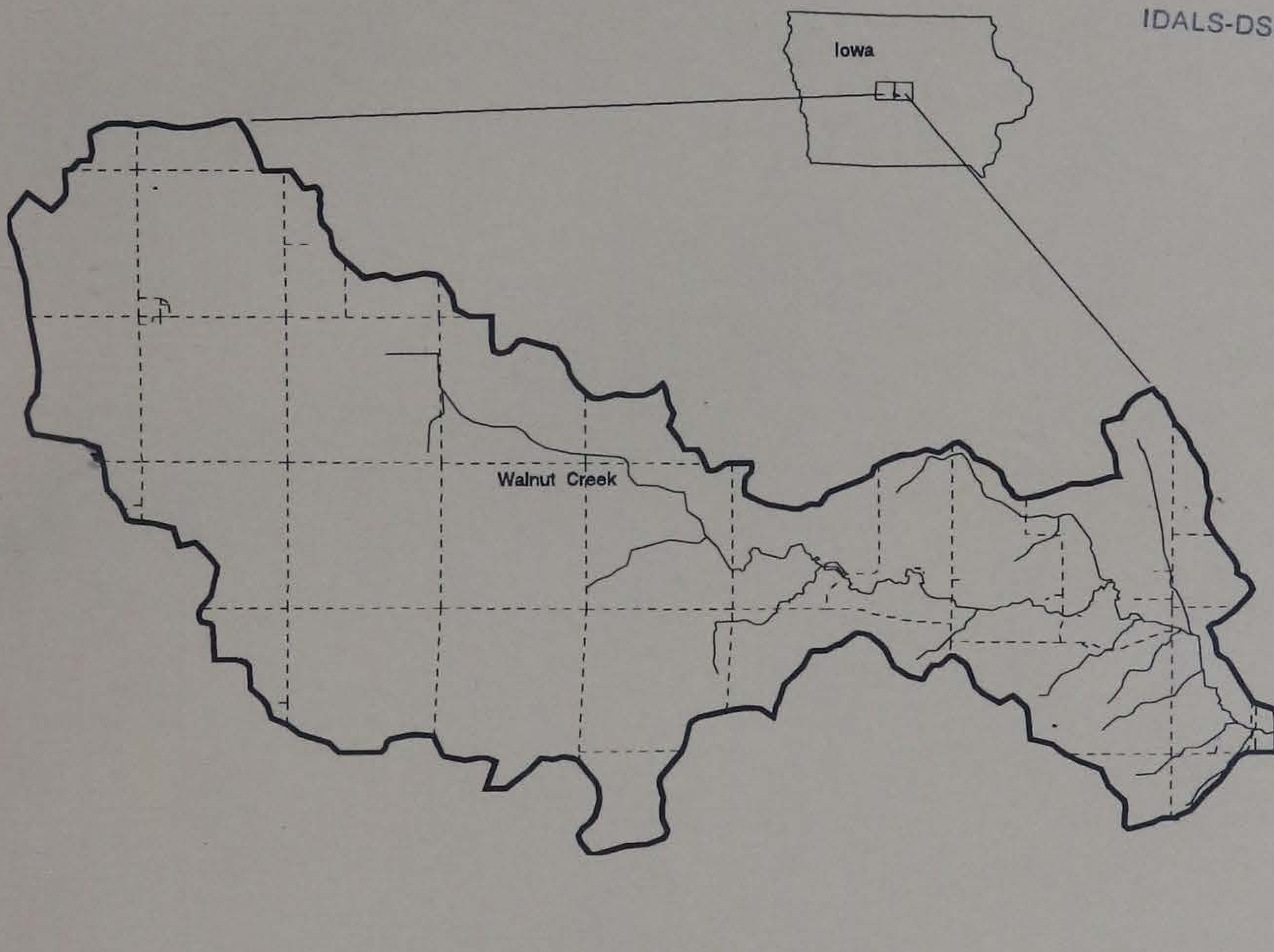
WALNUT CREEK WATERSHED RESEARCH PROTOCOL REPORT 1994



BULLETIN NUMBER: 94-1

Prepared by:
USDA-ARS
National Soil Tilth Laboratory

WALNUT CREEK WATERSHED

RESEARCH PROTOCOL REPORT

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Prepared by:

Patricia A. Sauer

Jerry L. Hatfield

A Combined MSEA and MASTER Project

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FOREWORD

Walnut Creek watershed in central Iowa was selected as a large scale watershed study site for part of the Management Systems Evaluation Areas (MSEA) Program. The selection of this watershed was completed in 1990 and a series of monitoring projects began that same year. In 1991, the watershed was selected as the primary research area for the U.S.EPA Midwest Agricultural Surface/Subsurface Transport and Effects Research (MASTER) project. Over the period from 1990 there have been continual additions to the original project scope as more investigators have become part of the research team. This report has been assembled to improve communication and exchange of information among the researchers and to document the different projects being conducted within the watershed. The report provides general information about the watershed and the surrounding area, project objectives and infrastructure, and research protocols of the various investigators. We hope that this report provides assistance to those who will be preparing project reports and manuscripts based on results from Walnut Creek watershed research projects.

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WALNUT CREEK WATERSHED

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INTRODUCTION

Water quality changes as a result of farming practices have been difficult to document. Several studies have shown the possible linkage between agricultural activities and detections of herbicides in groundwater and these studies served as a basis for the development of the Management Systems Evaluation Areas (MSEA) program sponsored by the USDA-ARS, USDA-CSRS, and USGS in cooperation with the USDA-ES and USDA-SCS. The MSEA study sites are located in Iowa, Minnesota, Missouri, Nebraska, and Ohio. The overall approaches for these studies have been described in an USDA report that was released in 1994 (USDA, 1994).

Site selection and development of the research programs for the MSEA sites began in 1990. In Iowa, three existing research sites were selected for MSEA research programs because they had a history of water quality research as part of their project design. These sites are located at the Northeast Research Station in Nashua, the Till Hydrology site near Boone, and the Deep Loess Research Station near Treynor. The MSEA program also required that a watershed study site be selected during the first year of the project. Walnut Creek watershed was selected after extensive surveys and initial reconnaissance of the Des Moines Landform region. In late 1990 and early 1991, a Walnut Creek watershed monitoring program was developed and implemented. The monitoring program is managed by the USDA National Soil Tilth Laboratory (NSTL). There are 28 investigators from five agencies that include USDA ARS, ISU experimental farm, ISU Extension Service, USGS and U.S.EPA that are involved with research projects in the watershed.

The impetus for selecting a watershed-scale study was to provide an evaluation of the on-site and off-site movement of herbicides and nitrate-nitrogen from from fields with different farming practices. Land use in Walnut Creek watershed is primarily row crop agriculture. The watershed is intensively tile drained and surface and subsurface water drains to Walnut Creek; open stream channel exists only in the lower half of the watershed. The watershed was divided into three subwatersheds with subbasins. Fields were selected within these subwatersheds for intensive evaluation of different farming practices and subbasins were selected for monitoring the integrative impact of farming practices. Farmers in the watershed have been very cooperative in allowing MSEA project researchers to monitor their operations that often results in an intrusion on their farming routines.

In 1991, Walnut Creek watershed (MSEA site in Iowa) was selected for the the U.S.EPA Midwest Agricultural Surface/Subsurface Transport and Effects Research (MASTER) project. The purpose of this project is to monitor the ecological impacts of agricultural practices on the terrestrial environment. Several agencies have worked cooperatively on this project and managers of these projects include: Jerry Hatfield of USDA-ARS, Jim Baker from Iowa State University (USDA-CSRS), Phil Soenksen from USGS-WRD, and Bob Swank from U.S.EPA. These individuals have guided the MASTER projects and the investigators listed in this document towards achieving project goals. In cooperation with the MSEA investigators, U.S.EPA scientist from five

U.S.EPA laboratories are involved in evaluating the ecological impact of farming practices on the terrestrial environment in Walnut Creek watershed.

This report documents the research protocols used in Walnut Creek watershed, provides of a summary of the types of data that are available from the MSEA and MASTER research studies, and shows the linkage among the different investigators. This document can be used as a reference by those who will be preparing project reports and manuscripts based on results of Walnut Creek watershed research projects and by those who are developing research projects similar to those described in this report.

SECTION 1. GEOGRAPHICAL SETTING

Section 1-A Soils of Walnut Creek Watershed

D.B. Jaynes NSTL

Soils within the Walnut Creek watershed were formed predominately in calcareous glacial till deposited within the Des Moines Lobe during the Cary substage of the Wisconsin glaciation (Figure 1). The till of the Des Moines Lobe is characterized by low relief swell and swale topography that is oriented transverse and slightly concave to the direction of ice flow. Within Walnut Creek, the swell-swale

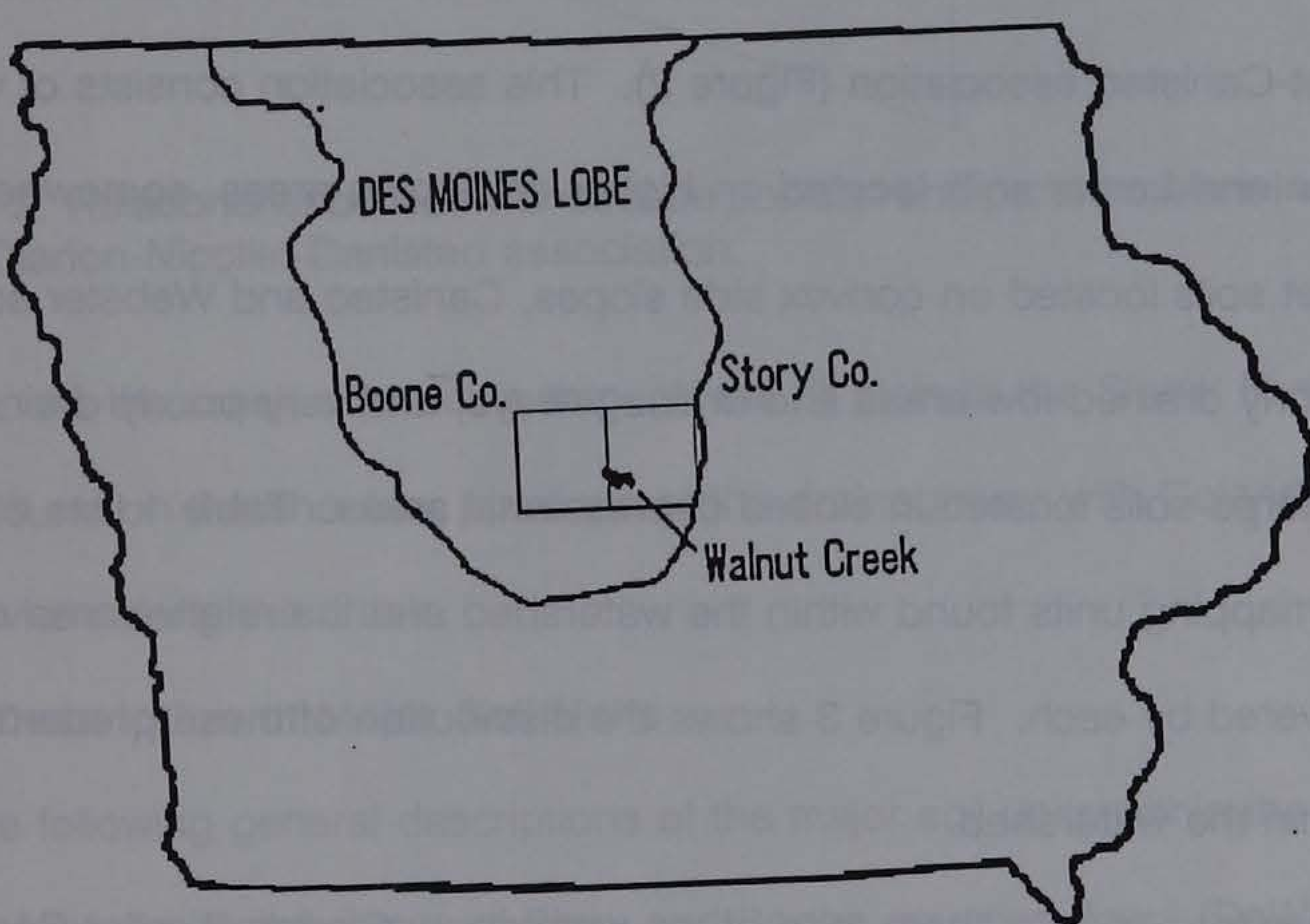

Figure 1. Location o. Des Moines Lobe and Walnut Creek watershed within the state of Iowa.

orientation is southwest to northeast with an average relief of several meters (Daniels and Handy, 1966).

Surface drainage within the Des Moines Lobe is poorly developed due to the low relief and the area's geologic youth. Numerous closed depressional areas exist that have accumulated material from surrounding side slopes. The thickness of the accumulated material can range up to several meters (Burras and Scholtes, 1987). The western half of Walnut Creek watershed is typical of this low relief till plane. However, the eastern portion of the watershed is characterized by increased surface relief on the order of 10 m due to head cutting of streams leading to the lower Skunk River floodplain. Soils within the Walnut Creek watershed are characterized by the Clarion-Nicollet-Canisteo association (Figure 2). This association consists of well drained Clarion and Lester soils located on higher or sloping areas, somewhat poorly drained Nicollet soils located on convex side slopes, Canisteo and Webster soils located on poorly drained low areas and drainageways, and very poorly drained Okoboji and Harps soils located in closed depressional areas. Table 1 lists the most common soil mapping units found within the watershed and the relative area of the watershed covered by each. Figure 3 shows the distribution of these predominant soil series within the watershed.

In the western and southern third of the watershed, Clarion-Nicollet-Canisteo soils predominate with Harps and Okoboji soils occupying the numerous closed depressions (Figure 3). Within the middle and eastern portions of the watershed, Webster soil replaces Canisteo and fewer depressions with Okoboji and Harps soils

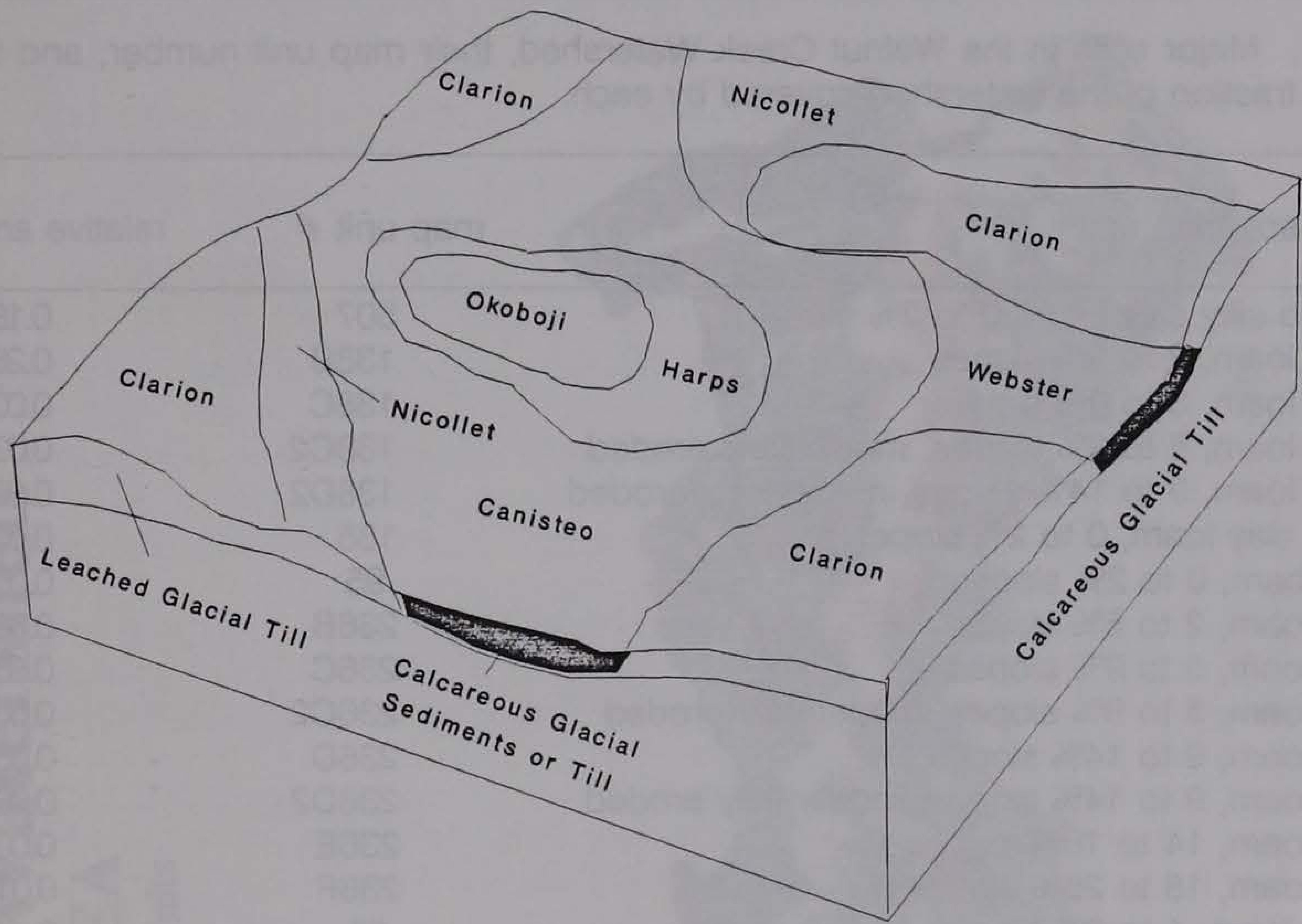

Figure 2. Relationship between landscape position and parent material to the soils in the Clarion-Nicollet-Canisteo association.

are found. As the creek down cuts through the till plain to the Skunk River, Lester soils are found on the shoulder positions of the drainageway with Coland soils formed in the alluvium along the creek.

General Description of Major Soil Units

The following general descriptions of the major soil units within the watershed are taken from the Soil Surveys of Story and Boone counties, Iowa (DeWitt, 1984; Andrews and Dideriksen, 1981).

Canisteo clay loam.

Canisteo is a poorly drained, moderately permeable soil found on nearly level

Table 1. Major soils in the Walnut Creek Watershed, their map unit number, and the relative fraction of the watershed covered by each.

soil map unit	map unit #	relative area
Canisteo silty clay loam, 0 to 2% slopes	507	0.1833
Clarion loam, 2 to 5% slopes	138B	0.2637
Clarion loam, 5 to 9% slopes	138C	0.0078
Clarion loam, 5 to 9% slopes, moderately eroded	138C2	0.0378
Clarion loam, 9 to 14% slopes, moderately eroded	138D2	0.0008
Coland clay loam, 0 to 2% slopes	135	0.0041
Harps loam, 0 to 2% slopes	95	0.0595
Lester loam, 2 to 5% slopes	236B	0.0017
Lester loam, 5 to 9% slopes	236C	0.0017
Lester loam, 5 to 9% slopes, moderately eroded	236C2	0.0074
Lester loam, 9 to 14% slopes	236D	0.0016
Lester loam, 9 to 14% slopes, moderately eroded	236D2	0.0016
Lester loam, 14 to 18% slopes	236E	0.0020
Lester loam, 18 to 25% slopes	236F	0.0131
Nicollet loam, 1 to 3% slopes	55	0.125
Okoboji mucky silt loam, 0 to 1% slopes	90	0.0146
Okoboji silty clay loam, 0 to 1% slopes	6	0.0195
Webster silty clay loam, 0 to 2% slopes	107	0.1893
Total		0.9345

(0 to 2%) swales on uplands. The soil is classified as a fine-loamy, mixed (calcareous), mesic Typic Haplaquoll. This soil was formed in calcareous till or local alluvium under water-tolerant grasses. Individual areas can range in size from 0.5 to 50 ha. The surface soil is black, silty clay loam to clay loam and from 35 to 60 cm thick. Total solum thickness ranges from 65 to 100 cm with free carbonates typically found within 25 to 50 cm of the surface. The subsoil is gleyed, and ranges in texture

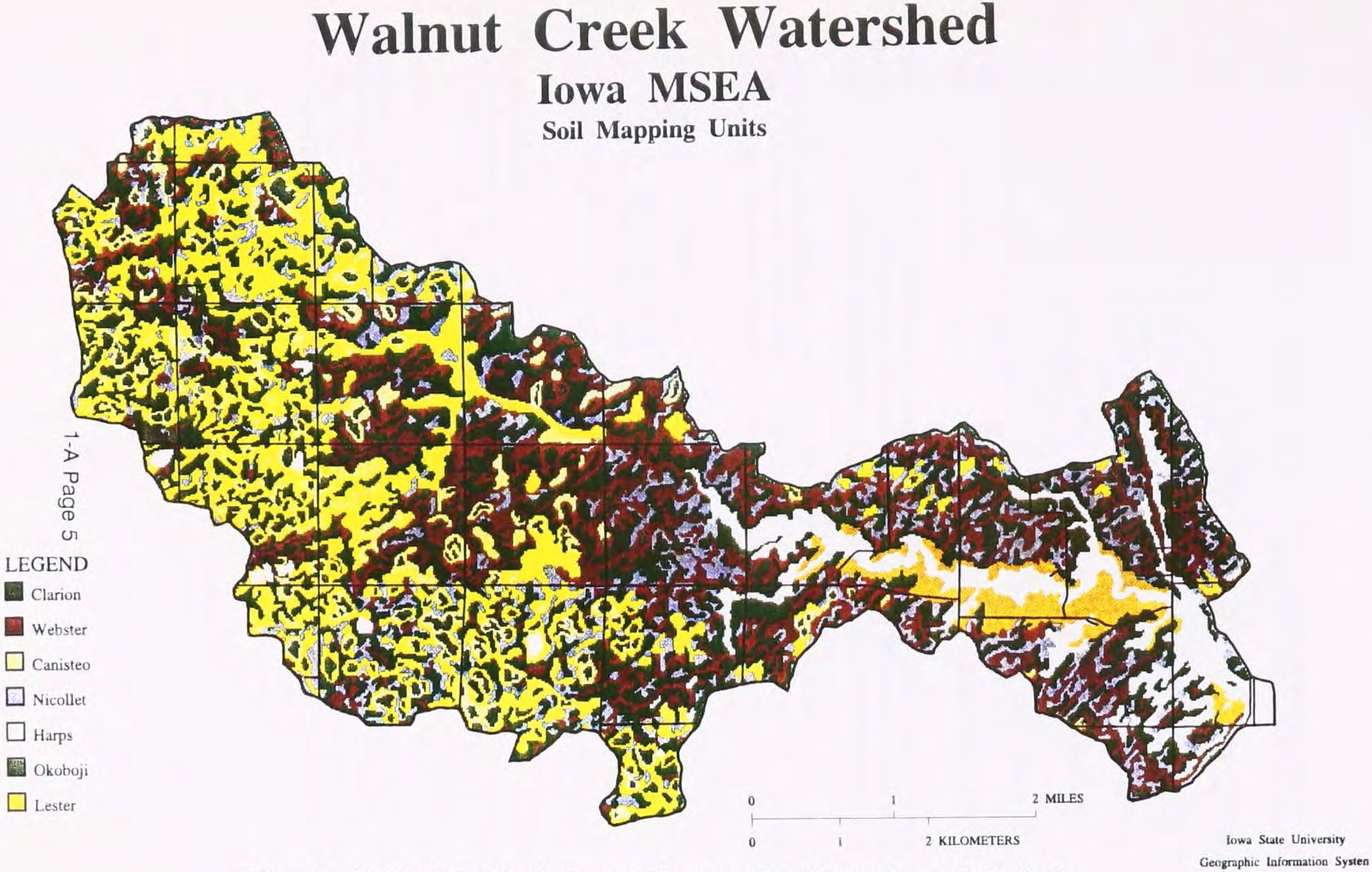

Figure 3. Distribution of predominant soil series within Walnut Creek Watershed.

from loam to clay loam. The subsolum is also gleyed with numerous lime concretions and a texture of loam or clay loam although stratified loam and sandy loam horizons are common at some locations. Organic carbon fraction of the surface soil is typically 3 to 3.5%. Available water capacity is high.

The following soil profile was located in Boone Co., Colfax Twnshp., Section 24 (41° 59' 17.39" N lat., 93° 42 min 28.57 sec W long.).

Soil Series: CANISTEO

Ap----0 to 22 inches; black (N 2/0) silty clay loam, black (10YR 2/1) dry; weak fine granular structure; friable; many fine roots throughout; many fine tubular pores; slightly effervescent; 2 percent rounded gravel; gradual smooth boundary.

A1----22 to 35 inches; black (10YR 2/1) silty clay loam, very dark gray (10YR 3/1) dry; weak fine subangular blocky structure; friable; many fine roots throughout; many tubular pores; slightly effervescent; 2 percent rounded gravel; gradual smooth boundary.

A2----35 to 56 inches; very dark gray (10YR 3.1) and black (10YR 2/1), exterior, clay loam; weak fine subangular blocky structure; friable; many fine roots throughout; many fine tubular pores; discontinuous very dark gray (10YR 3/1) organic coats; strongly effervescent; 2 percent rounded gravel; gradual smooth boundary.

Bg----56 to 79 inches; dark gray (10YR 4/1) clay loam; common fine distinct dark grayish brown (10YR 4/2) mottles; weak medium subangular blocky structure; friable; many fine roots throughout; many fine tubular pores; strongly effervescent; 2 percent rounded gravel; gradual wavy boundary.

BCg1--79 to 103 inches; dark gray (10YR 4/1) clay loam; common medium distinct grayish brown (10YR 5/2) and few fine prominent yellowish brown (10YR 5/8) mottles; weak medium subangular blocky structure; friable; many fine roots throughout; many fine tubular pores; strongly effervescent; 2 percent rounded gravel; gradual smooth boundary.

Cg1---103 to 127 inches; grayish brown (10YR 5/2) loam; common fine distinct dark grayish brown (10YR 4/2) and few fine prominent reddish gray (5YR 5/2) mottles; weak fine prismatic structure; friable; many fine roots throughout;

many fine tubular pores; violently effervescent; 2 percent rounded gravel; gradual smooth boundary.

Cg2---127 to 151 inches; weak red (2.5YR 5/2) loam; common fine prominent strong brown (7.5 YR 5/6) and common fine prominent yellowish red (5YR 5/8) mottles; massive; friable; many fine roots throughout; many fine tubular pores; violently effervescent; 2 percent rounded gravel; gradual smooth boundary.

Cg3---151 to 172 inches; light olive gray (5Y 6/2) loam; common medium prominent strong brown (7.5YR 5/6) and common fine and medium prominent dark gray (10YR 4/1) mottles; massive; friable; many fine roots throughout; many fine tubular pores; few fine rounded black (10YR 2/1) iron-manganese concretions; strongly effervescent; 2 percent rounded gravel; gradual smooth boundary.

Cg4---172 to 200 inches; light olive gray (5Y 6/2) loam; common fine and medium prominent strong brown (7.5YR 5/6) mottles; massive; friable; many fine roots throughout; many fine tubular pores; few fine and medium rounded black (10YR 2/1) iron-manganese concretions throughout; strongly effervescent; 2 percent rounded gravel.

Clarion loam.

Clarion soil is classified as a fine-loamy, mixed, mesic, Typic Hapludoll. This well drained soil is found on gently to strongly sloping knolls and side slopes with slopes ranging from 2 to 14 percent and was formed in till under prairie vegetation. Individual areas are 0.5 to 5 ha in area and elongated or oblong in shape reflecting the low relief swell-swale topography. A typical soil profile consists of a dark surface layer of loam 25 to 45 cm thick. Thickness of the solum ranges from 60 to 100 cm with the subsoil being a brown loam to clay loam. The subsolum contains free carbonates and ranges from sandy loam to clay loam. Organic carbon fraction of the surface layer is about 1.5 to 2%. The surface layers are slightly acid to neutral with pH increasing with depth. This moderately permeable soil has a high available water capacity.

The following soil profile was located in Boone Co., Colfax Twnshp., Section 24 (41° 59' 32.58: N lat., 93° 42' 28.57"W long.).

Soil Series: CLARION

Ap----0 to 23 inches; very dark brown (10YR 2/2) loam; weak fine granular structure; friable; many fine and medium roots throughout; many fine continuous tubular pores; noneffervescent; 2 percent rounded gravel; clear smooth boundary.

AB----23 to 33 inches; dark brown (10YR 3/3) and 10 percent brown (10YR 4/3) loam; weak fine granular structure; friable; noneffervescent; 2 percent rounded gravel; clear smooth boundary.

Bw1---33 to 48 inches; brown (10YR 4/3) and dark brown (10YR 3/3), exterior, loam; weak fine granular structure; friable; many fine and medium roots throughout; many fine continuous tubular pores; noneffervescent; 2 percent rounded gravel; gradual smooth boundary.

Bw2---48 to 70 inches; dark yellowish brown (10YR 4/4) and dark brown (10YR 3/3), exterior, loam; weak fine granular structure; friable; many fine and medium roots throughout; many fine continuous tubular pores; noneffervescent; 2 percent rounded gravel; gradual smooth boundary.

Bw3---70 to 87 inches; dark yellowish brown (10YR 4/4) loam; weak fine granular structure; friable; many fine and medium roots throughout; many fine continuous tubular pores; noneffervescent; 2 percent rounded gravel; gradual smooth boundary.

BC----87 to 102 inches; yellowish brown (10YR 5/4) loam; few fine distinct grayish brown (10YR 5/2) and few fine distinct yellowish brown (10YR 5/6) mottles; weak fine granular structure; friable; many fine and medium roots throughout; many fine continuous tubular pores; noneffervescent; 2 percent rounded gravel; gradual smooth boundary.

C1----102 to 120 inches; light yellowish brown (10YR 6/4) loam; common medium distinct light gray (10YR 7/2), common fine prominent yellowish red (5YR 4/6), and common fine faint very dark brown (10YR 2/2) mottles; weak fine granular structure; friable; many fine continuous tubular pores; slightly effervescent; 2 percent rounded gravel; gradual smooth boundary.

C2----120 to 151 inches; yellowish brown (10YR 5/6) loam; few fine prominent yellowish red (5YR 4/6) and common medium distinct light gray (10YR 7/2) mottles; weak fine granular structure; friable; many fine and medium roots throughout; many fine continuous tubular pores; few fine rounded dark reddish brown (5YR 2/2) iron-manganese concretions; strongly effervescent; 2 percent rounded gravel; gradual smooth boundary.

C3----151 to 183 inches; yellowish brown (10YR 5/6) loam; common coarse distinct light brownish gray (10YR 6/2) and common medium distinct strong brown (7.5YR 5/6) mottles; weak fine granular structure; friable; many fine and medium roots throughout; many fine continuous tubular pores; few fine rounded dark reddish brown (5YR 2/2) iron-manganese concretions; strongly effervescent; 2 percent rounded gravel; gradual smooth boundary.

C4----183 to 200 inches; yellowish brown (10YR 5/6) loam; common medium distinct light brownish gray (10YR 6/2) and common medium distinct strong brown (7.5YR 5/6) mottles; weak fine granular structure; friable; many fine and medium roots throughout; many fine continuous tubular pores; few fine rounded dark reddish brown (5YR 2/2) iron-manganese concretions; strongly effervescent; 2 percent rounded gravel.

Coland clay loam.

Coland is a nearly level, poorly drained soil found on bottom lands adjacent to streams. Coland soil is classified as a fine-loamy, mixed, mesic, Cumulic Haplaquoll. This soil was formed in loamy alluvium and is subject to flooding. The soil is moderately permeable with high available water capacity. Organic matter contents range from 2.5 to 3.5% and soil reaction is neutral to mildly alkaline throughout. Typically the surface soil is a black clay loam or silty clay loam that is high in sand content and extends at least 90 cm deep. The subsolum is sandy loam to clay loam and may contain thin strata of silty clay or loamy sand. The subsolum is a mottled olive gray. Depth to free carbonates is at least 120 cm.

Harps loam.

Harps is classified as a fine-loamy, mesic Typic Calciaquoll. It is a nearly level (0 to 2% slope), poorly drained calcareous soil on upland flats surrounding closed depressional areas. Typically, the surface soil is black loam or clay loam and is from 25 to 55 cm thick. The subsoil is from 75 to 135 cm thick, gray or dark gray in color with numerous mottles, and loam in texture. The subsolum is a mottled gray loam. Permeability is moderate and available water capacity high. The surface soil organic matter content is 3 to 3.5%. Free carbonates are found from the surface downward. Within the watershed, Harps soils are usually found as rings surrounding Okoboji soils in closed depressions.

The following soil profile was located in Boone Co., Colfax Twnshp., Section 14 (41° 59' 55.56" N lat., 93° 43' 23.65" W long.).

Soil Series: HARPS

Apk---0 to 19 inches; black (10YR 2/1) clay loam; weak fine granular structure; very friable; common fine roots throughout; many fine tubular pores; violently effervescent; 2 percent rounded gravel; clear smooth boundary.

Ak1---19 to 28 inches; black (10YR 2/1) clay loam; weak fine granular structure; very friable; common fine roots throughout; many fine tubular pores; violently effervescent; 2 percent rounded gravel; gradual smooth boundary.

Ak2---28 to 44 inches; very dark gray (10YR 3/1) clay loam; weak fine subangular blocky structure; very friable; common fine roots throughout; many fine tubular pores; violently effervescent; 2 percent rounded gravel; clear smooth boundary.

Bkg1--44 to 64 inches; dark gray (10YR 3/1) clay loam; weak fine subangular blocky structure; very friable; common fine roots throughout; many fine tubular pores; common fine and medium irregular soft masses of lime between peds; violently effervescent; 2 percent rounded gravel; clear smooth boundary.

Bkg2--64 to 85 inches; gray (10YR 5/1) clay loam; weak fine subangular blocky structure; very friable; common fine roots throughout; many fine tubular pores; faint discontinuous dark gray (10YR 4/1), moist, organic coats; common medium soft masses of lime nonpedogenic throughout; violently effervescent; 2 percent rounded gravel; gradual smooth boundary.

BCg---85 to 103 inches; grayish brown (2.5Y 5/2) loam; few medium prominent strong brown (7.5YR 5/6) moist and few fine faint dark grayish brown (10YR 4/2) moist mottles; weak fine subangular blocky structure; very friable; common fine roots throughout; many fine tubular pores; violently effervescent; 2 percent rounded gravel; gradual smooth boundary.

Cg1---103 to 132 inches; grayish brown (2.5Y 5/2) loam; common coarse prominent strong brown (7.5YR 5/8) moist and common medium distinct grayish brown (10YR 5/2) moist mottles; massive; very friable; common fine roots throughout; many fine tubular pores; violently effervescent; 2 percent rounded gravel; gradual smooth boundary.

Cg2---132 to 155 inches; grayish brown (2.5Y 5/2) loam; common medium prominent strong brown (7.5YR 5/8) moist and common medium prominent grayish brown (10YR 5/2) moist mottles; massive; very friable; common fine roots throughout; many fine tubular pores; common medium rounded hard carbonate nodules at top of horizon; violently effervescent; 2 percent rounded gravel.

Lester loam.

Lester is a gently to moderately sloping (2 to 9% slopes), well drained soil formed in glacial till on convex upland knolls and ridgetops. It is classified as fine-loamy, mixed, mesic, Mollic Hapludalf. The soil was formed under alternating forest and prairie vegetation. Permeability is moderate and available water capacity high. Organic carbon content of the surface soil ranges from 1 to 1.5%. The surface soil is typically a shallow (<20 cm) very dark grayish brown sandy loam to clay loam. The subsoil is a brown to yellowish brown, mottled clay loam, 60 to 120 thick and is void of free carbonates. The subsolum is a brown, mottled loam and clay loam with free carbonates. Reaction of the solum ranges from strongly acid to slightly acid.

The following soil profile was located in Story Co., Washington Twnshp., Section 35 (41° 57 min 5.0 sec N lat., 93° 36 min 8.0 sec W long.).

Soil Series: LESTER

Ap----0 to 21 inches; very dark brown (10YR 2/2) loam, very dark grayish brown (10YR 3/2) dry; weak fine granular structure; friable; many fine roots; common tubular pores; noneffervescent; clear boundary.

AE----21 to 35 inches; brown (10YR 4/3) loam, brown (10YR 5/3) dry; weak fine platy structure; friable; common fine roots; common very fine and fine tubular pores; continuous very dark grayish brown (10YR 3/2), moist, organic coats; noneffervescent; clear boundary.

Bt1---35 to 55 inches; dark yellowish brown (10YR 4/4) loam; weak fine subangular blocky structure; friable; many fine roots; common tubular pores; discontinuous dark brown (10YR 3/3), moist, organic coats; noneffervescent; gradual boundary.

Bt2---55 to 84 inches; dark yellowish brown (10YR 4/4) and brown (10YR 4/3), exterior, clay loam; moderate fine subangular blocky structure; friable; common fine roots; common fine tubular pores; strongly effervescent; clear boundary.

BC----84 to 105 inches; yellowish brown (10YR 5/4) loam; moderate fine subangular blocky structure; friable; common fine roots; common tubular pores; strongly effervescent; gradual boundary.

C1----105 to 120 inches; yellowish brown (10YR 5/6) loam and loam and loam; common fine prominent strong brown (7.5YR 5/6) mottles; massive; friable; common fine roots; common fine tubular pores; common fine rounded carbonate nodules throughout; strongly effervescent; gradual boundary.

C2----120 to 144 inches; yellowish (10YR 5/6) loam; common fine prominent yellowish red (5YR 5/6) moist and common fine distinct pale brown (10YR 6/3) moist mottles; massive; friable; common fine roots; common tubular pores; common fine and medium irregular carbonate concretions throughout; strongly effervescent; gradual boundary.

C3----144 to 162 inches; yellowish brown (10YR 5/6) loam; common fine distinct light yellowish brown (2.5Y 6/3), common fine prominent strong brown (7.5YR 4/6), and common fine prominent yellowish red (5YR 4/6) mottles; massive; friable; common fine roots; common fine tubular pores; common fine irregular carbonate concretions throughout; strongly effervescent; gradual boundary.

C4----162 to 190 inches; yellowish brown (10YR 5/6) and strong brown (7.5YR 4/6) and light gray (10YR 7/2) loam; massive; friable; common fine roots; common very fine tubular pores; strongly effervescent; gradual boundary.

C5----190 to 225 inches; yellowish brown (10YR 5/6) loam; massive; friable; common fine roots; common fine tubular pores; strongly effervescent; gradual boundary.

Nicollet loam.

Nicollet is a somewhat poorly drained, moderately permeable soil formed on uplands from loamy glacial till under prairie vegetation. Slopes range from 1 to 3% and are usually slightly convex with low relief. Nicollet is classified as a fine-loamy, mixed, mesic, Aquic Hapludoll. The surface soil is black and very dark gray loam to clay loam or silt loam high in sand content and is about 27 cm thick. The subsoil is a dark grayish brown loam or clay loam with high chroma mottles and is about 50 cm thick. The subsolum is a grayish brown and olive gray loam with chroma mottles. Organic carbon content of the surface soil range from 2 to 2.5%. Depth to free carbonates ranges from 60 to 120 cm. Nicollet soils usually occupy the landscape between the Clarion soils that are upslope and the Canisteo or Webster soils down slope. Available water capacity is high.

The following soil profile was located in Boone Co., Colfax Twnsp., Section 14 (41° 59' 53.93" N lat., 93° 43' 23.12" W long.).

Soil Series: NICOLLET

Ap----0 to 24 inches; black (10YR 2/1) loam; very dark gray (10YR 3/1) dry; weak fine granular structure; friable; many very fine and fine roots throughout; many fine tubular pores; noneffervescent; 2 percent rounded gravel; gradual smooth boundary.

A1----24 to 35 inches; very dark brown (10YR 2/2) loam, very dark grayish brown (10YR 3/2) dry; weak fine granular structure; friable; many very fine and fine roots throughout; many tubular pores; noneffervescent; 2 percent rounded gravel; gradual smooth boundary.

A2----35 to 50 inches; very dark grayish brown (10YR 3/2) loam, dark grayish brown (10YR 4/2) dry; weak fine subangular blocky structure; friable; many fine and fine roots throughout; many tubular pores; noneffervescent; 2 percent rounded gravel; gradual smooth boundary.

Bg1---50 to 65 inches; dark grayish brown (10YR 4/2) and very dark grayish brown (10YR 3/2), exterior, loam; few fine distinct dark grayish brown (2.5Y 4/2) mottles, weak fine subangular blocky structure; friable; many very fine and fine roots throughout; many fine tubular pores; noneffervescent; 2 percent rounded gravel; clear smooth boundary.

Bg2---65 to 80 inches; 50 percent grayish brown (10YR 5/2) and 50 percent dark grayish brown (10YR 4/2) loam; common fine prominent yellowish brown (10YR 5/8) mottles; weak fine subangular blocky structure; friable; many very fine and fine roots throughout; many tubular pores; strongly effervescent; 2 percent rounded gravel; gradual wavy boundary.

Cg1---80 to 110 inches; grayish brown (10YR 5/2) and yellowish brown (10YR 5/8) and light olive brown (2.5Y 5/3) loam; massive; friable; many very fine and fine roots throughout; many fine tubular pores; strongly effervescent; 2 percent rounded gravel; clear smooth boundary.

Cg2---110 to 138 inches; 50 percent yellowish brown (10YR 5/8) and 50 percent grayish brown (2.5Y 5/2) loam; massive; friable; many very fine and fine roots throughout; many fine tubular pores; strongly effervescent; 2 percent rounded gravel; gradual smooth boundary.

Cg3---138 to 178 inches; grayish grown (10YR 5/2) loam; common medium prominent yellowish brown (10YR 5/8) and few fine prominent reddish yellow (7.5YR 6/8) mottles; massive; friable; many very fine and fine roots throughout; many fine tubular pores; strongly effervescent; 2 percent rounded gravel; gradual smooth boundary.

Cg4---178 to 200 inches; 50 percent grayish brown (10YR 5/2) and 50 percent yellowish brown (10YR 5/8) loam; massive; friable; many very fine and fine roots throughout; many fine tubular pores; strongly effervescent; 2 percent rounded gravel.

Okoboji mucky silt loam and silty clay loam.

Okoboji is classified as a fine, montmorillonitic, mesic Cumulic haplaquoll and was formed in depressional areas on uplands from local sediments from surrounding uplands. This very poorly drained, moderately slow permeability soil is subject to periodic ponding and has slopes of 0 to 1%. Typically the surface soil is black and ranges in texture from mucky silt loam to silty clay loam and is typically 60 to 90 cm thick. The subsoil is a gleyed, heavy silty clay loam or silty clay, ranging from neutral to moderately alkaline, and extends to a depth of 100 to 150 cm deep. The subsoil color grades from gray and olive gray to yellowish brown and olive. The subsolum is silt loam to silty clay loam, may contain sand lenses in places, and is olive gray, olive, and yellowish brown. Organic carbon contents are high throughout the solum and range from 4 to 8% in the surface soil. Okoboji soils have a high available water capacity and a high shrink-swell potential.

The following soil profile was located in Boone Co., Colfax Twnsp., Section 14 (41° 59' 57.66" N lat., 93° 43' 23.58" W long.).

Soil Series: OKOBOJI

Ap----0 to 15 inches; black (N 2/0) silty clay loam, black (10YR 2/1) dry; weak medium subangular blocky structure; firm; common very fine and fine roots throughout; common very fine and fine tubular pores; noneffervescent; clear smooth boundary.

A1----15 to 25 inches; black (N 2/0) silty clay loam, black (10YR 2/1) dry; weak fine platy structure parting to weak fine subangular blocky; firm; common very fine and fine roots throughout; common fine tubular pores; noneffervescent; clear smooth boundary.

A2----25 to 33 inches; black (N 2/0) silty clay loam, black (10YR 2/1) dry; weak fine subangular blocky structure; firm; common very fine and fine roots throughout; common very fine and fine tubular pores; noneffervescent; clear smooth boundary.

A3----33 to 52 inches; black (N 2/0) silty clay loam, black (10YR 2/1) dry; weak medium subangular blocky structure; friable; common very fine and fine roots throughout; common fine tubular pores; noneffervescent; gradual smooth boundary.

A4----52 to 79 inches; black (10YR 2/1) silty clay loam, very dark gray (10YR 3/1) dry; weak medium subangular blocky structure; friable; common very fine and fine roots throughout; common fine tubular pores; noneffervescent; gradual smooth boundary.

Bg----79 to 105 inches; black (10YR 2/1) silty clay loam; weak fine subangular blocky structure; friable; common very fine and fine roots throughout; common fine tubular pores; noneffervescent; gradual smooth boundary.

Cg1---105 to 130 inches; gray (5Y 6/1) silt loam; common medium prominent dark yellowish brown (10YR 4/6) moist mottles; massive; friable; few medium rounded carbonate concretions throughout; slightly effervescent; clear wavy boundary.

Cg2---130 to 156 inches; gray (5Y 5/1) loam; common coarse prominent yellowish brown (10YR 5/6) moist mottles; massive; friable; few medium rounded carbonate concretions throughout; strongly effervescent; gradual smooth boundary.

Cg3---156 to 183 inches; dark gray (10YR 4/1) loam; common coarse prominent yellowish brown (10YR 5/6) mottles; massive; friable; few fine rounded carbonate concentrations throughout; strongly effervescent.

Webster silty clay loam.

Webster is a nearly level (0 to 2%), poorly drained soil formed on upland flats and drainageways from loamy glacial till and glacial sediments. Individual areas are irregular in shape and range from 5 to 20 ha in size. This moderately permeable soil is classified as a fine-loamy, mixed, mesic, Typic Haplaquoll. The surface soil is typically 35 to 60 cm thick, neutral in reaction, and very dark gray clay loam or silty clay loam. The very dark gray and olive gray subsoil is gleyed with few high chroma mottles, void of free carbonates, extends from 60 to 120 cm in thickness, and has a texture of clay loam or silty clay loam high in sand content. Reaction is neutral to slightly alkaline. The subsolum is a gleyed loam with high chroma mottles and has slight to violent effervescence when treated with dilute HCl. Permeability is moderate and water holding capacity high. Organic carbon contents of the surface soil range from 3 to 4%. Webster soils are very similar to Canisteo except that Canisteo has free carbonates within 25 cm of the surface.

The following soil profile was located in Boone Co., Colfax Twnsp., Section 14 (41° 59' 47.55" N lat., 93° 43' 24.64" W long.).

Soil Series: WEBSTER

Ap----0 to 16 inches; black (10YR 2/1) clay loam, very dark gray (10YR 3/1) dry; weak fine granular structure; friable; many fine roots throughout; common very fine and fine tubular pores; noneffervescent; 2 percent rounded gravel; clear smooth boundary.

A1----16 to 27 inches; black (10YR 2/1) clay loam, very dark gray (10YR 3/1) dry; weak fine subangular blocky structure; friable; many fine roots throughout; common very fine and fine tubular pores; noneffervescent; 2 percent rounded gravel; abrupt smooth boundary.

A2----27 to 46 inches; black (10YR 2/1) clay loam, very dark gray (10YR 3/1) dry; weak fine subangular blocky structure; friable; many fine roots throughout; common very fine and fine tubular pores; noneffervescent; 2 percent rounded gravel; gradual smooth boundary.

A3----46 to 66 inches; very dark gray (10YR 3/1) clay loam, dark gray (10YR 4/1) dry; weak fine subangular blocky structure; friable; many fine roots throughout; common very fine and fine tubular pores; noneffervescent; 2 percent rounded gravel; gradual smooth boundary.

Bg----66 to 92 inches; dark gray (10YR 4/1) clay loam; weak medium subangular blocky structure; friable; many fine roots throughout; common very fine and fine tubular pores; distinct continuous very dark gray (10YR 3/1), moist, organic coats on faces of peds; noneffervescent; 2 percent rounded gravel; clear wavy boundary.

Cg1----92 to 112 inches; dark gray (10YR 4/1) loam; common fine distinct grayish brown (2.5Y 5/2) and few fine distinct light olive brown (2.5Y 5/3) mottles; massive; friable; many fine roots throughout; common very fine and fine tubular pores; slightly effervescent; 2 percent rounded gravel; gradual smooth boundary.

2Cg2--112 to 134 inches; grayish brown (2.5Y 5/2) SR and SR and SR and loam and silt loam; common fine faint light yellowish brown (2.5Y 6/4) moist and common fine prominent yellowish brown (10YR 5/8) moist mottles; massive; friable; common fine roots throughout; common very fine and fine tubular pores; slightly effervescent; 2 percent rounded gravel; gradual smooth boundary.

2Cg3--134 to 148 inches; 50 percent light brownish gray (10YR 6/2) and 50 percent grayish brown (10YR 5/2) SR and silt loam and fine sandy loam; few fine prominent yellowish brown (10YR 5/8) mottles; massive; friable; common fine roots throughout; common very fine and fine tubular pores; slightly effervescent; 2 percent rounded gravel; clear smooth boundary.

3Cg4--148 to 185 inches; weak red (2.5YR 5/2) loam; common medium prominent yellowish brown (10YR 5/8) mottles; massive; friable; common fine roots throughout; common very fine and fine tubular pores; slightly effervescent; 2 percent rounded gravel.

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Section 1-B Climate of Walnut Creek Watershed

J. Hatfield NSTL

Walnut Creek watershed is located in central Iowa, latitude 41° 55'.N to 42° 00'.N and longitude 93° 32'.W to 93° 45'.W. The climate in this region of Iowa is characterized by cold winters and hot summers.

Weather Patterns

Prevailing weather fronts move from the west to east due to the presence of the jet stream over the northern United States. During the winter, high pressure systems are often associated with extreme cold events as arctic air is moved into the Midwest. In the summer, low pressure systems and fronts are responsible for the movement of warm, humid air from the Gulf of Mexico that supplies the moisture for thunderstorms that occur in the spring and summer.

Precipitation

Precipitation during the winter is usually in the form of snow and freezing rain and during the remainder of the year as rainfall periodically mixed with hail and sleet. Rainfall events during the spring and summer are often in the form of thunderstorms that occur as brief, intense showers. The 30-year normal (1951-80) monthly distribution of precipitation for Ames, Iowa, located approximately 3 km from the watershed, is shown in Figure 1. The greatest amount of precipitation is recorded in May and June. Surface water runoff events are most likely to occur during these months and in early spring during snow melt while the soil is still frozen.

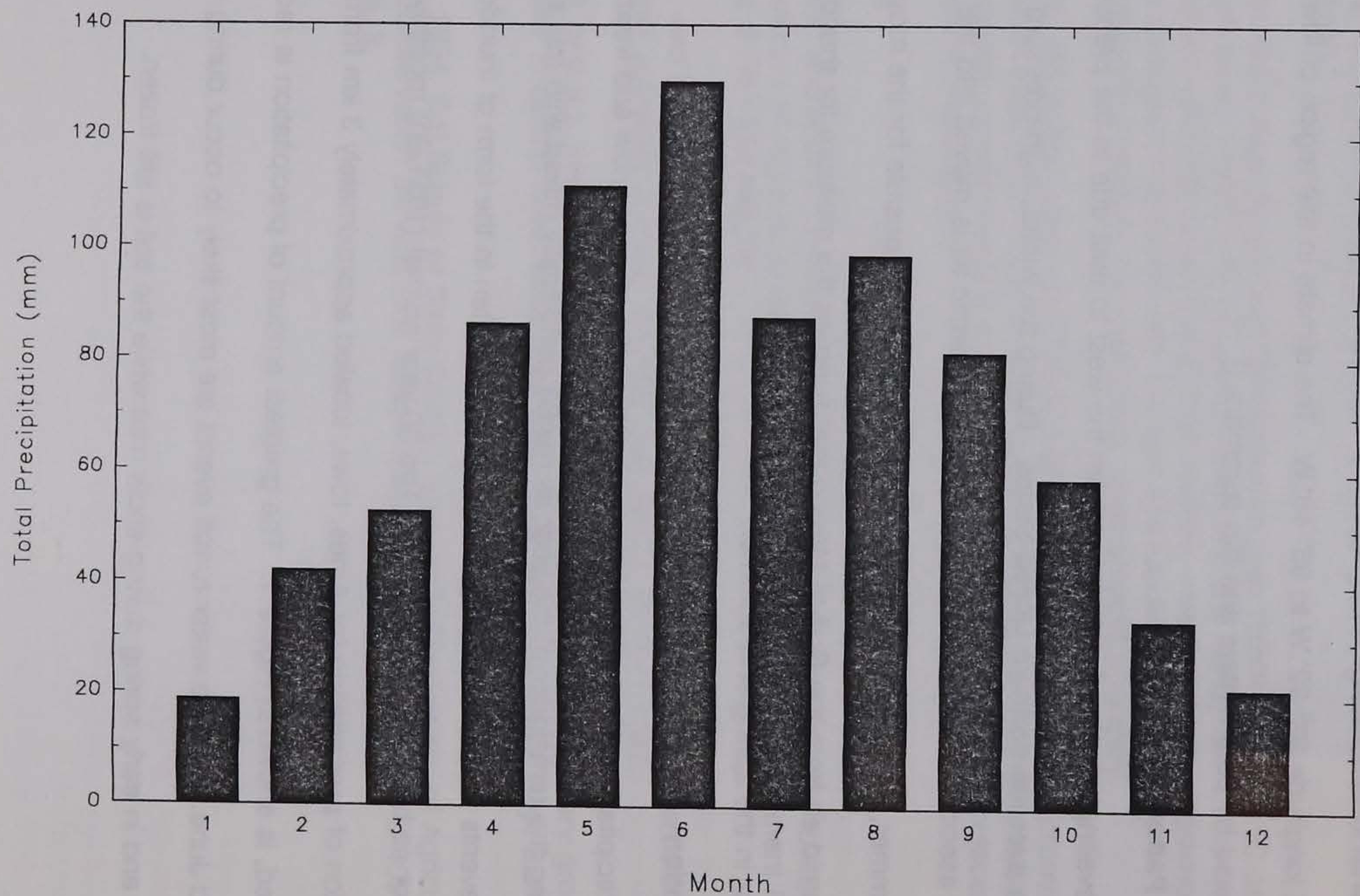

Figure 1. Monthly precipitation (1951-80 normals) for the ISU Agronomy Farm, Ames, Iowa (R.E. Carlson, ISU, Dept. of Agronomy).

Thunderstorms occur about 50 days each year. Probabilities of rainfall amounts and frequencies are available for the Iowa State University (ISU) Agronomy farm, Ames, Iowa.

Temperature

Temperatures range from an average monthly minimum in January of 13.4°C to an average monthly maximum in July of 29.4°C as shown in Figure 2 for Ames, Iowa. The variation in maximum and minimum temperatures remains fairly constant throughout the year on the monthly averages. However, on a daily basis the largest diurnal variations are typically in the spring and fall when the largest variation in weather patterns occurs. The length between the last freeze (0°C) in the spring and the first freeze in the fall ranges from 140 to 180 days. The first freezing temperature (0°C) occurs around October 6 in 5 years out of 10 and the last freezing temperature occurs around May 1 in 5 years out of 10.

Wind

The prevailing wind in the spring and summer is from the south to southeast directions. The highest wind velocities occur during this time of year. Wind velocities at this time may exceed 5 m/sec for several hours and may hamper the application of pesticides. During the winter high wind velocities may be associated with snowstorms and are from a northerly direction.

General Climate

Relative humidity is variable throughout the year and the day depending upon the movement of fronts and air masses through the area. Average relative humidity in

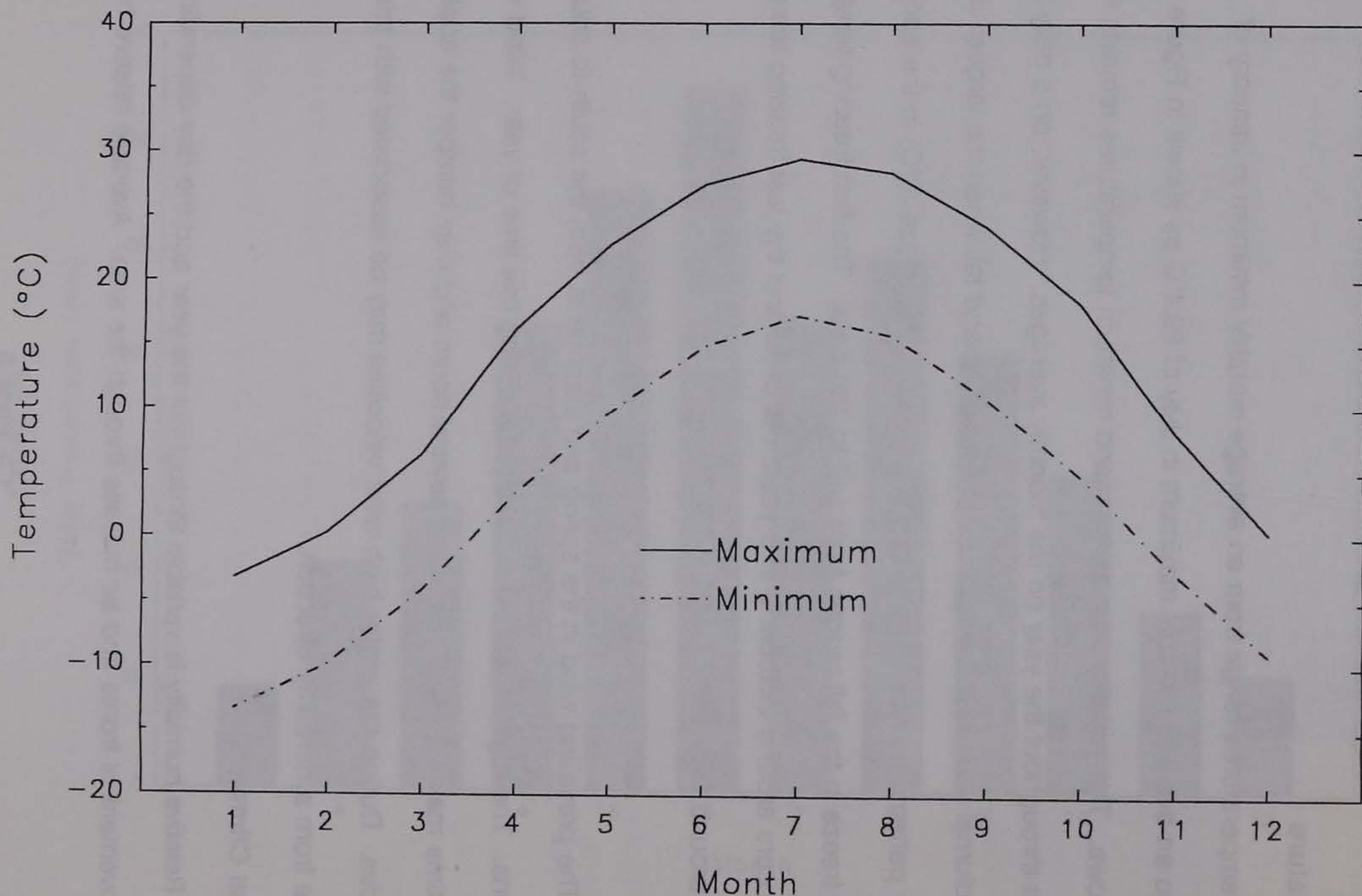

Figure 2. Monthly maximum and minimum air temperatures (1951-80 normals) for the ISU Agonomy Farm, Ames, Iowa (R.E. Carlson, ISU, Dept. of Agronomy).

the afternoon is around 60 percent. The average at dawn is around 80 percent. Sunshine is more prevalent during the summer when the sun shines 70 percent of the time possible. In the winter the sun shines 50 percent of the time possible.

Weather Records

The nearest weather station with long-term records is located in Des Moines, Iowa. Records date back to the late 1800's and have been used to evaluate precipitation and temperature probabilities in the local region. These probabilities can be used to determine the chance of occurrence of a specific amount of rainfall or a rain event on any given day or sequence of days.

Section 1-C Hydrology of Walnut Creek Watershed

D. Schmitz NSTL

Overview

The hydrology of Walnut Creek watershed is determined by climatic conditions--such as precipitation, temperature, and wind--and physical basin characteristics--such as topography, soils, land use, drainage network, and geology. Humans have influenced the hydrologic response of the watershed to climatic conditions by altering physical basin characteristics such as drainage network and land use. Data collected from rain gages, streamflow gaging stations, and groundwater monitoring wells in the watershed during 1991-93 are used to evaluate the hydrology of the watershed (Personal communication, Phil Soenksen, USGS, 1994).

General Hydrology of the Watershed

Walnut Creek watershed is in the Des Moines Lobe landform region that includes much of north-central and central Iowa. It is characterized by low relief and poor natural surface drainage. A topographical map of the watershed is shown in Figure 1. Channel slopes generally are not great except where tributaries have cut down from uplands to Walnut Creek.

Walnut Creek is a tributary of the South Skunk River that joins the north branch in Keokuk County, Iowa to become the Skunk River. The creek generally flows in a easterly direction to the South Skunk River. The Skunk River flows in a southeasterly direction and eventually empties into the Mississippi River. Walnut Creek is similar to many tributaries of rivers in the Des Moines Lobe in that it flows through glacial till in

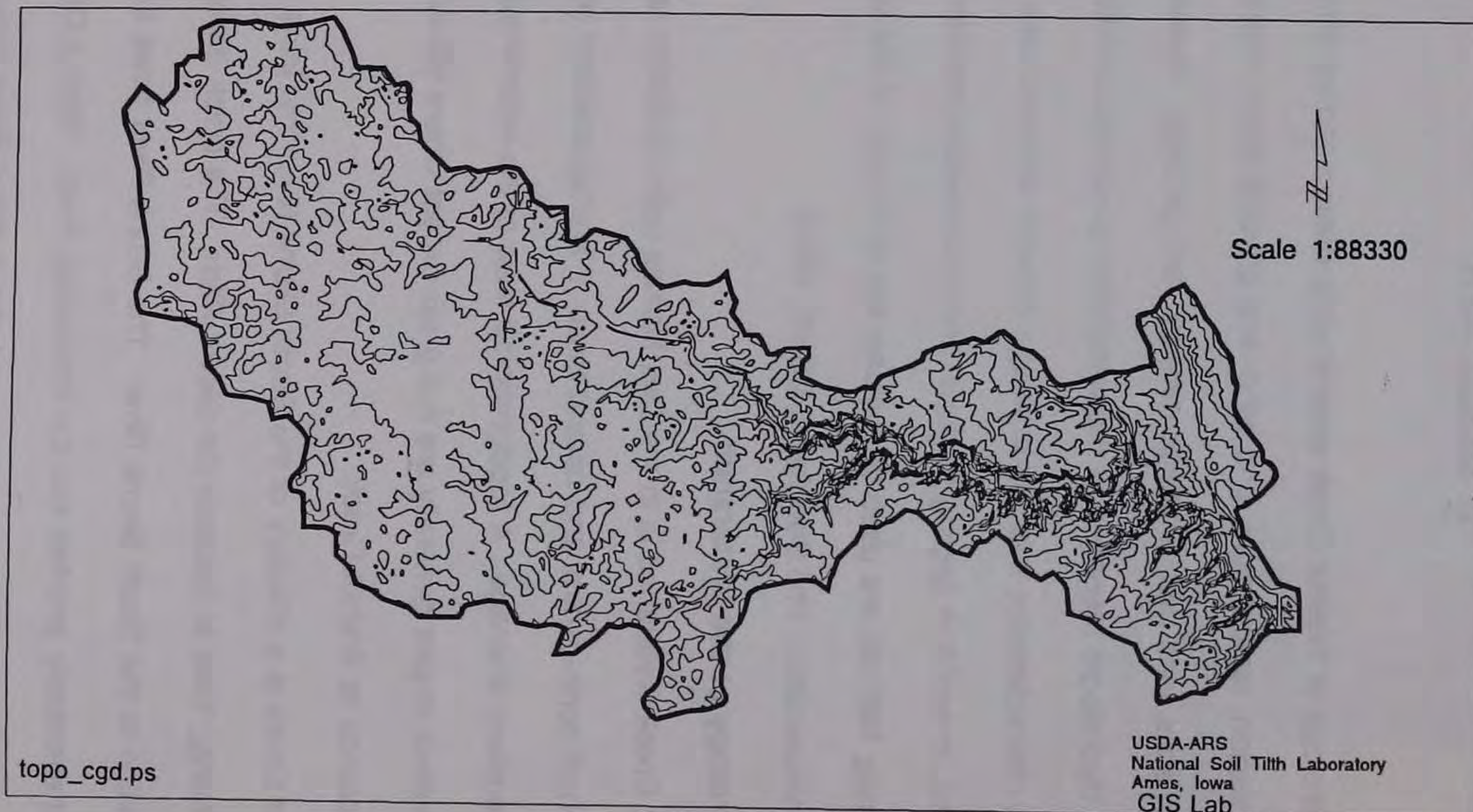

Figure 1. Topographical map of Walnut Creek watershed with elevations ranging from 860 feet in the east to 1060 feet in the west.

its upper reach and traverses across the South Skunk River flood plain in its lower reach.

Flood peaks in the watershed are not as large as for other landform regions in the state, and low flows are not well sustained in most of the region. In a statewide study of streamflow gaging station records, Lara (1979) developed regional equations to estimate average discharge and regional maps to estimate low-flow parameters at ungaged sites. Based on the Region II equation, the expected average annual runoff from Walnut Creek watershed is 180 mm (millimeters). The average annual runoff for the South Skunk River near Ames streamflow gaging station for the period 1920-27, 1932-93 is 192 mm. The highest annual runoff was 823 mm in 1993 and the lowest was 6 mm in 1956. Using low flow characteristics derived from Lara's regional maps, the 7-day, 2-year (recurrence interval) and 7-day, 10-year low flows are expected to be 0.003 $m^3 s^{-1}$ and zero flow respectively.

Flow duration curves represent the distribution of streamflow over time at a given location and show the percentage of time that a certain discharge is equaled or exceeded. Unit flow-duration curves for seven Iowa streams are shown in Figure 2; five of the streams drain out of the Des Moines Lobe in central Iowa. Four of the five Des Moines Lobe stations are within 40 km of Walnut Creek watershed and their flow duration characteristics may be indicators of the type of flow duration expected from the watershed. The curve for Little Maquoketa River near Durango, in northeast Iowa, shows more sustainable low-flows, an indicator of larger groundwater contributions to streamflow. The curve for East Fork Hardin Creek near Churdan, in central Iowa,

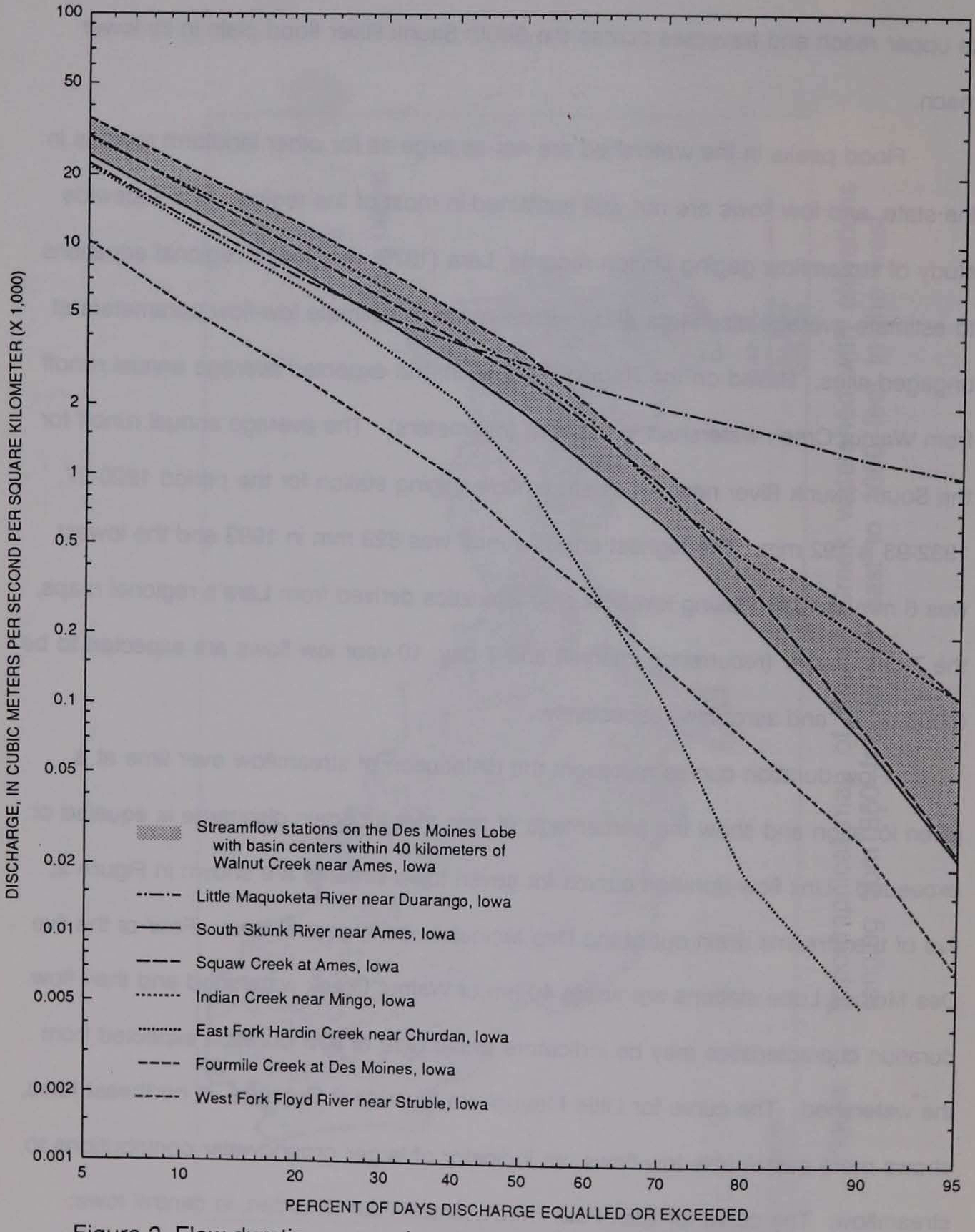

Figure 2. Flow duration curves for seven Iowa streams (Fischer et al., 1990).

indicates less sustainable low-flows, and the curve for West Fork Floyd River near Struble, in northwest Iowa, indicates less sustainable flows throughout the range of data shown. Data for the curves were taken from Fischer et al. (1990).

Physical Characteristics

Above the alluvial flood plain of the South Skunk River, the drainage area of Walnut Creek watershed is about 5100 hectares with total relief of 55 meters. The watershed can be divided into three subwatersheds (Figure 3). The northwestern subwatershed (NWSW), about 2600 hectares, and the southwestern subwatershed (SWSW), about 1200 hectares, are nearly level to rolling with numerous closed depressions in their upper portions. Drainage ditches, tile lines and surface inlets connected to tile lines have been added throughout to increase the naturally poor drainage. Relief of the eastern subwatershed (ESW), about 1300 hectares, is greater and the terrain is more dissected with streams and drainageways. Natural drainage is better, but some tile lines have been installed.

The NWSW and SWSW are almost entirely used for row-crop agriculture and there is little natural vegetation. The ESW is also used primarily for agriculture but has naturally-vegetated areas, mostly where the terrain is steeper and in riparian zones along Walnut Creek. Terraces that are used for controlling soil erosion have been built in the steep areas of the ESW.

Drainage

The depressions or "prairie potholes" in the NWSW and SWSW have been systematically drained in the past 100 years. Fields closest to natural drainageways

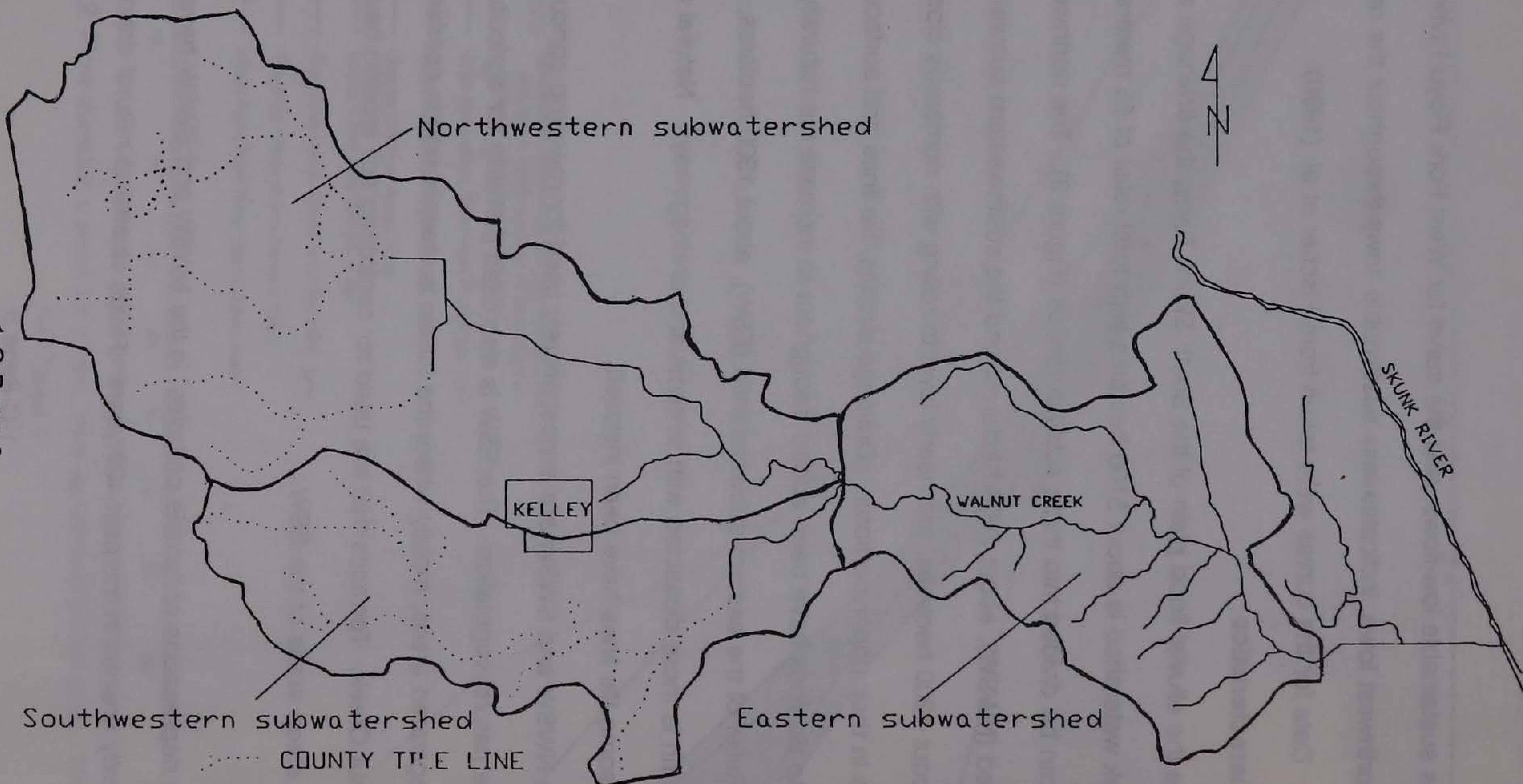

Figure 3. Northwestern, southwestern, and eastern subwatersheds in Walnut Creek watershed.

were the first to be tile drained. Legislation in 1904 enabled the establishment of drainage districts that accelerated large scale drainage. Between 1910 and 1920 larger county tiles were installed as the framework for draining the depressions in fields located farther away from drainage channels (Hewes and Frandson, 1952). Field and county tiles installed from the late 1800's to the 1950's were made of clay in approximately 0.60-m sections that were placed end-to-end in trenches with a small gap between each. Tiles installed since then are made of perforated, plastic tubing. Field tile diameters range from 12.7-40.6 cm depending on the drainage area. Most field tiles drain into county tiles; however, some discharge directly into drainage ditches or Walnut Creek. Main county tile diameters range from 25 to 91 cm and increase in diameter along their drainage route to accommodate additional discharges from field and county tiles.

In the northwestern subwatershed, the drainage channel was extended and straightened in sections 28, 29, 30 and 33 in T83N, R24W to expedite the removal of water at the county tile outlets. In very poorly drained areas of the watershed, field intakes were installed to direct surface water to subsurface tile drains. In addition to subsurface drainage, elevated straight roads were constructed and deep ditches were dug on either side to direct water to intakes installed in the ditches. These county roads have affected the natural surface runoff direction by dividing many of the low areas into several sections and also have, in effect, created "dams" along the original swales and drainageways. In the ESW, the lower reach of Walnut Creek, near the confluence with the Skunk River (2.4 km), was channelized. Levies were built along this stretch of the creek to contain flood waters.

Precipitation and Runoff

Average monthly precipitation, based on the Thiessen polygon method of area weighting, and runoff for the watershed and three subwatersheds are shown for the 1991-93 water years (WYs) in Figure 4. Also shown are the ratios of runoff to precipitation for the three subwatersheds and the monthly and mean monthly (1920-27, 1932-93) values of runoff for the South Skunk River near Ames, a nearby, long-term gaging station. Unit runoff of the watershed was similar to that for the South Skunk River for 1991-93. The runoff-precipitation ratio was greater than 1 during some periods as "stored" precipitation (snow, ice) was released to streams as temperatures increased. July 1992 and July 1993 were both periods with similar amounts of rainfall, but much different amounts of runoff. July 1992 was preceded by two fairly dry months with few cloudy days and good crop development which reduced soil moisture. July 1993 was preceded by two fairly wet months with many cloudy days and slow crop development which kept soil moisture high. Soil and depression storage were available for rainfall in 1992 and runoff was not large, but in 1993 little soil storage was available and much of the rainfall became runoff. The runoff-precipitation ratio for the ESW in July 1993 was almost 1. The ratios for NWSW and SWSW were high, though somewhat lower than for ESW, probably because of more depression storage in those two subwatersheds.

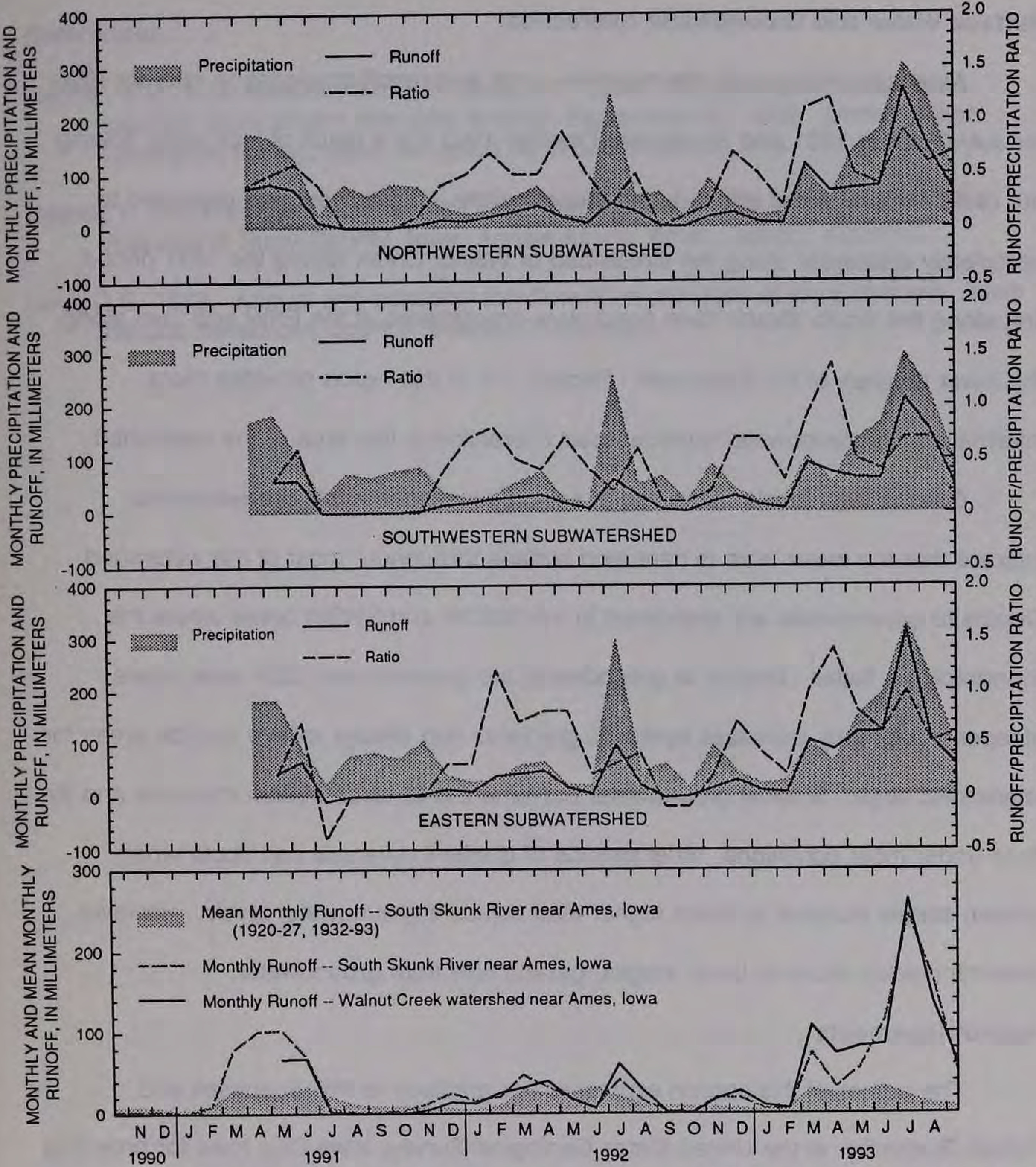

Figure 4. Monthly precipitation, runoff, and runoff/precipitation ratio for subwatersheds of Walnut Creek near Ames, Iowa for 1991-93 water years; monthly runoff for Walnut Creek watershed near Ames, Iowa, and South Skunk River near Ames, Iowa for 1991-93 water years; and mean monthly runoff for South Skunk River near Ames, Iowa for period of record, 1920-27, 1932-93 (Based on USGS and NSTL data).

Surface Water and Groundwater Interaction

As shown in Figure 4, the negative runoff and runoff-precipitation ratio for ESW for July-October 1991 and September-October 1992 are a result of less water flowing out of ESW than flowed into it during those months. Streamflow was observed to completely disappear along the streambed of Walnut Creek during the 1991 period, first along the South Skunk River flood plain downstream of the ESW and then along the lower reaches of the ESW itself. Section 1-D of this report provides more information on groundwater-surface water interaction in this area of the watershed.

Groundwater levels measured at selected locations within the watershed indicate that the water table is near land surface throughout most of the watershed. Depths to groundwater are shallowest in the NWSW and SWSW areas where the topography is flatter. Depths to groundwater are greater in the ESW area where steeper topography increases hydraulic gradients and stream valleys provide areas for lateral discharge. Shallow groundwater movement is towards stream channels and tile lines under most conditions. Brief periods of gradient reversals can occur when stream stages increase to levels higher than adjacent groundwater levels. However, streams quickly return to lower stages, gaining flow from groundwater.

Acknowlegements

The author of this section expresses her gratitude to Phil Soenksen and Robert Buchmiller at the United States Geological Survey, Iowa City, Iowa for providing information on the hydrological characteristics of Walnut Creek watershed.

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Section 1-D Hydrogeology of Walnut Creek Watershed

M. Burkart NSTL

The geology of the watershed may be discussed in two principal categories, bedrock and surficial sediments. An unconformity represented by the bedrock topographic surface (Hansen, 1985) separates the two distinct parts of the system. Many rocks beneath this surface form aquifers of regional importance such as the St. Peter-Jordan aquifer system (Horick and Steinhilber, 1978), Silurian-Devonian system of aquifers (Horick, 1984) and Mississippian aquifer (Horick and Steinhilber, 1973). The quality of water in these bedrock aquifers is not likely to be affected by surface sources of contamination in Walnut Creek watershed. In addition, the depth and naturally poor water quality of many bedrock aquifers beneath the watershed preclude their use as a source of potable water. Unconsolidated materials above the bedrock surface include sand and gravel aquifers of local importance as well as till and loess which provide the parent material for the soils of the watershed and a buffer between surface activities and ground-water resources.

Bedrock

<u>Cambrian and Ordovician Age Rocks</u>

The basal sedimentary rocks of Cambrian and Ordovician age are mostly sandstone, limestone, and dolomite, although shale constitutes a small part of the section. The Jordan Sandstone, Prairie du Chen Formation, and St. Peter Sandstone form the St. Peter-Jordan aquifer system that provides the most consistent large volume source of potable-quality water in the State, including beneath Walnut Creek watershed (Burkart and Buchmiller, 1990). The extreme depth (650 meters) of the St. Peter-Jordan aquifer system reduces the use of the aquifer in the watershed although the potentiometric surface is very near land surface. The aquifer system is recharged, in large part, through the overlying Dakota aquifer in northwestern Iowa (Burkart, 1984) where the two aquifer systems are in contact.

Silurian and Devonian Age Rocks

Silurian and Devonian age rocks are dominantly limestone and dolomite reaching a thickness of more than 700 meters (Horick, 1984). Many of these rock units form important aquifers in eastern and north central Iowa where they are closer to the land surface than beneath Walnut Creek watershed. In the study area, aquifers in these rocks yield water with excessive total dissolved solids (greater than 1500 mg/L). The relatively poor quality and the aquifer depths limit their potential use for drinking water supplies.

Mississippian Age Rocks

Rocks of Mississippian age form the uppermost bedrock beneath Walnut Creek watershed. Limestone and dolomite dominate this sequence, although siltstone, sandstone and shale occur as well. Walnut Creek is situated in the relatively narrow zone in the State where aquifers in these rocks produce potable-quality water (Horick and Steinhilber, 1973). Principal sources of water are in the Gilmore City and Hampton Formations of the Kinderhook Series. These aquifers are in limestone and dolomite and yield typically less than 200 liters per minute. This is generally sufficient to support several domestic wells in the area, but is not likely to be suitable for municipal supplies. Direct surface recharge to this aquifer does not occur near Walnut Creek, but there is a direct connection between the aquifer and the Des Moines River valley to the west. Discharge from these aquifers may occur to the Skunk River; however, sufficient information is not currently available to make an assessment of the flow system near Walnut Creek.

Surficial Deposits

The bedrock surface upon which glacial materials were deposited is deeply dissected with at least two ancient northwest-southeast river channels (Hansen, 1985). Both the Jordan channel, west of Walnut Creek, and the Skunk channel, beneath the eastern edge of Walnut Creek, have a relief of about 30 meters, similar to the modern Skunk valley. The Skunk channel contains a sand and gravel aquifer used for municipal water supplies north of the watershed.

Pleistocene deposits in the area form a confining unit over bedrock aquifers. These deposits include a thick Pre-Illinoian till overlain by a late Wisconsin (Peoria) loess with a late Wisconsin till forming the surficial material (Fig. 1).

<u>Pre-Illinoian Till</u>

The Pre-Illinoian consists of multiple till units with local gravel units. Two Pre-Illinoian till units were identified in the Ames area by Palmquist et al. (1974). These tills are older than the range of radiocarbon dating. They contain a nearly equal fraction of sand, silt and clay with clay in smaller percentage than silt or sand. The hydraulic conductivity of these tills is in the range of 10^{-11} ms^{-1} (W. Simpkins, ISU, Geology and Atmospheric Sciences Dept., written comm.). Compaction by subsequent glacial

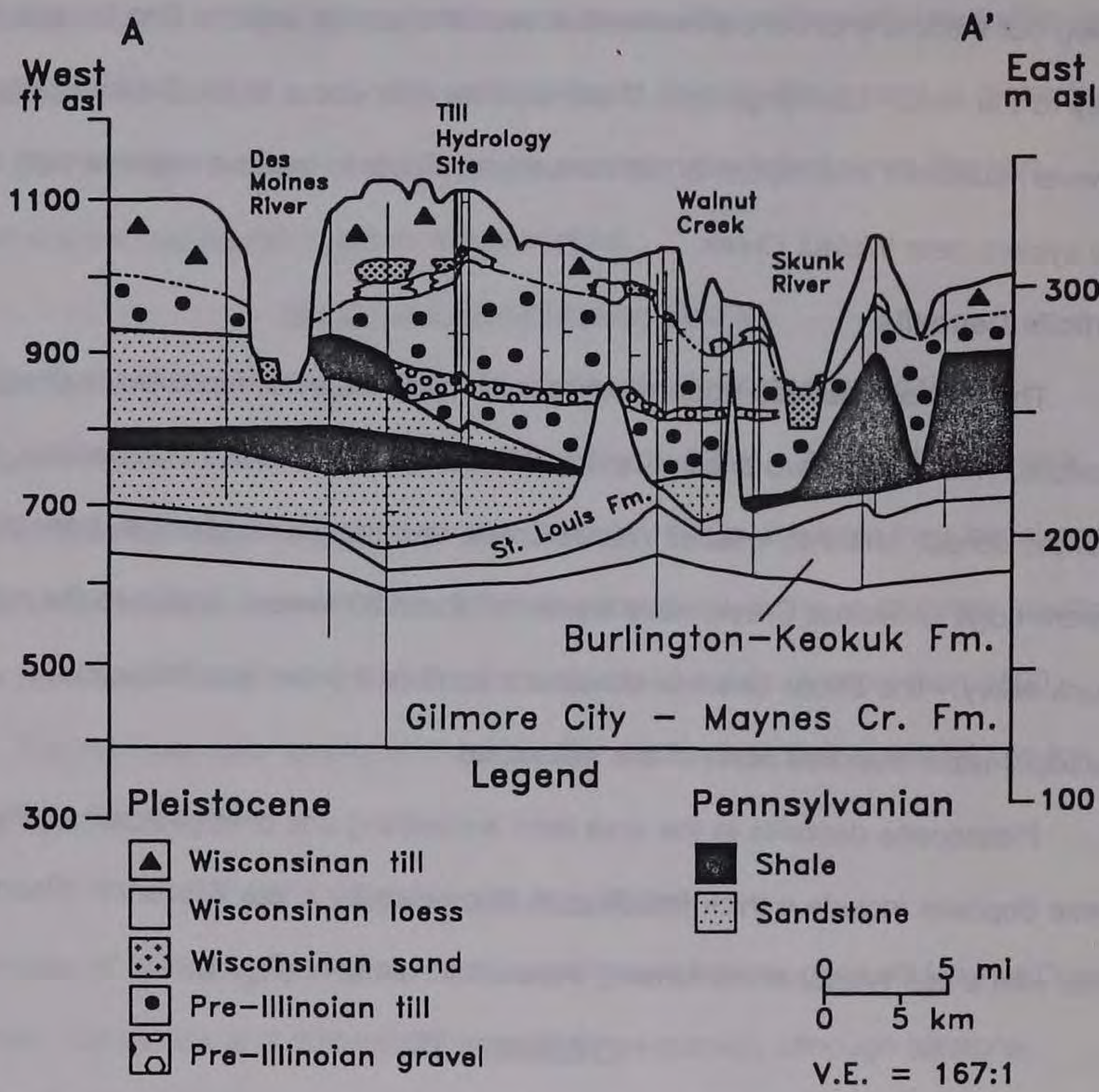

Figure 1. Preliminary cross-section showing the surficial deposits that overlie bedrock in central Iowa (B. Simpkins, 1992, ISU, Geology and Atmospheric Sciences Department).

advances have reduced the hydraulic conductivity to less than that of similarly textured Wisconsin till. Vertical hydraulic gradients in the unit approach 1.0. A laterally continuous Pre-Illinoian gravel unit occurs at depths of 69-76 meters. This unit supplies water to most domestic users in the watershed. This unit may be recharged by both downward flow through the fractured till and upward flow where it is in contact with underlying bedrock.

Late Wisconsin Loess

Overlying the Pre-Illinoian till is a late Wisconsin loess deposited between 14,000 and 17,000 years before present. This material is eolian silt and clay up to 8 meters thick. The loess has unusually large organic carbon content, nearly 1%, probably the remnants of a spruce forest that grew on the land surface and was subsequently buried by the advance of ice that deposited material in the Des Moines lobe. The hydraulic conductivity of the loess unit is about 10^{-8} ms^{-1} (W. Simpkins, ISU Geology and Atmospheric Sciences Dept., written comm.).

Late Wisconsin Till

Till deposits derived from late Wisconsin ice advances (14,000 to 12,000 years before present) form most of the surficial material in Walnut Creek watershed and the Des Moines Lobe of central Iowa. The thickness ranges from 4.5 to 25 meters and the tills have been formally classified as part of the Dows Formation consisting of the basal till Alden Member and the overlying supraglacial Morgan Member (Kemmis et al., 1981). The Morgan member varies considerably in texture but averages 44% sand, 42% silt, and 14% clay in Iowa, although it contains numerous sand lenses. Where present, it is frequently the surficial unit on the landscape. The Alden Member is texturally more uniform with an average 48% sand, 37% silt and 16% clay in Iowa (Kemmis et al., 1981). Both tills are light yellow brown (2.5 Y 6/4) where weathered (oxidized) to depths of 4 meters.

Weathering is generally deepest in upland areas and is the result of mid-Holocene water table depths lower than modern ones. Iron-coated fractures are commonly seen in the upper 4 meters of weathered till and show preferred orientation related to ice-flow direction (Lee, 1991). The hydraulic conductivity of the weathered till ranges from 10^{-3} to 10^{-5} ms^{-1}. The relatively large conductivity is a result of little compaction, relatively large sand fraction, and fracturing. The weathered zone is generally absent in topographic lows and near creeks.

The unweathered (unoxidized) Alden Member is dark grey (2.5 Y 4/0), more cohesive, and has a higher bulk density than the weathered till. Fractures have been observed in the upper meter. The overall hydraulic conductivity is much smaller than the weathered till, averaging 10^{-8} ms^{-1}. Vertical hydraulic gradients are about 0.05.

The till landscape in the watershed consists of low relief (2 m) arcuate-shaped ridges that approximately parallel the former ice margins and the Bemis end moraine to the south and the Altamont moraine to the north. These corrugated ridges were apparently formed when basal till and meltwater sediment squeezed into crevasses at the base of the ice (Stewart et al., 1988). Numerous small closed depressions, prairie potholes, can be found in the western half of the watershed. These depressions have received colluvial sand and silt sediments during the Holocene (Walker, 1966).

The extreme eastern part of the watershed is an alluvial flood plain underlain by sand and gravel of the Skunk River alluvial aquifer. The land surface in this area is essentially flat with a gentle slope from the bluffs on the west toward the Skunk River. Walnut creek has been straightened along a 2 kilometer reach as it flows across the alluvial plain. This aquifer is typical of alluvial aquifers in the Midwest, long and narrow, 5 to 15 m thick and composed of interbedded sand, gravel, and silt deposited by Holocene streams. Hydraulic conductivities of individual layers may range from 1 to 10^{-6} ms^{-1}, but the overall effect is to allow withdrawal of water at rates of from 500 to 5000 liters per minute. This and similar aquifers provide reliable quantities of water to municipal and domestic water supplies as well as isolated irrigation systems. However, they have been found to be the aquifer type most susceptible to contamination by agricultural chemicals (Burkart and Kolpin, 1993).

Recharge to the Skunk River alluvial aquifer in the watershed occurs through direct infiltration of rain and snow melt through a 4 meter thick modern flood plain deposit with generally more silt and clay than the aquifer. Recharge also comes from leakage through the Walnut Creek stream bed. The recharge contribution directly from Walnut Creek may be an important source of nitrate and herbicides to the aquifer.

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Section 1-E Landuse and Farming Practices in Walnut Creek Watershed

K. Keck NSTL

Information provided in this section was obtained from farming surveys conducted by Karen Keck and Margaret Smith at the National Soil Tilth Laboratory (NSTL) in 1991 and 1992 at every farm in the watershed. Section 5-Q of this report provides more detailed information on research protocol used for the surveys.

Landuse

Approximately 95% of the 5600 ha in Walnut Creek watershed are used for row crop agriculture with limited livestock production. Land not used for row crop agriculture is pasture, woodland, or residential. The upper three-quarters of the watershed is relatively flat and almost entirely in row crop production. Row crops, pasture, and woodlands are more evenly distributed in the lower quarter of the watershed, which has a more rolling topography and is more susceptible to erosion. Corn and soybeans are grown on 80% of the row crop acres in yearly rotations, although some continuous corn is also found in the watershed. Greater than 50% of the crop acres are commonly planted to corn and 40-45% are planted to soybeans. Alfalfa, grass and oats are grown on the remaining crop acres that are usually involved with a government land management program.

Farming Practices

Tillage Practices

Conventional tillage practices are used most commonly by farmers in the watershed. Management practices that include no tillage have recently been adopted by some farmers, but this alternative practice, in addition to ridge-tillage, are not widely adopted farming methods. Chisel plows are used by more than 90% of the farmers in the watershed. Moldboard plows, however, are used by fewer than 5% of the farmers. A typical conventional tillage pattern for a corn-soybean field in Walnut Creek watershed includes:

chisel plow after corn harvest

field cultivate in spring (2x)

row cultivate beans during summer (2x)

no fall tillage after bean harvest

field cultivate in spring (1x)

row cultivate corn during summer (1x)

This tillage pattern is generally followed at the intensively-monitored sites that are conventionally tilled. On the intensively-monitored no-till sites in the watershed, there is no fall, spring or summer tillage. Farmers in the watershed, however, commonly consider a system that includes row cultivation in the summer with no fall or spring tillage as no-till management.

<u>Erosion Control Practices</u>

Permanent grassed waterways are found in several areas of the watershed where gully formation is likely to occur. Terraces have been constructed within the last fifteen years on a few fields with steep slopes in the eastern half of the watershed to control erosion. The terraces usually include at least one tile intake at the border of every terrace level.

There is a general trend towards keeping more crop residue on fields during the winter. Soybean residue is commonly left on fields after harvest, with no tillage until spring. Often 10-20% of corn residue also remains on the soil surface over the winter until spring field cultivation.

Herbicides

Atrazine, metolachlor, cyanazine, alachlor, EPTC, and nicosulfuron are the most common active ingredients in corn herbicides used in the watershed; atrazine and metolachlor being used most extensively. Atrazine is typically applied to 40-50% of the corn acres at a maximum rate of 1.0 kg of atrazine per ha, and metolachlor is applied to 50-60% of the corn acres at a maximum rate of 2.8 kg per ha.

Trifluralin, imazethapyr, metolachlor, and metribuzin are common active ingredients in soybean herbicides. Approximately half of the soybean acres in the watershed are treated with trifluralin at a typical rate of 1.7 kg per ha.

Insecticides are seldom used in the watershed, except in the few areas of continuous corn. In continuous corn, without the benefits of crop rotation to break insect reproduction cycles, corn rootworm can be a problem without the use of insecticides.

Herbicides are incorporated into the soil with a field cultivator before planting and applied with a sprayer after emergence. Farmers typically use two herbicides per field, the pre-plant application is often banded and post-emergence application broadcasted. Banded applications are typically 38 cm spray bands over 76 cm crop rows. Aerial spraying is used only when tractors can't get into fields due to extremely wet weather.

Fertilizers

Fertilizers are applied to nearly 100% of the corn acres in the watershed. Anhydrous ammonia is injected either in late fall or early spring at an average application rate of 65 kg of nitrogen per ha. Dry fertilizers that contain nitrogen (N), phosphorus (P), and potassium (K) are typically spread by local farm cooperative trucks during the winter while the soil is frozen. The amount of dry nitrogen applied ranges from 5 to 22 kg per ha, phosphorus and potassium are applied at rates that range from 22 to 54 kg per ha and 16 to 109 kg per ha, respectively. The amount of dry fertilizer applied by many farmers depends on local farm cooperative soil tests that indicate N, P, and K requirements on a per field basis. Some growers also sidedress nitrogen in the early part of the growing season in a 28% or 32% liquid solution. Nitrogen fertilizer credits are also taken on a previous year's soybean crop, usually at the rate of one bushel yield from the previous year equivalent to 0.22 kg of nitrogen fertilizer.

Phosphorus and potassium fertilizers are typically applied to soybean fields in the spring. Soybean production does not generally require the use of additional nitrogen fertilizers. Where corn-soybean rotations are used, fields are typically fertilized only before the corn growing season with enough fertilizer to last through the next season of soybean production.

Livestock Production and Manure Management

Livestock production is limited to only a few farms in the watershed. Of the two major livestock operations, one raises cattle and the other hogs. Manure from these larger operations is spread on fields near livestock confinement facilities or feedlots. Small herds of sheep, horses, hogs, cattle and/or goats are raised on twelve farms in the watershed and most of these animals are kept in pasture areas near farmsteads.

Farm Tile Systems

An extensive tile drainage network exists in Walnut Creek watershed, especially in the western, more poorly drained, half of the watershed. The oldest tile lines called "mutuals", were hand dug in the late 1800's to early 1900's by early farmers in the watershed. These clay tiles were usually 8-23 cm in diameter, and placed less than a meter under the soil surface in marshy areas of the fields. Tiles installed since that time are now made of perforated, plastic tubing, are buried deeper to avoid damage by tillage equipment, and they drain extensive areas of the watershed.

Field tiles are connected to county tile lines that eventually drain into the main stream channel of Walnut Creek. In addition to tiles, some farmers have installed tile intakes, in areas of poorly drained soils, that collect surface runoff and discharge directly into drainage tiles.

SECTION 2. RESEARCH OBJECTIVES

Section 2-A MSEA Research Objectives

J. Hatfield NSTL

The research objectives of the Iowa Management Systems Evaluation Areas (MSEA) program are:

1. Quantify the physical, chemical, and biological factors affecting the transport and fate of agricultural chemicals;
2. Determine the effects of crop, tillage, and chemical management practices on the quality and quantity of surface runoff, subsurface drainage, and ground water recharge;
3. Integrate information from Objectives 1 and 2 with data about soil, atmospheric, geologic, and hydrologic processes to assess the impact of these factors on surface and groundwater quality;
4. Evaluate the socioeconomic impacts of current and developmental management practices that may emerge as most effective from Objectives 1, 2, and 3;
5. Develop an education and technology transfer program that would quickly disseminate information to the users.

These objectives deal with both the on-site and off-site impacts of current and emerging agricultural practices.

Section 2-B Master Objectives

J. Hatfield NSTL

The purpose of the Midwest Agricultural Surface/Subsurface Transport and Effects Research (MASTER) project is to study the ecological impacts of off-site movement of agricultural chemicals into a stream and to determine the effect of current agricultural management practices on the terrestrial ecology of an ecosystem. The objectives of the MASTER project are:

1. To understand and distinguish the ecological impacts of agricultural chemicals from the impacts of other agricultural practices;

2. To evaluate alternative management practices for their effectiveness and longevity in preventing ecological degradation;

3. To assess the ability of alternative practices to affect ecosystem restoration and maintain agricultural productivity.

Research projects that are conducted in Walnut Creek watershed are based on the MSEA and MASTER objectives.

SECTION 3. RESEARCH CRITERIA

Section 3 Research Criteria

J. Hatfield NSTL

The problem of integrating the water quality and ecological effects of agrichemicals in terrestrial and aquatic environments and evaluating the effectiveness of modifying agricultural practices is complex and requires a comprehensive research program. Within Walnut Creek watershed the research program is focused on measuring the soil, water, and terrestrial responses to the different farming practices and landscape management scenarios. The criteria for success in the initial phase of research studies in the watershed are relatively simple since the emphasis is on reconnaissance. During the latter phase of the research program that will commence in 1994, farming practices will be modified so that the changes can be detected on a watershed scale. Modifications of farming practices have been introduced within specific fields in the watershed; however, the emphasis of these studies has been on the on-site impact and movement within fields rather than the off-site impact within the watershed.

The research program in Walnut Creek watershed was developed to provide the maximum amount of sensitivity possible for all parameters. The sampling frequencies and numbers of samples collected are important criteria used to monitor the impact of agricultural practices on the environmental quality in the watershed. Within the research protocol sections of this report, brief descriptions of the Quality Assurance/Quality Control criteria that are used for each research project are provided to assist those who may be potential users of this information.

SECTION 4. INFORMATION BASE

Section 4-A Walnut Creek Watershed GIS Information Base

W. Oesterreich NSTL

Overview

The Walnut Creek Watershed geographic information system (GIS) database at the National Soil Tilth Laboratory (NSTL) represents spatial information at watershed and field scales. The ARC/INFO (Environmental Systems Research Institute, Redlands, CA, Version 6.1.1) GIS is used at the NSTL. Most of the research sites and sampling locations in the watershed have been transferred into the GIS database from Global Position System (GPS) points and in the future, collected data will be 'attached' (related) to geographic reference points in the watershed. The data will then be used to create maps, for identifying trends, and for incorporation into computer models.

GIS Platform

The NSTL uses a SUN (Sun Microsystems, Inc., Mountain View, CA) (SOLARIS 2.3 AND SUNOS 4.1.2) computer as the platform for the Walnut Creek watershed GIS database.

Watershed GIS Database Themes

The Walnut Creek Watershed GIS database consists of spatial data that are organized into multiple themes that include: a. administrative boundaries; b. elevation; c. groundwater; d. imagery; d. land use; e. monitoring systems; f. soils; g. surface water; and g. transportation. As listed below each theme may have many layers or coverages. Basic types of coverages include points, lines or arcs, and polygons. There are specialized, more complex coverages such as GRID or TINS that are developed from the basic coverages and used for spatial analyses. Walnut Creek Watershed GIS data within most coverages are single-precision, projected in Universal Transverse Mercator, zone 15 and North American Datum (NAD) 1927. Some spatial coverages such as those generated from GPS points are collected in NAD 83 and then converted to NAD 27.

Administrative Boundaries

BASIN
(Watershed Boundary) Type: Polygon
The boundary of the Walnut Creek MSEA site.

MBASIN
(Management Areas) Type: Polygon
Areas within the Walnut Creek Watershed divided as 6 sub-watershed basins as determined by USGS.

SECTIONS
(Section Lines) Type: Line
A data set of section lines not represented by the ROADS data set in Walnut Creek watershed.

TFIELD91
(Tract-Farm-Field) Type: Polygon
A data set of polygons identified by tract, farm, and field in Walnut Creek watershed in 1991. The data set includes attribute data on crops, acreages, farmer, and types and amounts chemicals used.

TFIELD92
(Tract-Farm-Field) Type: Polygon
A data set of polygons identified by tract, farm, and field in Walnut Creek watershed in 1992. The data set includes attribute data on crops, acreages, farmer, and types and amounts chemicals used.

TOWN
(Towns) Type: Line
The boundaries of Kelley and parts of Ames, Iowa, that are within the Walnut Creek watershed.

TRACT
(Tract Boundaries) Type: Polygon
The ASCS-defined tract boundaries in the Walnut Creek watershed.

TOPO_BASIN
(Topographic Basins) Type: Polygon
Subwatershed basins delineated by identifying ridge lines between drainage basins. A digital elevation model, compiled from the USGS 1:24000 scale elevation data set was used to map the topographic drainage patterns and perform the sub-watershed delineation. These basins were aggregated to best correspond to the data set AQ_BASIN.

Elevation

AQ_BASIN
(Aqua Terra Basins) Type: Polygon
Subwatershed basins divided by Aqua Terra Consultants based on the MBASIN and RIVER data sets. Aqua Terra is considering the use of this data set for use in the HSPF watershed model of Walnut Creek Watershed.

ASPECT
(Aspect) Type: Grid
A data set that identifies the down-slope direction of the maximum rate of change elevation for the Walnut Creek watershed. Aspect values were interpolated to the nearest integer.

CONTOUR
(Elevation Contours) Type: Line
Elevation contours (10 feet) at a scale of 1:24000 for the Walnut Creek MSEA site. It was compiled by USGS to correspond to the 1:24000 scale 7.5 minute quadrangle topographic map series.

ELEV_HS
(Shaded Relief) Type: Grid
A digital terrain model interpolated from the CONTOUR elevation data set using kriging estimation. Hillshade based on a sun angle of 310 degrees with an altitude of 30 degrees and an elevation exaggeration of 4x.

ELEV_MTR
(DEM Meters) Type: Grid
A digital terrain model interpolated from the CONTOUR elevation data set using kriging estimation. Surface elevation is measured in meters above mean sea level. The minimum resolution is 10 meters, the minimum map scale 1:24000.

SLOPE_P
(Percent Slope) Type: Grid
A data set that represents the slope in percent complied from the ELEV_MTR DEM. Slopes values were interpolated to the nearest integer.

Groundwater

OUTLET
(Tile Outlets) Type: Point
A data set that represents a partial sample of tile outlets in the Walnut Creek watershed.

POTWELL
(Monitoring Wells) Type: Point
A data set that represents the Jaynes well nests (15) in the pothole field in Walnut Creek watershed. Point data obtained via GPS and converted from NAD83.

PRIVWELL
(Monitoring Wells) Type: Point
A data set that represents the private, deep wells (46) in Walnut Creek Watershed. Point data obtained via GPS and converted from NAD83.

TILE
(Tiles) Type: Line
A data set that represents the tile lines in the Walnut Creek Watershed. This data set may not be complete.

WELLS_WC
(Monitoring Wells) Type: Point
The location of 85 monitoring wells or well nests in the Walnut Creek MSEA site. Point data obtained via GPS and converted from NAD83.

Imagery

1980G
(1980 Aerial Photos) Type: Grid
A set of TIF files were scanned from 1980 aerial photography obtained from the ASCS for the Walnut Creek MSEA site. The photography was flown in July at a scale of 1:40000. This grid data set was compiled from the TIF files.

1990G
(1990 Aerial Photos) Type: Grid
A set of TIF files were scanned from 1990 aerial photography obtained from the ASCS for the Walnut Creek MSEA site. The photography was flown on 12 March and 04 April at a scale of 1:40000. This grid data set was compiled from the TIF files.

Land Use

LU39_ALLG
(1939 Land Use) Type: Grid
Interpreted land use classification from 1939 aerial photographs of Walnut Creek watershed. Shows all land features together.

LU90_ALLG
(1990 Land Use) Type: Grid
Interpreted land use classification from 1990 aerial photographs of Walnut Creek watershed. Shows all land features together.

LU39_LINE
(1939 Land Use) Type: Line
Interpreted land use classification from 1939 aerial photographs of Walnut Creek watershed. Shows line-type land use features.

LU90_LINE
(1990 Land Use) Type: Line
Interpreted land use classification from 1990 aerial photographs of Walnut Creek watershed. Shows line-type land use features.

LU39_PFLD
(1939 Land Use) Type: Polygon
Interpreted land use classification from 1939 aerial photographs of Walnut Creek watershed. Shows polygon-type land use features with interpolated field boundaries.

LU90_PFLD
(1990 Land Use) Type: Polygon
Interpreted land use classification from 1990 aerial photographs of Walnut Creek watershed. Shows polygon-type land use features with interpolated field boundaries.

LU39_POLY
(1939 Land Use) Type: Polygon
Interpreted land use classification from 1939 aerial photographs of Walnut Creek watershed. Shows polygon-type land use features.

LU90_POLY
(1990 Land Use) Type: Polygon
Interpreted land use classification from 1990 aerial photographs of Walnut Creek watershed. Shows polygon-type land use features.

Monitoring Systems

BASE_WC
(Meteorological) Type: Point
The location of weather stations 701 & 702 in Walnut Creek watershed. Point data obtained via GPS and converted from NAD83.

BIRD
(Bird Survey) Type: Point
Locations of Lou Best's bird survey sites in Walnut Creek watershed. Point data obtained via GPS and converted from NAD83.

BIRD2
(Bird Survey) Type: Point
Locations of Doug Bergin's 1993 bird survey sites in Walnut Creek Watershed. Point data obtained via GPS and converted from NAD83.

BOWRAT92
(Evapotranspiration, 1992) Type: Point
1992 locations of the energy balance stations (715, 716, 717, & 718) in Walnut Creek watershed. Point data obtained via GPS and converted from NAD83.

BOWRAT93
(Evapotranspiration, 1993) Type: Point
1993 locations of the energy balance stations (715, 716, 717, 718, 731, & 732) in Walnut Creek watershed. Point data obtained via GPS and converted from NAD83.

BUGTRAP
(Insect Traps) Type: Point
1993 locations of insect traps in Walnut Creek watershed. Point data obtained via GPS and converted from NAD83.

CORE92
(Soil Cores) Type: Point
A data set that represents the 1992 soil core sampling sites in Walnut Creek watershed. Point data obtained via GPS and converted from NAD83.

CORE93BE
(Soil Cores) Type: Point
A data set that represents the 1993 soil core sampling sites at the Black East Field in Walnut Creek watershed. Point data obtained via GPS and converted from NAD83.

GRIDPTS
(Grid Points) Type: Point
Location grid points for soil core sampling sites on field T3016 in Walnut Creek watershed. Point data obtained via GPS and converted from NAD83.

NTHARV93
(Harvest Points) Type: Point
A data set of 1993 harvest points in Bassett's No-Till field in Walnut Creek watershed. Point data obtained via GPS and converted from NAD83. The data set includes the attribute yield, in bushels/acre.

POTNODE
(Node Points) Type: Point
A data set that represents Moorman's node points in the pothole field in Walnut Creek watershed. Point data obtained via GPS and converted from NAD83.

SPORETRAP
(Spore Traps) Type: Point
A data set that represents Vakili's 1992 & 1993 spore trap locations in Walnut Creek watershed. Point data obtained via GPS and converted from NAD83.

STRMGAGE
(Stream Gage) Type: Point
A data set that represents the stream gage sites (310, 320, & 330) in Walnut Creek watershed. Point data obtained via GPS and converted from NAD83.

TBUC_WC
(Precipitation) Type: Point
A data set that represents the locations of all 15 tipping rain buckets in the Walnut Creek watershed. Point data obtained via GPS and converted from NAD83.

Soils

SOIL
(Boone & Story County Soils) Type: Polygon
A data set of soils identified by their Soil Mapping Symbol (SMS) and can be related to the Iowa Soil Properties and Interpretation Database (ISPAID).

SOILPIT
(Soil Pits) Type: Point
A data set that represents the locations of soil pits dug in early 1993 in Walnut Creek watershed. The pits were characterized by Jaynes, Fenton, & SCS. Point data obtained via GPS and converted from NAD83.

SPOTS
(Spot Symbols) Type: Point
A data set that represents the spot symbols found on the county soil maps in Walnut Creek watershed.

Surface Water

DRAINS
(Drainage) Type: Line
A data set that represents the surface drainage in Walnut Creek watershed.

INLET
(Tile Inlets) Type: Point
A data set that represents a partial sample of tile inlets in Walnut Creek watershed.

PONDS
(Ponds) Type: Polygon
A data set representing ponds or lakes in the Walnut Creek watershed.

RIVER
(Streams & Rivers) Type: Line
A data set that represents the streams and rivers in the Walnut Creek watershed. Stream type is not identified in this data set.

WETAREA
(Wet Areas) Type: Polygon
A data set that represents wet areas as identified from soil maps in the Walnut Creek watershed.

Transportation

RAILROAD
(Railroads) Type: Line
A data set that represents the former railroad lines in the Walnut Creek watershed.

ROADS
(Roads) Type: Line
A data set representing roads in the Walnut Creek watershed. Road type is identified.

IS Output and Analyses

Many maps, in both plotter (HP) and postscript formats, have been created using the coverages that are currently available in ARC/INFO at the NSTL. The following lists some of the maps that are available.

HP Plotter Format Files

watershed2
: Map of Walnut Creek Watershed showing well, base, stream gage, & rain gage sites, intensively studied fields, tiles & streams, and watershed boundary.

core93be
: Map of Black East field showing 1993 soil core sampling sites and soil polygons.

gridpts
: Map of field T3016 showing the grid points for the so" core sampling sites.

harv93soil
: Map of Bassett's No-Till field showing 1993 harvest points by yield category, overlaying the soil polygons.

in2
: Map of Walnut Creek Watershed. Includes: streams and contours (major lines are colored).

okob

Map of Walnut Creek watershed showing Okoboji soils. Also includes: roads (by type), basin boundaries, and streams.

road3

Road map of Walnut Creek Watershed. Includes roads (by type), basin boundaries, and streams.

soil1_kk2

Soil map of the Bassett No-Till Field. Soil polygon information (acres & soil name) can be found in the two tables.

watershed

Map of Walnut Creek watershed. Includes: basin boundaries, roads (as lines, not by type), tiles, streams, and intensively studied fields.

Postscript Format Files

ac_sbas

Map of Walnut Creek watershed showing the modified AquaTerra-defined subbasins, tiles, and streams. Includes acreage values for each subbasin.

basebuc

Map of Walnut Creek watershed showing basins. Included: a table listing acres and square meters per subbasin.

bowen

Map of Walnut Creek showing the GRID hydrogeologic modeling tools determined subbasins. Included are the subbasin acreages.

cs91_msea

slide (and map) of Walnut Creek showing basin boundaries, bowen-ratio stations, rivers, roads, and intensively studied fields.

cs92_msea

Slide (and map) of Walnut Creek showing the 1992 distribution of corn and soybean for 1992.

hydric2

Map of Hydric Soils of Walnut Creek watershed (hydric soils & moderate to well-drained soils) watershed2

Map of Walnut Creek watershed showing well, base, stream gage, & rain gage sites, intensively studied fields, tiles & streams, and watershed boundary.

wc_well

Map of Walnut Creek watershed showing basin boundaries, streams, roads, sections, and well locations.

wccont

Map of Walnut Creek watershed showing contour lines within the watershed boundary.

The Postscript-format output can be used with other software to create color 35mm slide files or can be sent directly to the Iowa State University photo-media facility (slide camera).

Data in Statistical Analysis Systems (SAS) files will eventually be transferred into ARC/INFO data files. Coverages can be related to data or they can be imported directly into the coverages so that data can be related to a geographical reference point. The GIS will be used to query the database based on a geographic location. For example to list all no-till fields in Walnut Creek watershed that are planted to corn in a specific year(s). The GIS data can be saved in ASCII format and then brought into SAS for statistical analysis.

Section 4-B Walnut Creek Watershed Database

B. Jaquis NSTL

Overview

Development of the Walnut Creek watershed database was undertaken to provide a comprehensive compilation of data for use by researchers involved with studies in the watershed. The platform selected for this database was SAS (Statistical Analysis Systems) because of its capabilities in analyzing, cross-referencing, and retrieving data in various formats.

Database Management System Concepts

The following are concepts used to describe the database management system used at the NSTL. Figure 1 shows a conceptual model of the components of the NSTL database management system.

Data Collectors

Those that gather raw data and assemble it into usable files.

Flagging Routines

Automated routines designed to examine the raw data and flag records with values that fall outside of pre-determined screening rules. The flagging routines identify data that may be incorrect, invalid, or suspect.

DBMS

Database Management System (DBMS). The software, hardware, people, and documentation that turn screened data into useful output for data users.

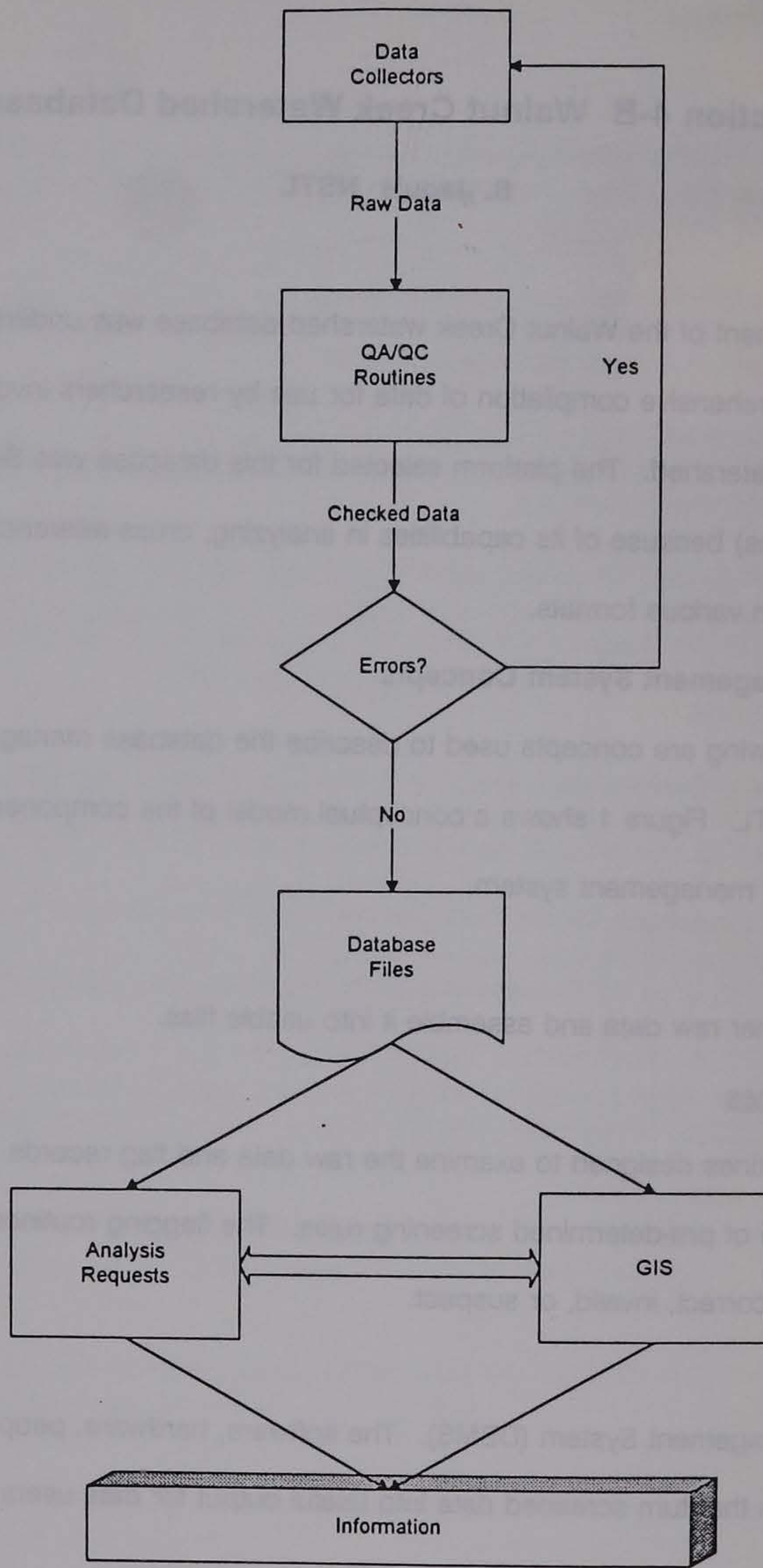

Figure 1. The National Soil Tilth Laboratory Database Management System.

Database Files

Data that have been screened. The files are organized in such a manner to facilitate the use of SQL in retrieving subsets of the data to meet user requests.

Analysis

Data analysis conducted by DBMS personnel. The analysis could be done to verify the quality of the database or to answer user requests.

Users

Data sent directly to users for their own analysis.

GIS

Data output to the Geographic Information System.

Information

The ultimate goal of the DBMS. Raw data are analyzed and organized into a form useful for supporting the research goals at the NSTL.

Data Processing and the NSTL Database

Data that are collected in the watershed for inclusion in the NSTL database and/or for researcher use are reviewed by researchers and then saved as files in ASCII format. The data are flagged to identify incorrect, invalid, or suspect values in a QA/QC check and may be organized into files according to time averages (e.g., 5 minute or daily averages. The data are then streamlined into user files for output to personal computers and/or the SAS database. Figure 2 is an example of the data processing involved with tipping bucket files.

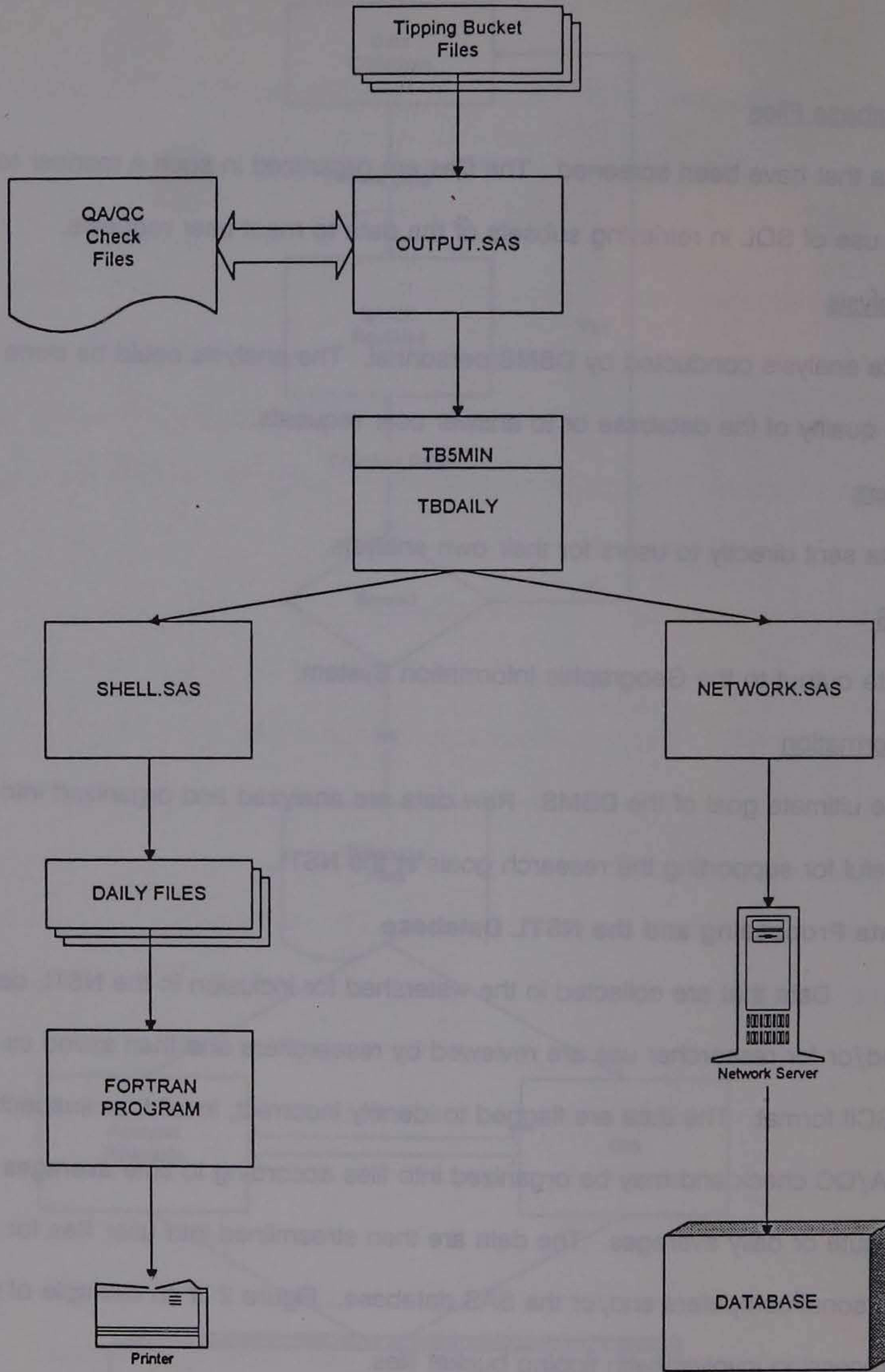

Figure 2. Data processing involved with Walnut Creek watershed tipping bucket data.

The NSTL SAS database contains numerous files. Attachment I lists all of the database files and the library (directory) where they are located. Attachment II lists the variables in each file along with an explanation. Where multiple files contain the same variables, only on file representative file is listed. Figure 3 shows the processing sequence involved with the database files.

Data in the NSTL database can be analyzed statistically and could be used in computer models and/or transferred to the NSTL GIS.

Data Policy

Distribution

Purpose

Data are collected and distributed for the purposes of furthering the understanding of the effects of agricultural practices on environmental quality.

Data Coverage Policy

Data covered under these policies include those that are collected on a routine manner throughout the watershed. These data include: well heights and quality; tile flow and quality; stream flow and quality; soil analyses for agrichemicals; meteorological data; rainfall intensity; farming practice information; and GIS layers. Some of the information collected may not be released because of the confidential nature of the information that pertains to each field.

Data collected through the efforts of individual scientists or teams of scientists addressing a particular research question are considered to be available only when the original hypothesis(es) has been tested and the report prepared. Individual

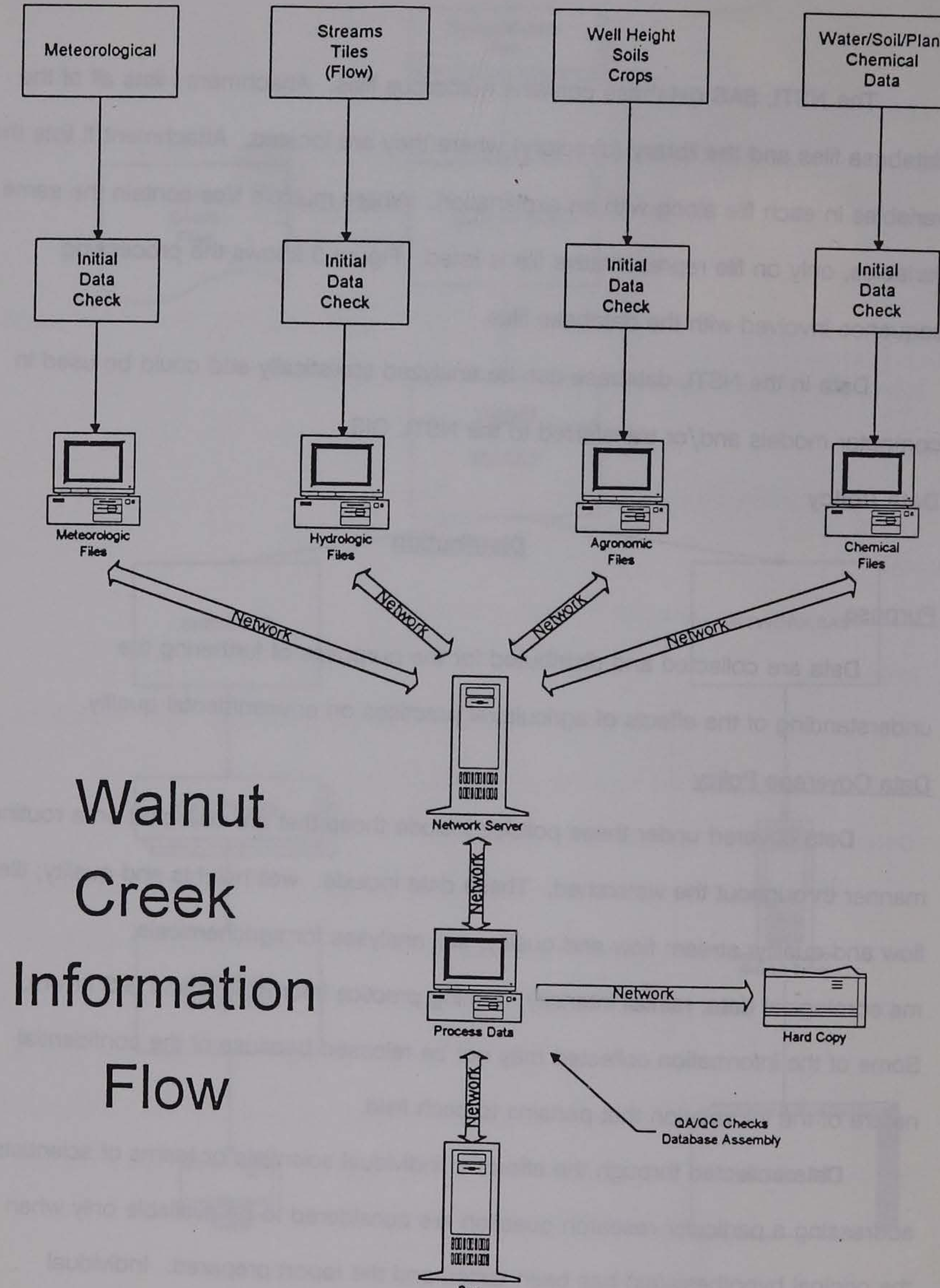

Figure 3. The processing sequence involved with Walnut Creek watershed database files.

scientists are free to share their information at any time with other cooperators within the project. This decision is left to their discretion.

Availability

Data are available for distribution to cooperators of the National Soil Tilth Laboratory (NSTL), United States Geological Survey (USGS), and United States Environmental Agency (U.S.EPA)-MASTER as part of the ongoing investigators on environmental quality. The distribution of data does not permit the use in scientific publications without the review and authorization of the Principal Investigators from NSTL, and the Project Managers from USGS and U.S.EPA.

Data that are quality controlled and screened are available for use to develop and test hypotheses and are considered suitable for publication. These data are listed in the data dictionary for Walnut Creek. A data catalog that covers each parameter, the current state of the data processing, and the release codes is available from NSTL.

Quality Assurance/Quality Control (QA/QC) of the Database

Data released without any quality control of screening should be considered preliminary and not to be used in publications. These data are considered for release to calibrate models or develop concepts.

Geographical information system data layers require checking by NSTL before distribution to ensure quality control and accuracy of map locations.

Acknowledgements

Data that are used in evaluation of any hypotheses should be acknowledged as to the source and authenticity.

Data Availability and Release Codes

Each data set or subset of the database will carry a code describing the availability and degree of release. Code A, data set is available for general use and may be used in publications and reports with only an acknowledgement as to source and project; Code R, data use is restricted to internal analyses and may not be published until permission is obtained; Code P, data are preliminary for evaluating concepts and hypotheses, these data are not to be published or used in any report; Code S, data are part of an ancillary scientific project and are not available until the initial study is complete.

Data Release

Data may be available upon request, however, the schedule of release will depend on the complexity of the request and the current state of the database. Schedule of the data release is coded in the data catalog and is updated every quarter. Release of data will be on either disk or tape. Updates to the database will forwarded on a six-month interval; however, updates must be requested at the time of the original request. The NSTL will assume responsibility for the error checking and will notify the users of any errors detected after the time of release.

A form describing the data and release codes will be signed by each requestor prior to data release (ATTACHMENT III). All data released will be available only to the original requestors and shall not be shared with other projects or investigators outside the original data request without written permission from the NSTL.

Data Contact

The NSTL contact for the database is J.L. Hatfield, NSTL director, and all data will be requested through his office.

Acceptance

Policy

Data are collected throughout the watershed for a variety of assessments of environmental quality and this policy covers the entry of these data into the overall database. All data collected within the watershed are assumed to be entered into the database.

Data Forms and Documentations

All data collected within the watershed will be entered into the database and maintained as part of the MSEA/MASTER project. Each data element will be detailed in the data catalog. As part of the data integration process, each data element will be required to have on file a document describing the form of the data, the collection procedures, and the QA/QC protocols that have been followed for the screening of the data set, and the individual responsible for the collection and quality control of the data.

Entry into the Data Catalog

Data will be entered into the data catalog for the purpose of detailing the record of information within the watershed and providing a long-term storage of the data that can be used in future assessments. Entry in the data catalog can occur when the data collection procedures and the quality control is complete. The NSTL will not be responsible for checking the data and will note on each entry the level of checking completed.

Link with the Distribution Policy

The acceptance of data and the distribution of data are integral parts of the data policy for the watershed. All data entered into the data catalog will be handled under one of the data release codes.

Summary of QA/QC

Each parameter entered into the database will carry a summary sheet of the QA/QC conducted and the efforts made to screen the data. These forms will be completed at the time of data submission and will be maintained as part of the data catalog; however, these will not be released with the data set unless the original data collector provides the release.

ATTACHMENT I

Walnut Creek Watershed
Database File List

Library Name	File Name
MET	WC701
MET	WC702
SOIL	SOILCHEM
SOIL	SOILFARM
SOIL	SOILLINK
SOIL	SOILTYPE
STREAM	CHEM140
STREAM	CHEM223
STREAM	CHEM310
STREAM	CHEM320
STREAM	CHEM330
STREAM	FLOW140
STREAM	FLOW223
STREAM	FLOW310
STREAM	FLOW320
STREAM	FLOW330
STREAM	TIMEP140
STREAM	TIMEP223
STREAM	TIMEP310
STREAM	TIMEP320
STREAM	TIMEP330
TILE	CHEM110
TILE	CHEM132
TILE	CHEM210
TILE	CHEM220
TILE	CHEM230
TILE	FLOW110
TILE	FLOW132
TILE	FLOW210
TILE	FLOW220
TILE	FLOW230
TILE	TIMEP110
TILE	TIMEP132
TILE	TIMEP210
TILE	TIMEP220
TILE	TIMEP230
TIPBUKT	TB7035M
TIPBUKT	TB7045M
TIPBUKT	TB7055M
TIPBUKT	TB7065M
TIPBUKT	TB7075M
TIPBUKT	TB7085M
TIPBUKT	TB7095M
TIPBUKT	TB7105M
TIPBUKT	TB7125M
TIPBUKT	TB7135M
TIPBUKT	TB7145M
TIPBUKT	TB7195M
TIPBUKT	TB7205M
TIPBUKT	TB7215M
TIPBUKT	TB7225M
TIPBUKT	TBDAILY
WELL	WELLCHEM
WELL	WELLDEPT
WELL	WELLINFO

ATTACHMENT II

Walnut Creek Watershed
Database File Contents

Library Name	File Name	Variable Name	Variable Label
MET	WC701	ACTVP	Actual Vapor Pressure (kPa)
MET	WC701	ATEMP2	Air Temp (C) @ 2m
MET	WC701	BVOLT	Battery Voltage
MET	WC701	DATE	Sample Date
MET	WC701	DAY	
MET	WC701	HOUR	Sample Time
MET	WC701	PGM	
MET	WC701	PTEMP	Panel Temp (C)
MET	WC701	RAINH	Hourly Rainfall (mm/h) run
MET	WC701	SATVP	Sat Vapor Pressure (kPa)
MET	WC701	SITE_ID	Site Identification Code
MET	WC701	SOLRAD	Solar Irradiance (MJ/m2)
MET	WC701	STM4	Soil Temp (C) @ 4cm
MET	WC701	STM10	Soil Temp (C) @ 10cm
MET	WC701	STM20	Soil Temp (C) @ 20cm
MET	WC701	U2R	
MET	WC701	U2S	
MET	WC701	WNDDIR	Wind Direction (deg) @ 2m
MET	WC701	WNDSTD	Std Dev of Wind Direction
MET	WC701	WSP2	Wind Speed (m/s) @ 2m
MET	WC701	YEAR	
MET	WC702	ACTVP	Actual Vapor Pressure (kPa)
MET	WC702	ATEMP2	Air Temp (C) @ 2m
MET	WC702	BPRESS	Barometric Pressure (kPa)
MET	WC702	BVOLT	Battery Voltage
MET	WC702	DATE	Sample Date
MET	WC702	DAY	
MET	WC702	HOUR	Sample Time
MET	WC702	PGM	
MET	WC702	PTEMP	Panel Temp (C)
MET	WC702	RAINH	Hourly Rainfall (mm/h) run
MET	WC702	SATVP	Sat Vapor Pressure (kPa)
MET	WC702	SITE_ID	Site Identification Code
MET	WC702	SOLRAD	Solar Irradiance (MJ/m2)
MET	WC702	STM4	Soil Temp (C) @ 4cm
MET	WC702	STM10	Soil Temp (C) @ 10cm
MET	WC702	STM20	Soil Temp (C) @ 20cm
MET	WC702	WNDDIR	Wind Direction (deg) @ 2m
MET	WC702	WNDSTD	Std Dev of Wind Direction
MET	WC702	WSP2	Wind Speed (m/s) @ 2m
MET	WC702	YEAR	

Walnut Creek Watershed
Database File Contents

Library Name	File Name	Variable Name	Variable Label
SOIL	SOILCHEM	ALA	Alachlor (ng/mL)
SOIL	SOILCHEM	ATR	Atrazine (ng/mL)
SOIL	SOILCHEM	DEPTH	Sample Depth (cm)
SOIL	SOILCHEM	H2O	Moisture %
SOIL	SOILCHEM	IDCODE	Identification Code
SOIL	SOILCHEM	LOGN	Lab ID
SOIL	SOILCHEM	METO	Metolachlor (ng/mL)
SOIL	SOILCHEM	METR	Metribuzin (ng/mL)
SOIL	SOILCHEM	NO3_N	Nitrate-Nitrogen (mu_g/mL)
SOIL	SOILCHEM	SUBSAMP	Subsample Number
SOIL	SOILFARM	COMMONID	
SOIL	SOILFARM	FARM	
SOIL	SOILFARM	FIELD	
SOIL	SOILFARM	TRACT	
SOIL	SOILLINK	BARCODE	Location ID
SOIL	SOILLINK	COMMONID	
SOIL	SOILLINK	COREDEP	Core Depth (cm)
SOIL	SOILLINK	DATTIM	Sample Date
SOIL	SOILLINK	FARM	
SOIL	SOILLINK	FIELD	
SOIL	SOILLINK	IDCODE	Identification Code
SOIL	SOILLINK	SAMPLE	Field Sample #
SOIL	SOILLINK	TRACT	
SOIL	SOILTYPE	BARCODE	Location ID
SOIL	SOILTYPE	COMMONID	
SOIL	SOILTYPE	COREDEP	Core Depth (cm)
SOIL	SOILTYPE	DATTIM	Sample Date
SOIL	SOILTYPE	FARM	
SOIL	SOILTYPE	FIELD	
SOIL	SOILTYPE	IDCODE	Identification Code
SOIL	SOILTYPE	SAMPLE	Field Sample #
SOIL	SOILTYPE	STYPE	Soil Type
SOIL	SOILTYPE	TRACT	
SOIL	SOILTYPE	YEAR	

Walnut Creek Watershed
Database File Contents

Library Name	File Name	Variable Name	Variable Label
STREAM	CHEM140	ALA	Alachlor (ng/mL)
STREAM	CHEM140	ATR	Atrazine (ng/mL)
STREAM	CHEM140	DATE	Date
STREAM	CHEM140	FLAG	
STREAM	CHEM140	METO	Metolachlor (ng/mL)
STREAM	CHEM140	METR	Metribuzin (ng/mL)
STREAM	CHEM140	NO3_N	Nitrate-Nitrogen (mu_g/mL)
STREAM	CHEM140	NUM	
STREAM	CHEM140	SITE_ID	Site ID
STREAM	CHEM140	TIME	Time
STREAM	CHEM140	TIME_P	4hr Period
STREAM	FLOW140	DATE	Sample Date
STREAM	FLOW140	FLOW140	Tile Flow (cfs)
STREAM	FLOW140	TIME	Sample Time
STREAM	TIMEP140	DATE	
STREAM	TIMEP140	MEDIAN	the median, FLOW140
STREAM	TIMEP140	SITE_ID	Site ID
STREAM	TIMEP140	TIME_P	4hr Period

Walnut Creek Watershed
Database File Contents

Library Name	File Name	Variable Name	Variable Label
TILE	CHEM110	ALA	Alachlor (ng/mL)
TILE	CHEM110	ATR	Atrazine (ng/mL)
TILE	CHEM110	DATE	Date
TILE	CHEM110	FLAG	
TILE	CHEM110	METO	Metolachlor (ng/mL)
TILE	CHEM110	METR	Metribuzin (ng/mL)
TILE	CHEM110	NO3_N	Nitrate-Nitrogen (mu_g/mL)
TILE	CHEM110	NUM	
TILE	CHEM110	SITE_ID	Site ID
TILE	CHEM110	TIME	Time
TILE	CHEM110	TIME_P	
TILE	FLOW110	DATE	Date
TILE	FLOW110	FLAG	Flag
TILE	FLOW110	STAGE	Stage [in]
TILE	FLOW110	TFLOW	Streamflow [cfs]
TILE	FLOW110	TIME	Time
TILE	FLOW110	VELOC	Velocity [fps]
TILE	TIMEP110	DATE	Date
TILE	TIMEP110	MEAN	the mean, TFLOW
TILE	TIMEP110	MEDIAN	the median, TFLOW
TILE	TIMEP110	N	number of nonmissing values, TFLOW
TILE	TIMEP110	NMISS	number of missing values, TFLOW
TILE	TIMEP110	TIME_P	4hr Period

Walnut Creek Watershed
Database File Contents

Library Name	File Name	Variable Name	Variable Label
TIPBUKT	TB7035M	ATEMP2	Ambient Air Temp (C)
TIPBUKT	TB7035M	BVOLT	Battery Voltage
TIPBUKT	TB7035M	DAY	Sample Day
TIPBUKT	TB7035M	HOUR	Sample Time
TIPBUKT	TB7035M	PTEMP	Panel Temp (C)
TIPBUKT	TB7035M	RAIN5	Five Minute Rainfall (mm)
TIPBUKT	TB7035M	SITE_ID	Site Identification
TIPBUKT	TB7035M	YEAR	Sample Year
TIPBUKT	TBDAILY	DAY	Sample Day
TIPBUKT	TBDAILY	MAXTEMP	Max Air Temp (C) @ 2m
TIPBUKT	TBDAILY	MINTEMP	Min Air Temp (C) @ 2m
TIPBUKT	TBDAILY	PGM	
TIPBUKT	TBDAILY	SITE_ID	Site Identification
TIPBUKT	TBDAILY	TOTRAIN	Daily Rainfall (mm)
TIPBUKT	TBDAILY	YEAR	Sample Year

Walnut Creek Watershed
Database File Contents

Library Name	File Name	Variable Name	Variable Label
WELL	WELLCHEM	ALA	Alachlor (ng/mL)
WELL	WELLCHEM	ATEMP	Air Temperature (C)
WELL	WELLCHEM	ATR	Atrazine (ng/mL)
WELL	WELLCHEM	CODE	Identification Code
WELL	WELLCHEM	DATE	Sample Date
WELL	WELLCHEM	ELCOND	Electrical Conductivity (dS/m)
WELL	WELLCHEM	H2OTMP	Water Temperature (C)
WELL	WELLCHEM	LOGN	Lab. Log ID Number
WELL	WELLCHEM	METO	Metolachlor (ng/mL)
WELL	WELLCHEM	METR	Metribuzin (ng/mL)
WELL	WELLCHEM	NO3_N	Nitrate-Nitrogen (mu_g/mL)
WELL	WELLCHEM	PH	Acidity (pH)
WELL	WELLDEPT	CHECKED	
WELL	WELLDEPT	DATTIM	Sample Date run
WELL	WELLDEPT	FWLDEPT	
WELL	WELLDEPT	IDCODE	Identification Code
WELL	WELLDEPT	WLDEPT	Depth to Water (ft)
WELL	WELLDEPT	WLELEV	Water Table Elevation (ft)
WELL	WELLINFO	DATTIM	Survey Date
WELL	WELLINFO	IDCODE	Identification Code
WELL	WELLINFO	MAP_ID	Field Station or Site Alias
WELL	WELLINFO	RISEFT	Riser Height
WELL	WELLINFO	SCRNBOT	Bottom of Screen (ft)
WELL	WELLINFO	SCRNTOP	Top of Screen (ft)
WELL	WELLINFO	TOPPVC	Top of PVC (ft)
WELL	WELLINFO	X	X Coordinate
WELL	WELLINFO	Y	Y Coordinate

DATA REQUEST FORM

Requestor ______________________________

Date ______________________

Agency ______________________________

Address ______________________________

____

____

Telephone ______________________

Fax ______________________

E-mail Address ______________________

Data Application ______________________

____

____

____

Data Needs:

Parameters ______________________

Time Scale ______________________

Length of Record ______________________

Data Use Code Assigned ______________________

Data Media (Tape or Disk) ______________________

Data Agreement

We request these data for use in projects associated with Walnut Creek. We agree to use these solely in the application requested and to abide by the data use codes. We agree to acknowledge the source and project in any report or publication.

Signature ______________________

Typed Name ______________________

SECTION 5. RESEARCH PROTOCOLS

METEOROLOGICAL RESEARCH

SURFACE AND SUBSURFACE WATER RESEARCH

TERRESTRIAL ECOLOGY RESEARCH

GROUNDWATER RESEARCH

SOIL RESEARCH

AGRONOMIC RESEARCH

SUPPORT PROTOCOLS

Section 5-A Meteorological Stations

T. Hart NSTL

Site Locations

Two meteorological stations (met stations), sites 701 and 702, are located in Walnut Creek watershed. Figure 1 shows the locations of the stations in the watershed. Site descriptions follow:

<u>Site 701</u>

Site 701 is located on the flat surface of a lawn on a farmstead (located about 50 m west of Kaultenhauser farm buildings) in Agricultural Stabilization and Conservation Service (ASCS) Tract #2802, in the NE 1/4, Section 31, T83N, R24W, Story County.

<u>Site 702</u>

Site 702 is on a hilltop in a pasture on the Black farm in ASCS Tract #9494 in the SE 1/4, Section 33, T83N, R24W, Story county.

Rain gage stations are located at each met station. Section 5-B of this report provides information on the rain gage network in the watershed.

Sampling Techniques and Observation Schedule

Each weather station is equipped to measure: wind speed and direction; air, soil and panel temperatures; actual and saturated vapor pressures; total radiation; and rainfall. Site 702 met station is also equipped to measure barometric pressure.

Walnut Creek Watershed, IA

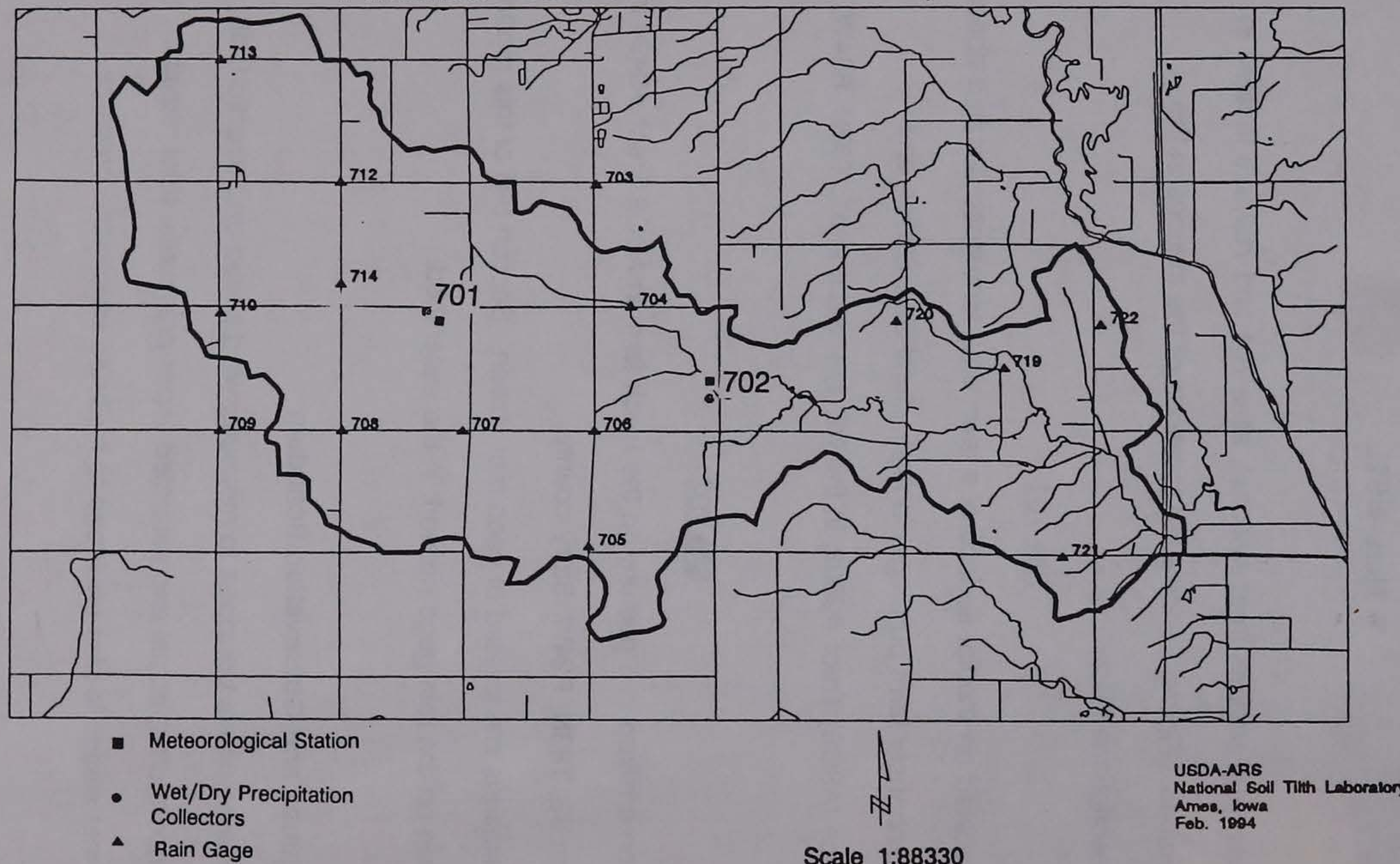

Figure 1. Meteorological stations in Walnut Creek watershed.

The following equipment has been installed at both meteorological stations:

Met One 3-cup anemometer (model 014a wind speed sensor) 2m height
Met One Wind Direction Sensor (model 024A) 2m height
Vaisala Temperature and Relative Humidity Probe (model HMP35C) 2m height
Gill 12 plate Radiation Shield (model 41002-2) 2m height
Li-Cor Pyranometer (model Li-200S) 2-m height
Texas Electronics Tipping Bucket Rain Gage (model TE525) 1-m height
Campbell Scientific Inc. (CSI) Tripod (model CM6)
Soil Temperature Probe (model 107B) 10-cm depth
Two Soil Thermocouples 4- and 20-cm depths
CSI 21X Micrologger
Solarex MSX-5 Solar Panel
Vaisala Barometric Pressure Transmitter (model PTA 427)(site 702 only)

Meteorological instruments at both stations are connected to dataloggers; wiring configurations and datalogging programs at both stations are similar. Station 702 has additional connections and programming for the barometric pressure sensor. Dataloggers are programmed to record meteorological data every 60 seconds and average and record outputs every 60 minutes. Meteorological data is downloaded from dataloggers into a CSI SM716 storage module on a weekly basis.

Met stations 701 and 702 were installed March 5, 1991 and March 19, 1991, respectively. Data has been collected from each station continuously since they were installed.

Quality Assurance and Quality Control

Meteorological instruments at each station are checked weekly and after precipitation events to ensure that all equipment is functioning properly. Anemometers and windvanes are cleaned and checked for free movement. Pyranometers and tipping buckets are cleaned and leveled. Wiring connections between instruments and dataloggers are checked for loose or damaged wires.

During site visits, instrument input values in each datalogger are observed for unusual values and the battery voltage of the datalogger is checked. If any of the equipment appears to be malfunctioning it is either repaired or replaced depending on the nature of the malfunction.

Data Format and Processing

At each met station: total radiation is recorded in kJ/m^2/60 min; air, soil, and panel temperatures are recorded in degrees Celsius; wind speeds are recorded in m/sec; total rainfall per hour is recorded in mm; and barometric pressure at site 702 is recorded in millibars. Mean wind speed, mean wind vector magnitude (m/s), mean wind vector direction (degrees) and standard deviation of direction are recorded by the datalogger. Maximum and minimum air temperatures, total rainfall, and maximum wind speed per day are logged as end of day variables.

Data is downloaded once per week from each datalogger into a CSI SM716 storage module. The storage module is returned to NSTL where the data is downloaded from the module, using CSI software, into raw data files that are then copied to disks. Data are screened for any missing, out of range or irregular values and run through a Fortran program that summarizes the daily values in tabular form. Hardcopies and diskcopies of these files are stored in the SUN computer room at NSTL (Wolf Oesterreich). These files are also entered into Statistical Analysis Systems (SAS) files. Data in storage modules will eventually be downloaded directly into the SAS database.

Section 5-B Rain Gage Network

T. Hart NSTL

Site Locations

Rain gage stations are located at twenty sites in Walnut Creek Watershed. Figure 1 shows the locations of these stations and Table 1 provides location descriptions for each site. Stations are located in almost all sections in the watershed to determine the general distribution of precipitation. Most stations are situated at or near section corners. Five of the sites are located at stream gaging stations in Walnut Creek (site descriptions are provided in Section 5-F of this report).

Sampling Techniques and Observation Schedule

Each rain gage station is equipped to measure rainfall rates (mm) and at sites 703-722 air temperature (°C) is also recorded. Each station contains the following equipment:

Texas Electronics Tipping Bucket Rain Gauge (model TE525)
Air Temperature Thermocouple and Radiation Shield (sites 703-722)
Campbell Scientific (CSI) CR10 Datalogger
CSI PS12 Power Supply and Charging Regulator
Yuasa 12 volt battery (CSI)
Metal Enclosure Box
Solarex Solar Panel (model MSX-5)

Rainfall and air temperature measurements starting dates are shown in Table 1.

Tipping buckets at sites 703-722 are mounted to the tops of 1.5-m tall poles that were driven 0.3 m into the soil. At sites 723-727, tipping buckets are attached to

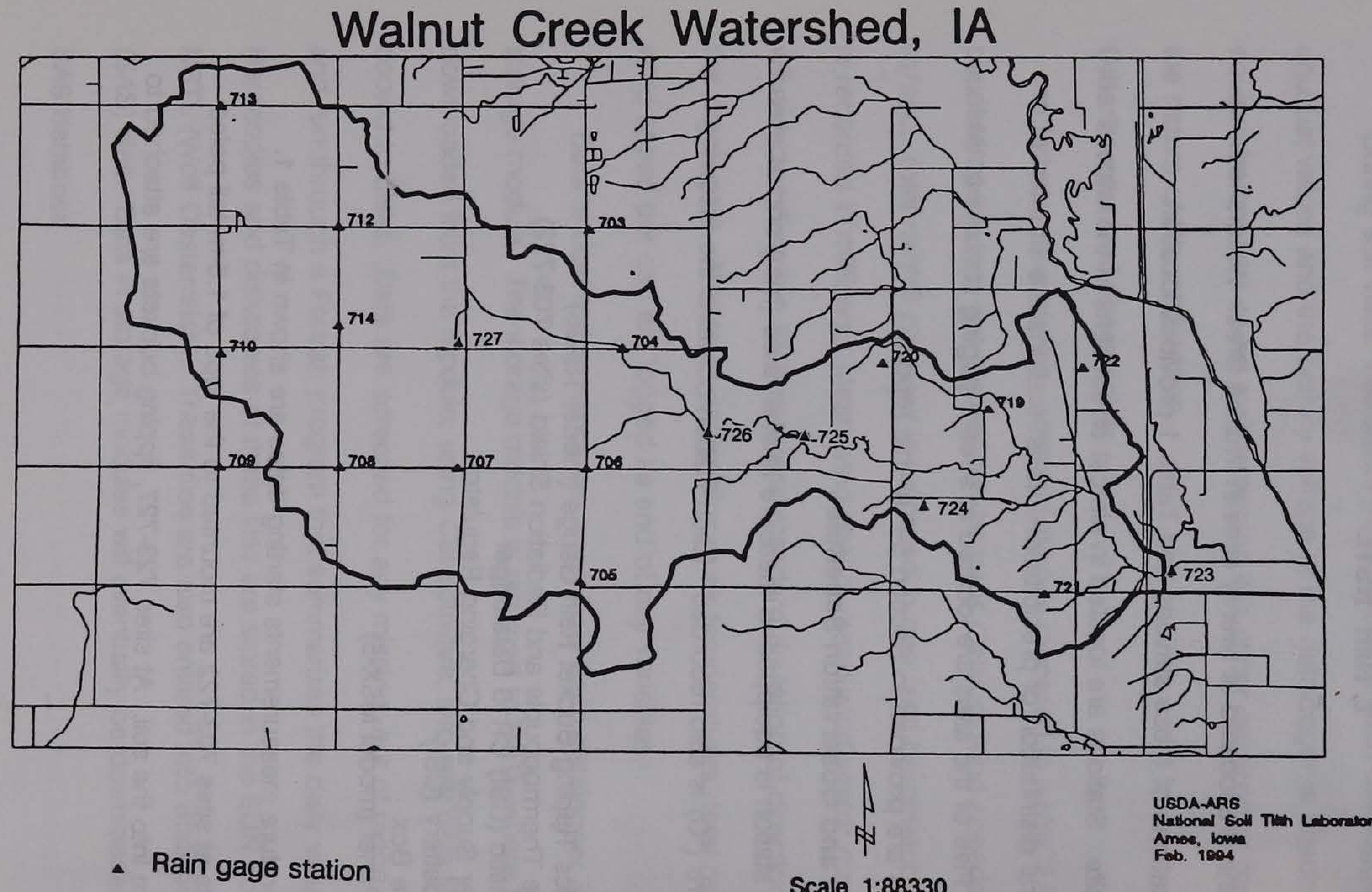

Figure 1. Walnut Creek watershed rain gage network.

Table 1. Walnut Creek watershed rain gage station site numbers, locations, and starting dates for rainfall and air temperature measurements (sites 703-722).

Site Number	Location	ASCS Tract	Measurement Starting Date
703	NW 1/4, Sec. 28, T83N, R24W, Story county	8999	03/29/91
704	SW 1/4, Sec. 28, T83N, R24W, Story county	8999	04/01/91
705	SE 1/4, Sec. 5, T82N, R24W, Story county	2750	04/05/91
706	SE 1/4, Sec. 32, T83N, R24W, Story county	1989	04/03/91
707	SE 1/4, Sec. 31, T83N, R24W, Story county	2736	04/01/91
708	SW 1/4, Sec. 31, T83N, R24W, Story county	2703	04/03/91
709	SW 1/4, Sec. 36, T83N, R25W, Boone county	3007	04/03/91
710	NW 1/4, Sec. 36, T83N, R25W, Boone county	4234	05/17/91
712	SE 1/4, Sec. 24, T83N, R25W, Boone county	2910	04/03/91
713	NW 1/4, Sec. 24, T83N, R25W, Boone county	3016	04/03/91
714	SW 1/4, Sec. 25, T83N, R25W, Boone county	3017	04/05/91
719	SW 1/4, Sec. 36, T83N, R24W, Story county	2787	04/06/91
720	SE 1/4, Sec. 35, T83N, R24W, Story county	2697	04/15/92
721	NE 1/4, Sec. 12, T82N, R24W, Story county	2008	04/23/92
722	NW 1/4, Sec. 31, T82N, R24W, Story county	512	04/28/92
723	SE 1/4, Sec. 6, T83N, R23W, Story county	Stream gaging station	04/12/93
724	NE 1/4, Sec. 2, T82N, R24W, Story county	Stream gaging station	04/12/93
725	SE 1/4, Sec. 34, T83N, R24W, Story county	Stream gaging station	04/12/93
726	SE 1/4, Sec. 33, T83N, R24W, Story county	Stream gaging station	04/12/93
727	SE 1/4, Sec. 30, T83N, R24W, Story county	Stream gaging station	04/12/93

the tops of 1.8-m tall poles that are mounted at their bases to the tops of stream gaging stations.

Tipping buckets are designed to measure rainfall rates at five minute intervals and total rainfall per day. Air temperature thermocouples measure average air temperatures every five minutes. Rain gages and air temperature sensors at stations are connected to dataloggers; wiring configurations and datalogging programs at all stations are identical, except rainfall daily totals are not calculated and air and panel temperatures are not recorded by dataloggers at sites 723-727. Dataloggers are programmed to record data every 60 seconds and output average air and panel temperatures (sites 703-722), average battery voltage and total rainfall every 5 minutes. At sites 703-722, at the end of each 24 hour period, maximum air temperature, minimum air temperature and total rainfall are logged into final storage.

Quality Assurance and Quality Control

Monitoring equipment at each station are checked weekly to ensure that all instruments are functioning properly. Tipping buckets are levelled and cleaned with distilled water. Air temperature thermocouples (sites 703-722) are inspected for breaks in the insulation. Wiring connections between instruments and dataloggers are checked for loose or damaged wires.

During visits to each station, rain gage and air temperature (sites 703-722) input values in dataloggers are observed for unusual values. The battery voltage of each datalogger is checked. Total rainfall is compared between the 19 sites to ensure that the tipping buckets are functioning properly. If any equipment appears to be malfunctioning it is either repaired or replaced depending on the degree of the problem.

Data Format and Processing

Rainfall is measured in mm (1 tip = .254mm) and air temperatures in °C. Data are downloaded once per week from each datalogger at sites 703-722 into a CSI SM716 storage module (Tim Hart, NSTL). At sites 723-727, rainfall data are included with stream gaging data and are downloaded from CSI SM176 storage modules that are attached to each datalogger into a CSI SM716 storage module every two weeks (Donna Schmitz, NSTL). Storage modules are returned to the National Soil Tilth Laboratory (NSTL) where the data are downloaded from modules using CSI software into raw data files that are copied to disks. Rainfall data collected at sites 723-727 is extracted from stream gaging data files using CSI SPLIT software.

Data are screened for any missing, out of range or irregular values. Data files are then run through a Fortran program that summarizes end-of-day totals in tabular form. Hardcopies and diskcopies of these files are stored in the SUN computer room at NSTL (Wolfgang Oesterreich). These files will be put into the NSTL Statistical Analysis Systems (SAS) database. Data in storage modules will eventually be downloaded directly into the SAS database.

Section 5-C Wet and Dry Precipitation Collector Stations

T. Hart NSTL

Site Locations

Wet and dry precipitation collector stations are located at each meteorological station (met station), sites 701 and 702, in Walnut Creek Watershed. Site locations are shown in Figure 1 and described in Section 5-A of this report.

Sampling Techniques and Observation Schedule

Aerochem Metrics 301 wet/dry precipitation collectors are located at each met station. Each collector is equipped with the following:

Aerochem Metrics stand
two three-gallon, plastic collector buckets (wet and dry collectors)
Aerochem Metrics sensor plate
Aerochem Metrics motor drive
Solarex model MSX-60 solar panel
12 volt deep-cycle marine battery

The sensor plate controls the lid movement of each collector bucket that is powered by the motor drive. A 12 volt deep-cycle marine battery provides power to the collector and is recharged by the solar panel.

Wet and dry collectors were installed March 5, 1991 and March 19, 1991 respectively. Wet precipitation data has been collected from each station continuously since they were installed.

During a precipitation event, the dry collector remains covered while precipitation accumulates in the wet collector. After the event, the wet collector is covered and the dry collector is open. A collector cycles back and forth, covering

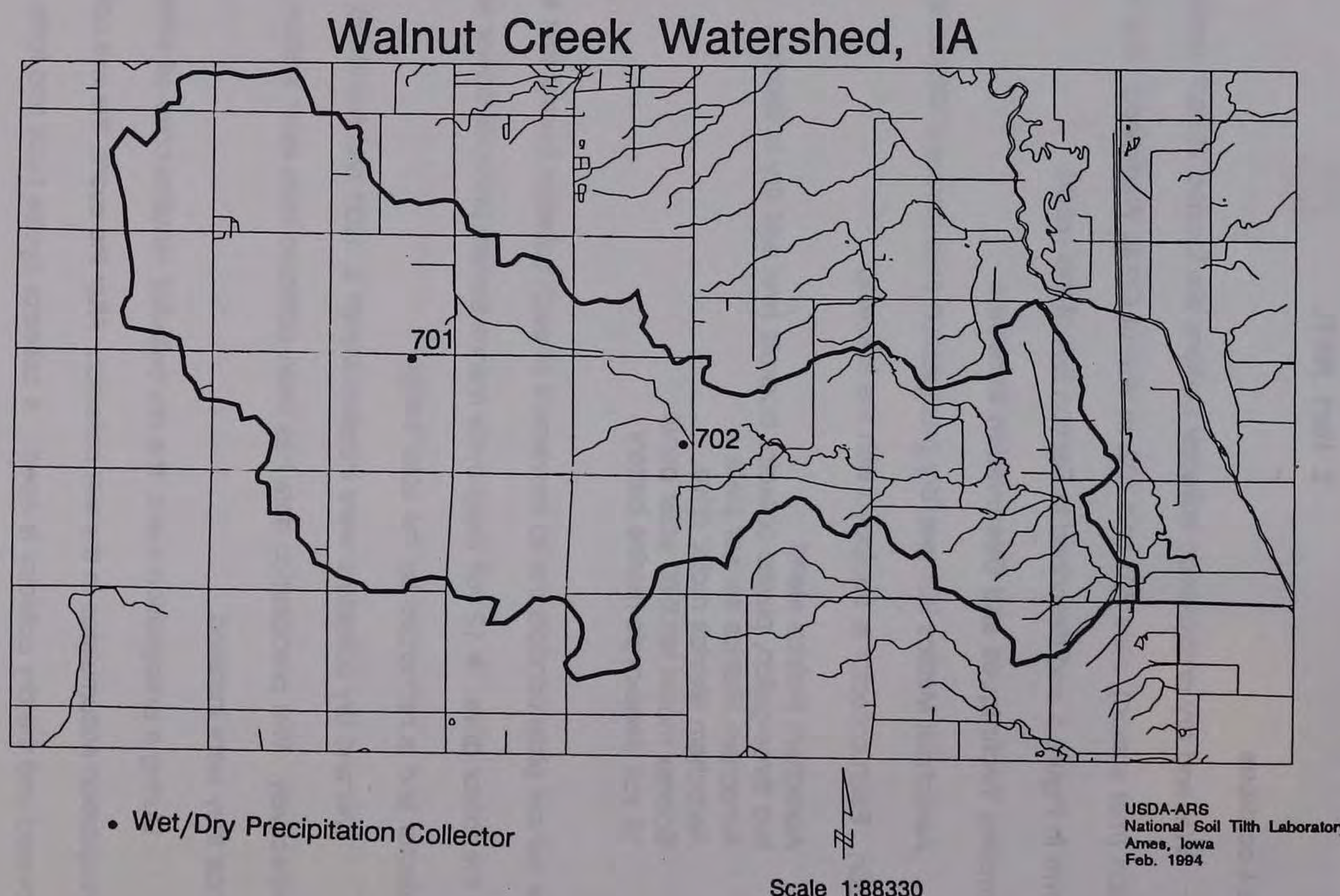

Figure 1. Wet and dry precipitation collector stations in Walnut Creek watershed.

either a wet or dry collector, depending on the amount of moisture present on the sensor plate.

After every rain or snow event, the volume of precipitation collected in a wet collector is recorded in a logbook by National Soil Tilth Laboratory (NSTL) staff, 350 ml of the sample is transferred to an amber glass sample bottle and the collector is emptied. Dry collector data is not collected. The logbook also contains precipitation event and sampling dates, sample collection times, and the site number and location of where each sample was collected. After sample collection, bottles are labelled and delivered to the NSTL Analytical Laboratory. Samples are analyzed for atrazine, metribuzin, alachlor, metolachlor, and nitrate-nitrogen using methods described in Section 5-O of this report.

Quality Assurance and Quality Control

After collector buckets are emptied they are rinsed with distilled water, followed by a methanol rinse, then wiped dry and returned to the collector unit. The collector sensor plate is checked after every precipitation event or weekly, to ensure that it is functioning properly and the MSX-60 solar panel is cleaned weekly.

Data Format and Processing

The NSTL Analytical Laboratory provides hardcopies of herbicide and nitrate analytical results from wet collector samples to the NSTL technician who manages the wet and dry precipitation collector stations. The data is entered into the Statistical Analysis Systems (SAS) database and reviewed by a NSTL researcher. Wet collector herbicide and nitrate data are matched with tipping bucket data (Section 5-B) in the SAS database. Future plans are to use these two data sets to calculate herbicide and nitrate loads.

Section 5-D Energy Balance and Evapotranspiration Monitoring Network

J. Prueger NSTL

Overview

Bowen ratios (Bowen, 1926) are measurements of temperature and vapor pressure differences across a specific height above a canopy or soil surface and are used with net radiation and soil heat flux measurements to provide estimates of latent and sensible heat fluxes. These fluxes are used in the energy balance equation to compute evapotranspiration of field crops. Eddy correlations provide direct measurements of latent and sensible heat flux and can be used in place of Bowen ratios.

Site Locations

Bowen-ratio energy balance stations are located at six sites in Walnut Creek watershed. Figure 1 shows the locations of these sites in the watershed and Table 1 provides descriptions, start-up dates, and locations for the stations. Sites are located in fields with conventional tillage, no-till, or ridge till cropping systems. Evapotranspiration losses will be compared between the different tillage practices. In addition to Bowen-ratio stations, two eddy correlation (EC) systems are used in the watershed. In 1992, the EC systems were rotated between all sites. In 1993, the use of these systems in the watershed was limited by the extremely wet weather conditions

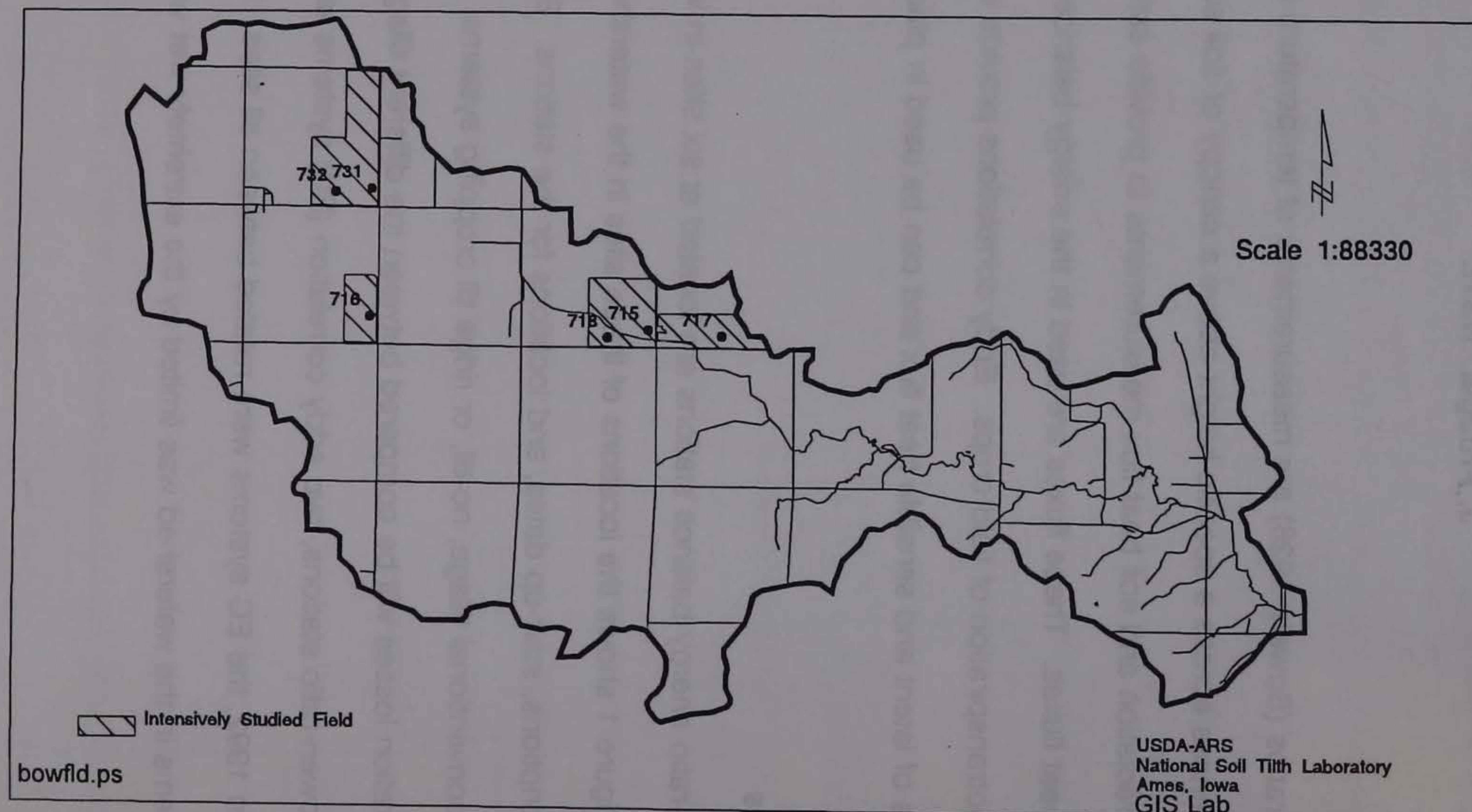

Figure 1. Bowen-ratio stations in Walnut Creek Watershed. 1993.

Table 1. Descriptions, start-up dates and locations of Bowen-ratio energy balance stations in Walnut Creek watershed.

Site #	Site Name	Start-up Date	ASCS Tract	Location
715	Black's ridge till (west) field	7/11/91	9002	N 1/2, SE 1/4, Sec. 29, T83N, R24W, Story Co.
716	Bassett's conventional tillage field "pothole field"	7/12/91	3010	E 1/2, SE 1/4, Sec. 25, T83N, R25W, Boone Co.
717	Black's conventional tillage (east) field	3/20/92	8999	S 1/2, Sec. 28, T83N, R24W, Story Co.
718	Black's no-till field	5/19/92	9002-S	S 1/2, SE 1/4, Sec. 29, T83N, R24W, Story Co.
731	Bassett's no-till (east) field	6/3/93	3016-E	E 1/2, NE 1/4, Sec. 24 and E 1/2, E 1/2, SE 1/4, Sec. 24 T83N, R25W, Boone Co.
732	Bassett's no-till (west) field	6/12/93	3016-W	W 1/2, E 1/2, SE 1/4, Sec. 24 and W 1/2, SE 1/4, Sec. 24, T83N, R25W, Boone Co.

and equipment failures. In 1994, plans are to install EC stations at sites 717 and 731. Latent heat and sensible heat fluxes obtained from Bowen-ratio stations will be compared to the eddy correlation measurements.

Sampling Techniques and Observation Schedule

<u>Bowen Ratio Stations</u>

Summer Monitoring:

The following instruments are used at Bowen ratio stations:

Radiation Energy Balance Systems net radiometer
Radiation Energy Balance Systems soil heat flux plate
six copper/constantan soil thermocouples
two three-cup R. M. Young anemometers
two pairs of aspirated wet and dry thermocouples
Everest Interscience Inc. infrared thermometer
Campbell Scientific Inc. (CSI) 21X datalogger

Instruments at each station are attached to a tripod and connected to a CSI datalogger for continuous monitoring from the time that stations are set-up at each site after spring planting until crop harvest. The sampling frequency at all stations is typically once every 60 seconds, except at site 717, where the sampling interval is once every 30 seconds and variables are averaged and/or totaled every 30 minutes. Dataloggers are programmed to output 30 minute totals for net radiation and soil heat flux, while temperatures from all thermocouples and wind speeds from the anemometers are output as 30 minute averages. All Bowen ratio stations are monitored continuously throughout the growing season.

Winter Monitoring:

Prior to harvest, all Bowen ratio stations are removed from each site and after harvest, the stations are returned to each site as modified winter weather stations. Winter monitoring is conducted until approximately one month prior to spring planting. After spring planting, the winter stations are converted back to Bowen ratio stations.

Net radiation and soil heat flux along with the accompanying soil temperature measurements are maintained similar to the summer monitoring mode. The two aspirated psychrometers are replaced with a Vaisala temperature and relative humidity sensor at a single height. Wind speed is measured at a single 2-m height with a 3-cup anemometer. Mean air and soil temperatures, saturation and actual vapor pressures, and wind speeds are sampled every 60 seconds and output to a CSI datalogger as 30 minute averages. Net radiation and soil heat flux are sampled every 60 seconds and output as 30 minute totals.

Eddy Correlation Stations

The following equipment is used at each eddy correlation (EC) station:

CSI 1-D sonic anemometer
fine wire thermocouple
CSI krypton hygrometer
CSI 21X datalogger

The sonic anemometer, thermocouple, and krypton hygrometer (KH20) directly measure the sensible and latent heat flux. The EC stations are located next to Bowen ratio stations so that in conjunction with net radiation and soil heat flux measurements, the surface energy balance can be measured and compared to that estimated from the Bowen ratio stations. Due to the sensitivity of the sonic anemometer to water, measurements can only be made during periods in which there is no possibility of a precipitation event occurring. In central Iowa during the summer months this leads to very sporadic sampling events. The sampling interval for the sonic, fine wire thermocouple, and KH20, is 10 hz (10 times per second). Data are averaged every 10 minutes for an intermediate storage value and at the end of every 30 minutes these values are averaged for sensible and latent heat flux output.

Data Format and Processing

Data from all micrometeorological stations (Bowen ratio, winter weather, and eddy correlation stations) are downloaded into a storage module (CSI SM716) on a weekly basis. The data is then downloaded to a PC using CSI software in ASCII form and copied to disks. Bowen ratio data are run through a Fortran program that outputs data on an hourly basis and calculates a Bowen-ratio, latent, and sensible heat fluxes. Hourly averages of wet/dry bulb temperatures, net radiation, soil heat flux, soil temperature at two depths, wind speed at two heights, and surface temperature are also recorded at hourly intervals. Net radiation and soil heat flux values are recorded as hourly totals and not averages.

Eddy correlation data are summarized and tabulated in spreadsheets (Quattro Pro). All micrometeorological data are initially screened by technicians for missing and out of range values. At this point no attempt is being made to interpolate or estimate missing or out of range data. Only data that are actually collected and recorded are being used. Data will also be evaluated by a researcher prior to submittal to the Statistical Analysis System (SAS) database. The data may also be used in the National Soil Tilth Laboratory (NSTL) Geographical Information System (GIS).

Quality Assurance and Control

Calibration of all micrometeorological equipment are conducted on a yearly basis usually in the winter and early spring. Infrared thermometers, 1-D sonic anemometers, krypton hygrometers, and Vaisala relative humidity sensors are sent to the manufacturers for annual calibration. Net radiometers are calibrated against a single manufacturer certified net radiometer in the early spring. This certified net radiometer is calibrated every year by the manufacturer. All cup anemometers are calibrated every winter using an instrument supplied by the manufacturer and/or calibrated inside the wind tunnel located in the Aerospace Engineering and Engineering Mechanics Department at Iowa State University, Ames, Iowa. Wet-dry bulb psychrometers are all placed in a horizontal position at a uniform height within an environmentally controlled chamber and evaluated for thermocouple and fan bias under a range of temperatures, relative humidities and light intensities. Soil heat flux plates are calibrated against a manufacturer's standard.

Calibrations are conducted by a technician. A researcher reviews the calibrations as well as calibration procedures on an annual basis with the technician. Calibration procedures, notes and values are recorded on either computer disks or laboratory notebooks.

Micrometeorological equipment is checked weekly at all stations to ensure that the instruments are functioning properly. In addition, since the data is downloaded on a weekly basis from the stations to personal computer files and hardcopies of the data generated from Fortran programs, final output values are evaluated by the technician for irregular and/or missing data. At the beginning of each field season instruments are checked every other day by a technician until a level of confidence in the instruments performance is achieved, at which point instrument inspections are scaled back to weekly intervals. As problems occur with the micrometeorological instruments, a technician, in consultation with a researcher, immediately takes corrective measures to resolve the problems.

References

Bowen, I.S. 1926. The ratio of heat losses by conduction and by evaporation from any water surface. Phys. Rev. 27:779-787.

Section 5-E Volatilization of Pesticides and Soil Gas Studies

J. Prueger NSTL

Overview

Pesticide volatilization represents the largest means by which pesticides are lost from the target application area. Once volatilized to the atmosphere, the range of pesticide transport can be tens of meters to hundreds of kilometers. Relatively little is known about pesticide volatilization in the Midwest despite the fact that annual usage of pesticides in this region of the United States is in the millions of pounds. Understanding the fundamental processes of pesticide transport to the atmosphere will provide information that may be used to improve pesticide application techniques.

Trace gas monitoring of methane (CH_4), carbon dioxide (CO_2), and nitrous oxide (N_2O), are conducted in the watershed over fields that have been treated with swine manure. The level of research in this area has been directed toward developing a micrometeorological technique for measuring trace gas flux between the soil surface and atmosphere.

Site Locations

Dual® (a.i. metolachlor) volat. ization studies and trace gas sampling were conducted at site 717 located in Black's conventional tillage (east) field. A description of this field is provided in Section 5-D of this report. Volatilization studies were conducted in 1992, 1993, and 1994 in the spring immediately after field application of Dual®. Trace gas sampling was conducted in 1992 and 1993 on two fields located in the watershed that were treated with broadcast and injected swine manure.

Sampling Techniques and Observation Schedule

Pesticide Volatilization Studies

The apparatus used for pesticide sampling consists of two 3-m long by 2.54-cm diameter steel pipes to which are attached pesticide samplers. One steel pipe serves as support for four Teflon™ canisters that hold 40 ml each of a polymeric resin (XAD-7, Sigma Co.) for trapping pesticide vapors. The canisters are cylindrical in shape and are attached at their base to the steel support so that they are vertically aligned. Each canister contains an inlet port (threaded teflon nipple) located on the side of the canister near the top, and an outlet port (threaded teflon nipple) located at the bottom of the canister. Tygon™ tubing is attached to the outlet port that is connected to a plexiglass manifold that is attached to a high-volume vacuum pump.

During a sampling event, ambient air is pulled through the inlet port into the canister through the polymeric resin and out the outlet port. The second steel mast serves as a support for four cylindrical glass containers which serve as housing units for polyurethane foam plugs (PUF) that are used as an alternative trapping media for pesticide vapors. The cylindrical containers have a tapered glass stem to which tygon tubing is attached at the end of the stem. The tygon tubing is also connected to the same plexiglass manifold and high volume vacuum pump used for the XAD-7 canisters.

Sampling flow rates for the XAD-7 and PUF samplers are between 50 and 60 liters per minute. Sampling canisters are exchanged every two hours for the first 48 hours after the pesticide has been applied. During the next 72 hours the canisters are exchanged every four hours, 24 hours per day, and finally during the last sampling interval the canisters are exchanged every eight hours. The window of opportunity for sampling pre-emergence pesticides in the Walnut Creek watershed occurs between May 1 and June 15 and is highly dependent on weather conditions and the farmer's operating schedule.

The pesticide sampling apparatus is positioned near the Bowen ratio and eddy correlation stations at site 717. In addition to the micrometeorological equipment at these stations, a wind profile station is also installed at this site. The profile station consists of four to six anemometers and psychrometers spaced logarithmically in a vertical direction on a 2.5-cm diameter steel post. The wind profile station and pesticide sampling equipment are removed from this site after sampling is completed. The surface energy measurements and wind speed and wet/dry bulb profile measurements are used to calculate appropriate transfer coefficients for pesticide flux calculations.

After pesticide sampling, XAD-7 and PUF samplers are returned to the National Soil Tilth Laboratory (NSTL) where they are analyzed for metolachlor using methods described in Section 5-S of this report.

Trace Gas Monitoring

Trace gas sampling involves the use of small DC powered pumps which are connected to one-liter capacity mylar balloons. The balloons are located at different heights to determine gradients of methane, nitrous oxide and carbon dioxide. The flow rates of the sampling pumps are calibrated to 15 ml per min. At the end of every hour the balloons are removed and replaced with new, evacuated replacements. The filled balloons are transported to the laboratory where an 8 ml sample is drawn from the one liter reservoir and stored in a vacuum tube until analysis by gas chromatography can be performed. As with the pesticide sampling apparatus, a Bowen-ratio surface energy balance station is located near the trace gas sampling unit to calculate appropriate transfer coefficients. Samples are analyzed for methane, carbon dioxide, and nitrous oxide using methods described in Section 5-S of this report.

Quality Assurance and Quality Control (QA/QC)

Sampling pumps are calibrated to deliver accurate flow rates. Flow rates are measured at the beginning and end of each sampling event to monitor changes in flow rates that may be due to low battery voltage, pump diaphragm damage, or dirty air filters. A sampling event is defined within this text as every time pesticide canisters or mylar balloons are changed.

Quality assurance and control are also critical in sampling media preparation, canister loading and unloading, and sample storage and transport. The XAD-7 is purchased pre-cleaned and therefore does not require additional cleaning; however, random samples are taken from each batch and are analyzed for contaminants. The PUF plugs are rinsed for 30 minutes in a methanol bath, are allowed to air dry, and are then rinsed in a hexane bath for 10 minutes. Random samples of the PUF are analyzed for contaminants present on the plugs. After the media in samplers has been exchanged in the field, the samples are wrapped in aluminum foil and transported to the laboratory where they are wrapped in more aluminum foil, catalogued and stored in a freezer at the National Soil Tilth Laboratory (NSTL) Soil Analysis Laboratory until analyzed.

Data Format and Processing

Micrometeorological station data format and processing information are provided in Section 5-D of this report.

Eddy correlation, pesticide and trace gas data are summarized and tabulated in spreadsheets (Quattro Pro). All data are screened initially by technicians for missing or out of range values. Data are analyzed and appropriate flux calculations are made by a scientist. Data are then converted to ASCII format and will be submitted to Bob Jaquis at the NSTL for inclusion in the Statistical Analysis System (SAS) database.

SURFACE AND SUBSURFACE WATER RESEARCH

Section 5-F Stream Gaging and Water Quality Monitoring

P.J. Soenksen USGS

Site Locations

Water quality monitoring and stream gaging stations were established at various locations within Walnut Creek Watershed to obtain data at scales ranging from specific fields to the entire watershed. This monitoring network was designed to isolate areas of the watershed for specific study such as determining the impact of a farming practice on water quality. Whenever possible, more specific siting decisions were based on availability of existing stable flow-controls (natural: rock riffles, artificial: culverts) or on suitability for installation of an artificial control weir to improve the quality of flow records (Rantz, 1982: p. 4-22).

Water quality monitoring and stream gaging stations are located at five sites in the watershed. Monitoring network design allows for isolated study of surface water flow from three subwatersheds (13 to 20 km^2) and the entire watershed (approximately 47 km^2). Table 1 provides site locations and descriptions and Figure 1 shows the site locations in the watershed.

Monitoring and Sampling Techniques

Table 2 lists water sampling and stream gaging equipment at each site in the watershed.

Discharge at streamflow-gaging stations is computed from recorded water stage measurements via theoretical or measured stage-discharge relations (discharge ratings) (Rantz, 1982: p. 3, 285-344). Each stream gaging station has at least

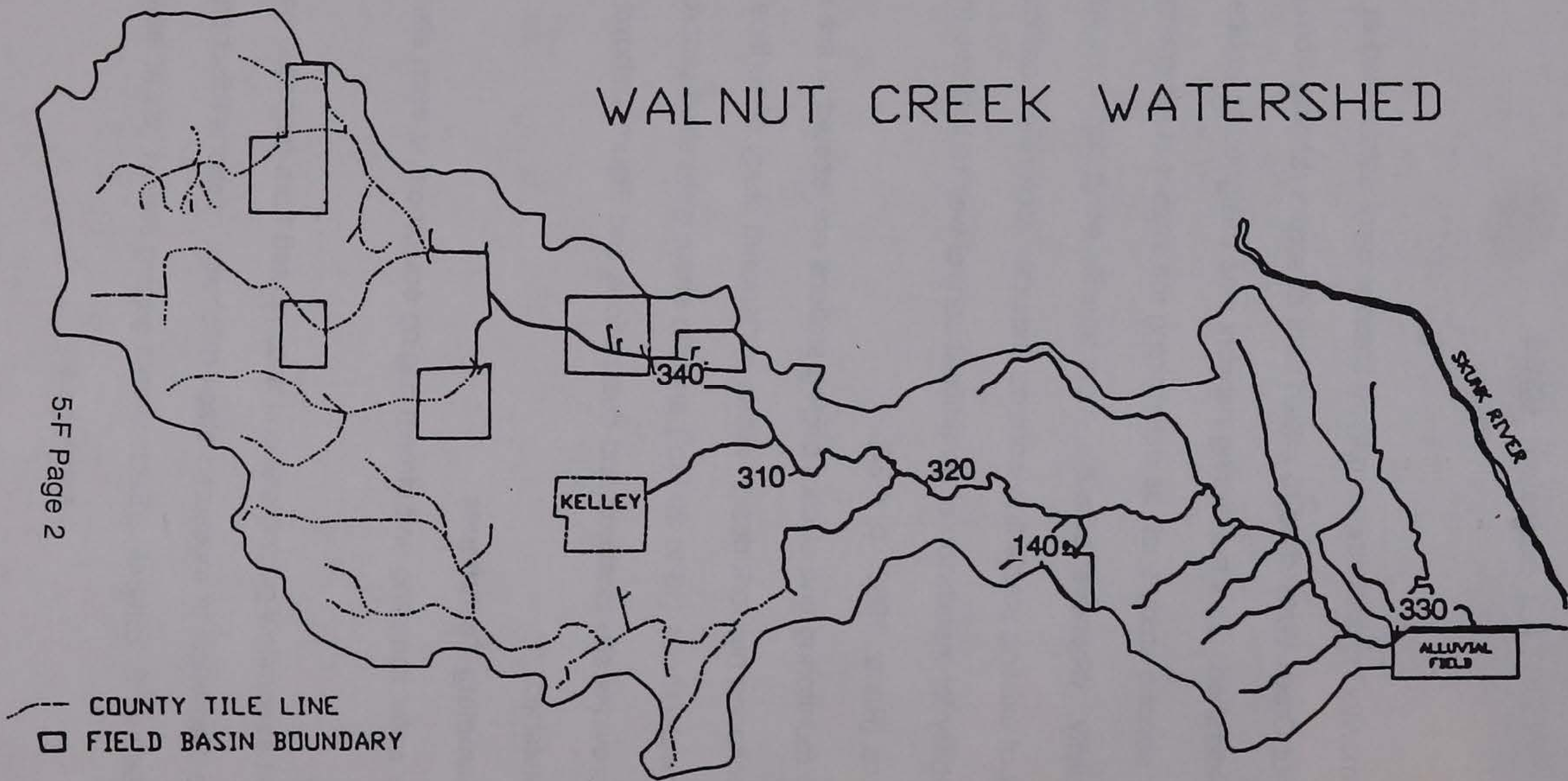

Figure 1. Locations of stream gaging and water quality sampling stations in Walnut Creek Watershed.

Table 1. Site locations and descriptions for water quality monitoring and stream gaging stations in Walnut Creek watershed.

Site Number	Location	Description
330	SE 1/4, Sec. 6, T82N, R23W	The site is located along the main stream of Walnut Creek where the watershed outlets onto the Skunk River flood plain.
310	SE 1/4, Sec. 33, T83N, R24W	The site is located above and below the major tributary of Walnut Creek.
320	SE 1/4, Sec. 34, T83N, R24W	Same description as site 310.
340	SW 1/4, Sec. 28, T83N, R24W	The site is a water quality station only and is located along the main stream of Walnut Creek above site 310.
140	NE 1/4, Sec. 2, T82N, R24W	The site is located below a field basin in the lower third, steeper portion of the watershed.

one stage measuring device such as a potentiometer driven by a float, potentiometer driven by a balanced-beam manometer, or a pressure transducer. All devices are electronically connected to a Campbell Scientific Inc. (CSI) CR10 datalogger. Floats are located in stilling wells hydraulically connected to the stream, whereas manometers and transducers sense pressure through a bubbler line which has one end anchored in the flow of the deepest part of the stream channel.

Theoretical equations are used to initially develop discharge ratings for artificial controls. Actual discharge measurements are used to develop discharge ratings for natural controls and to verify or modify discharge ratings for artificial controls. Low-flow control of discharge is provided by a natural rock riffle at site 320 and by weirs at sites 310, 330, and 140. High-flow control of the discharge rating is provided by culverts at sites 310, 320, and 140 and by the stream channel at site 330. Discharge

Table 2. Water sampling and stage measurement equipment at water quality monitoring and stream gaging stations in Walnut Creek watershed.

Site Number	Stage Measuring Device	Low Flow Control	High Flow Control	Water Samplers	Other Equipment
330	WaterGage II balanced beam manometer and USGS Pressure Sensor-2 (PS-2) transducer	weir	stream channel	ISCO and Manning samplers	CSI CR10 datalogger, thermocouple
310	WaterGage II balanced beam manometer, Spectra float gage potentiometer, and PS-2 transducer	weir	culvert	ISCO and Manning samplers	CSI CR10 datalogger, thermocouple
320	WaterGage II balanced beam manometer	natural rock riffle	culvert	ISCO and Manning samplers	CSI CR10 datalogger, thermocouple
340*	N/A	N/A	N/A	N/A	N/A
140	WaterGage II balanced beam manometer; Spectra float gage potentiometer, and a USGS Pressure Sensor System-1 transducer	weir	culvert	ISCO and Manning samplers	CSI CR10 datalogger, thermocouple

* site 340 is only a water quality monitoring station (manually-collected samples)

measurements used to develop ratings or verify theoretical ratings for the artificial stream controls are made manually using current-meters, portable flumes, and indirect methods (Rantz, 1982: p. 22-184, 265-267, 273-284). Adjustments are periodically made to ratings based on the most recent discharge measurements (Rantz, 1982: p. 344-360, 376-389). Artificial controls limit the need for such adjustments and significantly improve data quality during the winter when backwater from ice can adversely affect the discharge rating. Any remaining effects of backwater from ice or other sources are accounted for using a method described by Rantz (1982: p. 360-376).

Automatic water quality (WQ) and suspended-sediment samples are collected with ISCO peristaltic pump samplers and Manning vacuum-pump samplers, respectively, triggered by dataloggers using real-time stage data and programmed decision aids. The WQ samplers consist of peristaltic pumps which draw water samples from the stream via Teflon™-coated polyethylene tubing and discharge into clear, glass bottles. Suspended-sediment samplers are vacuum pumps that draw water samples through reinforced polyvinyl chloride (PVC) tubing and discharge into polyethylene sample bottles (Edwards and Glysson, 1988: p. 43).

In addition to automated collection, WQ samples are collected manually on a weekly basis by dipping (sterilized) glass bottles into stream flow.

Suspended-sediment samples from a single vertical stream section are collected manually in glass bottles with a depth-integrating rod or handline sampler using the equal-transit-rate (ETR) method (Edward and Glysson, 1988: p. 32-33). Stream cross-section, discharge-weighted samples are collected using the ETR method in combination with the equal-width-increment (EWI) method (Edward and Glysson, 1988: p. 5-11, 49-65).

The WQ samples are analyzed for nitrates, atrazine, alachlor, metribuzin, and metolachlor at the National Soil Tilth Lab (NSTL) Analytical Laboratory using methods referenced in Section 5-S of this report.

Suspended-sediment samples are analyzed for sediment concentration or particle-size at the U. S. Geological Survey Sediment Laboratory (USGS) in Iowa City, Iowa. Suspended-sediment concentrations (mg/L) are obtained by dividing the dry weight of the sediment by the volume of the water-sediment mixture. Sediment dry weight is determined by separating sediment from the water, using either filtration or evaporation methods, then drying and weighing the filtrate or evaporate on a balance. The wet-sieve method (0.062mm mesh sieve) is used prior to drying and weighing to separate sand and fine sediment fractions. Visual-accumulation-tube (fraction > 62mm) and pipet (fraction < 62mm) methods are used after wet-sieving for particle size analyses (Guy, 1969).

Automatic measurements of stream temperature are recorded electronically with thermocouples connected to dataloggers and attached to the insides of open pipes anchored near stream bottoms. Manual temperature measurements are made with standardized thermometers. Rainfall is also measured at each station, refer to Section 5-C for rain gage network protocols.

Observation Schedule

Table 3 lists stream gaging and WQ monitoring stations and starting dates for initial stage measurements and WQ sampling.

Stage measurements are recorded every five-minutes. Observed readings of stage are usually made whenever NSTL or USGS staff inspect or service the equipment at each site.

Low-flow discharge measurements are usually made monthly by NSTL, along with periodic quality control checks by USGS. High-flow discharge measurements are made by USGS.

Table 3. Stream gaging and WQ monitoring stations located in Walnut Creek watershed. Included in the table are site numbers, starting dates for stage measurements, water sampling and stream temperature measurements.

Site #	Stage Measmts.	WQ Weekly Manual	WQ Event Automatic	WQ Sediment	Stream Temp.
310	4/2/91	3/4/92	4/10/91	4/10/91	4/10/91
320	4/11/91	6/22/90	4/13/91	4/13/91	N/A
330	5/2/91	6/22/90	5/7/91	5/7/91	5/7/91
*340	N/A	6/22/90	N/A	N/A	N/A
140	11/13/91	1/22/92	1/8/92	1/8/92	N/A

*Site 340 is only a water quality monitoring station (manually-collected samples)

N/A = parameter not monitored for at specified station

Suspended-sediment samples are collected manually from each station by USGS and NSTL during high flows from a single stream section using ETR, by USGS during low and high flows from an entire stream cross-section using EWI and ETR, and by USGS during low flow from a single stream section using ETR.

The WQ and suspended sediment samples (automatic) are taken every seven days (cumulative) in base mode which is below the trigger stage. At and above the trigger stage (event mode), samples are taken based on the rate of change in stage or elapsed time criteria, whichever criteria is met first. Both criteria are compared every 15-minutes (minimum possible time between samples) to real-time stage data and stage data of the last sample. When either of the criteria is met or exceeded, a sample is collected. During rapid rises/recessions the rate of change criteria will usually govern and during slow rises/recessions the time criteria usually governs. Samples are retrieved from each site weekly and after major rainfall events.

Automatic stream temperature measurements are recorded every five minutes and manual measurements are taken monthly.

Electronically recorded stage and temperature measurements are downloaded from dataloggers (CSI SM192 storage modules) at each station to CSI SM716 storage modules every two weeks.

Quality Assurance and Quality Control (QA/QC)

On a weekly basis, NSTL personnel service WQ samplers and stream gages and check automatically-recorded measurements of stage and stream temperature. Staff at USGS periodically inspect equipment, troubleshoot malfunctioning stream gaging and suspended-sediment sampling equipment, and provide stream gage training programs for NSTL staff.

Automatic recorded measurements of stage at gaging stations are compared to observed stage readings from staff gages and reference points, and to high water marks. Suspended sediment, point sample (automatic) concentrations are compared to seasonally-collected EWI and ETR samples (manual) and to single-section ETR samples (manual) collected during medium and high stream flows.

Discharge and suspended-sediment data are processed by USGS using standard procedures as described by Rantz (1982, p. 544-600), Kennedy (1983), and Porterfield (1972).

The WQ samples are labeled with site name and date and time of collection and submitted to the NSTL Analytical Laboratory. Section O of this report provides information on QA/QC procedures used by this laboratory. Samples for sediment and particle size analyses are analyzed at the USGS sediment laboratory using a QA/QC plan recommended by Matthes et al. (1988). Laboratory quality control includes the analysis of blanks and reference samples. An annual report required by USGS is prepared by the laboratory and summarizes the results of QA/QC samples and proficiency in analytical skills of laboratory personnel.

Stream temperature measurements recorded automatically are compared to manually taken measurements.

Data Format and Processing

Stream stage and temperature data in storage modules are interrogated at NSTL and downloaded into computer files and organized by site with a unique identification number. Files are transferred electronically to the USGS office in Iowa City for determination of discharge. Sampler initiation time-stamps are also extracted to cross reference sample analyses.

At the USGS office in Iowa City, Iowa, discharge measurement data are manually entered and stage data from NSTL are read into its Automated Data Processing System (ADAPS). Periods of missing or poor quality stage data are reconstructed, when possible, from observed stage readings, high-water mark elevations, and comparisons with stage weather data from nearby sites. Stage-discharge ratings are developed and then entered into ADAPS along with time, datum, and rating shift adjustments based on check readings/measurements. The ADAPS outputs Unit-Values and Daily-Values files of discharge using all of the input data. Periods of missing or poor quality discharge data are determined and values updated based on techniques previously referenced. All data and procedures are reviewed by several USGS staff before release as preliminary data. Data are considered final when published by USGS. Streamflow discharge data are made available through the USGS's Water Data Storage and Retrieval System (WATSTORE) (Kennedy, 1983).

Chemical and suspended sediment loads flowing past streamflow gaging stations are computed by the USGS by multiplying instantaneous concentration values from a time-concentration curve by values of instantaneous streamflow discharge for the corresponding time step (Porterfield, 1972, p. 66). The resulting values represent the instantaneous chemical or sediment discharge (mass/time) at that time step. The instantaneous chemical or sediment discharge is multiplied by the time step interval to obtain the load (mass) for that individual time step interval. Individual loads are summed to determine loads for longer periods (daily, monthly, yearly). Time-concentration curves are developed from discrete sample concentrations, determined by NSTL, and compared to the corresponding time-discharge curve. Chemical concentrations for individual time steps are determined by an interpolation program from key values along the time-concentration curve.

References

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Section 5-G. Surface Water Runoff and Water Quality Sampling

D. Schmitz NSTL

Site Locations

Surface water runoff and water quality (WQ) monitoring stations have been installed in three field basins at sites 133, 124, and 223 in Walnut Creek watershed. Site locations and descriptions are provided in Table 1 and Figure 1 shows the locations of the sites within the watershed.

Table 1. Locations and descriptions of surface water runoff and water quality monitoring sites in Walnut Creek watershed.

Site Number	ASCS Tract	Location	Description
133	8999	SW 1/4, Sec. 28, T83N, R24W	The field is conventionally-farmed and is in a corn/soybean rotation.
124	9002	SW 1/4, Sec. 29, T83N, R24W	The field is ridge-tilled and is in a corn/soybean rotation.
223	2802	SE 1/4, Sec. 30, T83N, R24W	Same description as site 133.

Sampling Techniques

Sites 133 and 124

The following equipment have been installed at sites 133 and 124:

ISCO H-flume (91-cm depth)
ISCO bubbler flow meter (model 3230)
Solarex solar panel (model MSX-10)
12 volt deep cycle marine battery

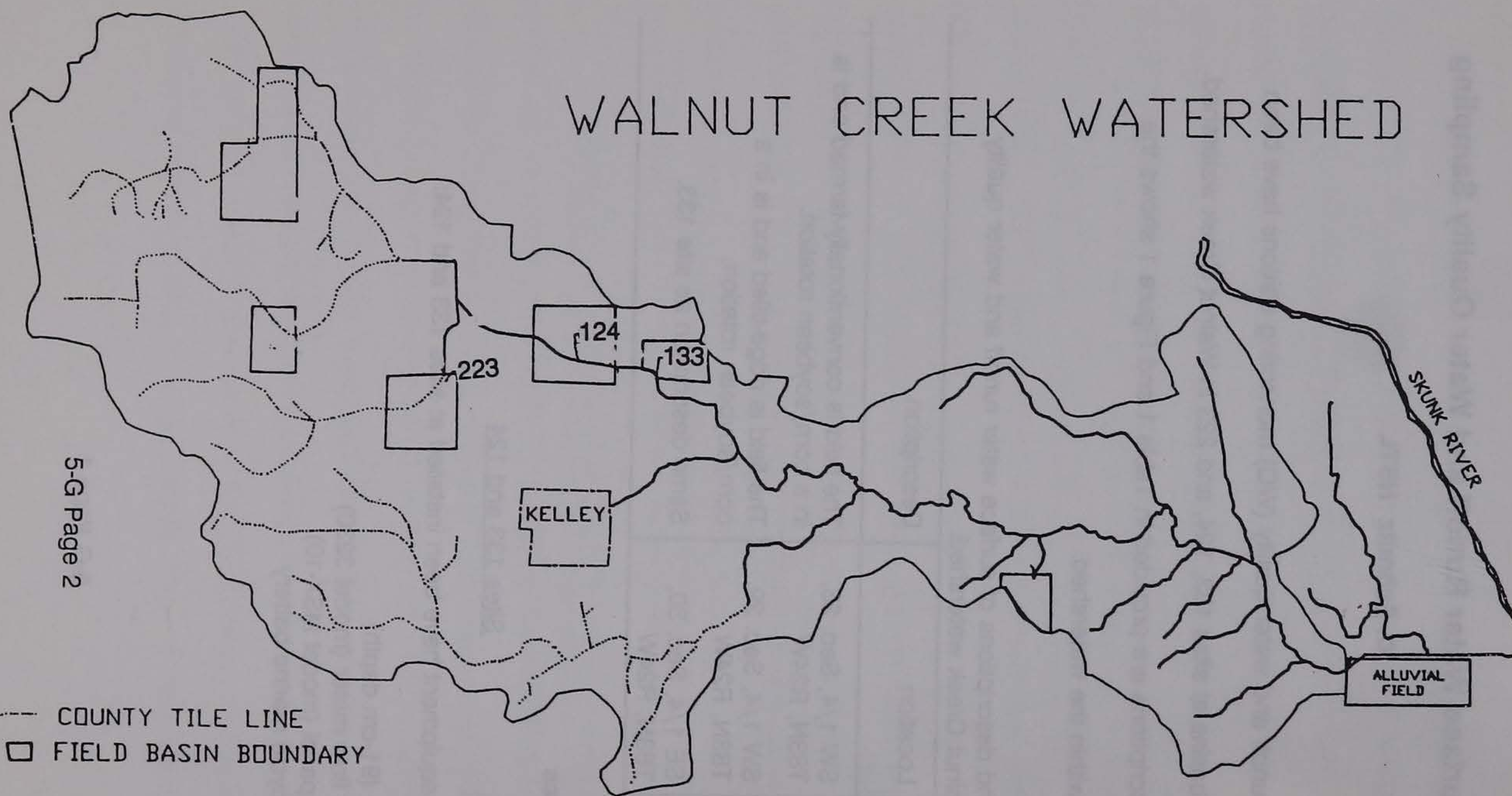

Figure 1. Surface water runoff and water quality monitoring stations in Walnut Creek Watershed.

Due to the variability of flow rates, and amounts of sediment and plant residue transported by surface runoff from agricultural fields, H-type flumes were installed as primary measuring devices at sites 133 and 124. The H-flume is located at the lowest point in each field and berms were built to effectively contain all runoff from each field.

A bubbler flow meter which is housed next to each flume, is used to record stage. The flow meter datalogger converts these stage values into discharge values according to the level-flow rate relationship developed for the flume (Kilpatrick and Schneider, 1983). Stage is measured as a change in pressure required to maintain a constant bubble rate (60 bubbles per second) from the bubbler line which is mounted in a stilling well on the flume bottom (Grant 1989). Stage is measured every minute and five-minute averages are recorded by the ISCO flow meter datalogger. Automatic composite water samples are taken for analysis of chemical concentrations and sediment load. The ISCO sampler is triggered by the flow meter to take a 75-80-ml subsample at the start of sensed flow and consecutive subsamples after 250 cubic feet of runoff has been tallied. Thus, each 350-ml sample bottle contains a composite of four subsamples. A total of 24 bottles can be taken before the sampler is emptied.

Site 223

The following equipment have been installed at site 223:

Campbell Scientific Inc. (CSI) CR10 datalogger
CSI SM192 storage modules
2 Spectra potentiometers
2 float gages with measuring tapes
Mannings Sampler
Solarex solar panel (model MSX-10)
12 volt deep cycle marine battery
2 metal boxes to house the potentiometers

At site 223, two float gage potentiometers are installed in metal boxes at the upstream and downstream sides of a 91-cm diameter culvert. Potentiometers measure changes of stage during runoff events using principles described by Buchanan and Somers (1978). They are connected to a datalogger that records average stage every five minutes. Runoff samples are collected automatically by an ISCO sampler that is triggered by the datalogger (located in a steel gaging station) to take one 350-ml sample based on a predetermined change of stage during major runoff events. Suspended-sediment samples are taken by Mannings samplers which have vacuum pumps that draw water samples through reinforced polyvinyl chloride (PVC) tubing and discharge into polyethylene bottles.

After each runoff event, water quality samples are collected and labelled with the site number and event date. Subsamples (50ml) are drawn from sites 133 and 124 sample bottles at the Iowa State University, Department of Agricultural and Biosystems Engineering Laboratory (Davidson Hall) for analysis of total solids using standard methods (Method 209A) (APHA, AWWA and WPCF, 1985). The remainder of each sample, after subsamples are removed, is analyzed for nitrates, atrazine, alachlor, metribuzin, and metolachlor at the National Soil Tilth Laboratory (NSTL) Analytical Laboratory using methods described in Section 5-S of this report.

Sediment samples obtained from runoff collected at site 223 are sent to the United States Geological Survey (USGS) in Iowa City, Iowa and analyzed at their laboratory for suspended sediment using the method described in Section 5-F of this report.

Observation Schedule

Table 2 lists starting dates for discharge measurements and water sampling at the surface water runoff sites.

Table 2. Starting dates for flow measurements and water sampling at surface water runoff sites in Walnut Creek watershed.

Site Number	Discharge	Water Quality Samples	Sediment Samples
133	7/1/92	7/16/92	7/16/92
124	7/1/92	7/15/92	7/15/92
223	8/2/91	8/11/91	8/11/91

Quality Assurance and Quality Control

At sites 133 and 124, accuracy of flow meter stage readings are checked prior to spring runoff. Water is pumped into each flume and stage is measured at the stilling well containing the bubble line. Stage is also checked during runoff events. During site visits, debris is cleared from flume mouths and sediment is removed from stilling wells.

At site 223, the stilling wells which house the floats, are flushed before and after runoff events to remove silt build-up. During an event, actual stage is measured manually. These stage readings are compared to automatically-recorded float gage readings and are adjusted if necessary.

Automatic water quality and sediment samplers are calibrated when flow meters are checked to ensure volume accuracy.

Data Format and Processing

Discharge measurements from flow meters at sites 133 and 124 are downloaded from dataloggers into laptop computer files using Flowlink software after every event. Following data retrieval, runoff volume tallies are reset to zero and automatic runoff samplers are reset to guarantee that during the next major runoff event the first sample is discharged into the first bottle of the set of 24 bottles. At NSTL, Flowlink software is used to convert discharge data to ASCII files.

At site 223, data are downloaded every two weeks from the datalogger and transferred into CSI SM192 storage modules that are returned to the NSTL. At the NSTL, data are downloaded from modules and transferred into a personal computer where they are converted to ASCII files. Files are sent electronically to USGS at Iowa City where culvert stage values are screened for missing and unusual values. Discharge is calculated from these values using the theoretical rating curve developed for the culvert. Discharge data are sent electronically to NSTL and will be entered into the Statistical Analysis Systems (SAS) database.

Water quality and sediment analytical results are organized by site number in ASCII files and will be entered into the NSTL SAS database. Discharge and herbicide, nitrate, and sediment data will be used to compute herbicide, nitrate and sediment loads in surface runoff at each monitoring station.

References

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Section 5-H. Tile Flow and Water Quality Monitoring

D. Schmitz NSTL

Overview

Two field and three county drainage district tiles in Walnut Creek watershed are currently monitored to characterize the water quality, chemical and water losses by tile drainage. At each site, flow is monitored continuously and water quality samples are taken weekly. In addition, automatic samplers are triggered by flow meters to take additional samples.

Site Locations

Field basins

Two field basin tiles at sites 110 and 132 are being monitored to define the relationship between farming practices and water quality in tile flows where shallow groundwater is the only source of flow. There is no surface water component to flow in the field tiles due to the lack of surface inlets. Tile outlets, and various points along the tile lines have been located using laser "total station" surveying equipment. These positions have been projected to 1983 Universal Transverse Mercator coordinates by siting in benchmarks established in the fields by a Global Positioning System unit. Water quality samples are taken weekly at field basin tile sites 122, 123 and 170 to assess these sites for future tile flow monitoring stations. Tile locations and descriptions are provided in Table 1. Tile discharge sampling locations in both basins are shown in Figure 1.

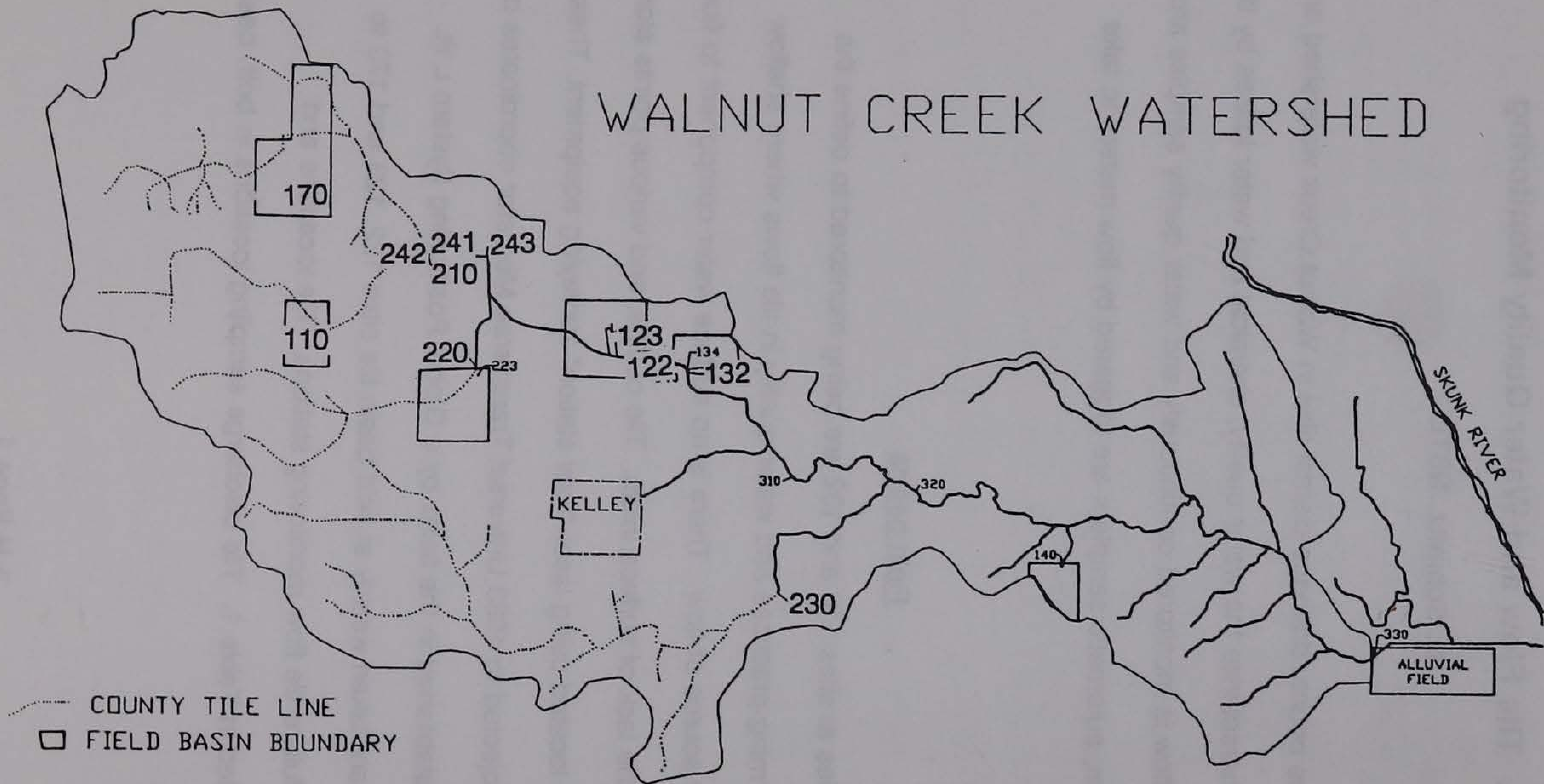

Figure 1. Tile flow and water quality monitoring sites in Walnut Creek watershed.

Table 1. Locations of tile flow and water quality monitoring sites in Walnut Creek watershed field basins.

Tile Site	ASCS Tract	Location	Description
110	3010	SE 1/4, S. 25, T83N, R25W	This 20-cm diam. (diameter) tile drains the southern 8.5 ha of the tract. The field is under a corn/soybean rotation and a chisel/disk tillage system.
132	8999	SW 1/4, S. 28, T83N, R24W	Tile flow is monitored in a 19-cm diam. tile that drains the tract. The field is under a corn/soybean rotation and a chisel plow tillage system. Monitored flow rates indicated that the drainage area is larger than tile maps show. Lateral lines, that may contribute flow, have not been located.
122	9002	SE 1/4, S. 29, T83N, R24W	This 25-cm diam. tile drains a field under a corn/soybean rotation and ridge tillage system. Drainage areas are undetermined.
123	9002	SE 1/4, S. 29, T83N, R24W	Same description as site 122.
170	3016	SW 1/4, S. 24, T83N, R25W	The 15-cm diam. tile drains a 5 ha field that is under a corn/soybean rotation and no-tillage system.

Small Basins

Three county drainage tiles, at sites 210 in basin 1, 220 in basin 2, and 230 in basin 3, in the western half of Walnut Creek watershed are monitored for discharge and water quality (Figure 1). These locations correspond to the terminal end of three subbasins. The dendritic patterns of the county tile drainage systems serve to transport subsurface flow collected from many farm field tiles and surface runoff entering surface inlets in poorly drained farm fields and road ditches. County tiles at sites 241, 242, and 243 drain the northwest small basin of the watershed. Collectively, they comprise the Boone-Story Joint sub-drain #1. Tile drainage maps indicate that these tiles overlap each other such that drainage areas are difficult to delineate. These sites were monitored only for water quality until the sampling was discontinued in 1994 (Table 2). Tile site locations and descriptions are provided in Table 2.

Table 2. Locations of small basin tile flow and water quality monitoring sites in Walnut Creek watershed.

Tile Site	Drainage Basin	Location	Description
210	#1, Boone-Story District 1	NE 1/4, Sec. 30, T83N, R24W	The 52-cm diameter (diam.) tile is the main branch of the district.
220	#2, Boone-Story District Joint 1	SE 1/4, Sec. 30, T83N, R24W	The 46-cm diam. tile is the south branch of the district.
230	#3, Boone-Story District 10	NE 1/4, Sec. 4, T82N, R24W	The 92-cm diam. tile drains district # 10.
241	#4, Boone-Story Joint sub-drain 1	NE 1/4, Sec. 30, T83N, R24W	The 91-cm diam. tile drains the northwest small basin of the watershed and terminates at the north branch of the Walnut Creek "open channel ditch". The drainage area is not delineated.
242	Same as 241	Same as 241	Same description as Site 241
243	Same as 241	Same as 241	Two parallel 30-cm diam. tile lines terminate 0.54 km downstream from sites 241 and 242 into the open ditch.

Sampling Techniques

Flowtote (Marsh-McBirney, 1989) flow meters were installed at sites where tile discharge is monitored. The flow meter, which contains an internal datalogger, calculates tile discharge, based on rating curves, from recorded stage and velocity measurements. Stage is measured with a submerged pressure transducer and velocity with an electromagnetic sensor. Both devices are housed in one unit and installed directly on the bottom of the tile line. The meter is able to measure flow in both full pipe and less than full conditions. A minimum of 1.27 cm of water depth above the tile bottom is required by the flow meter.

Field Basins

Site 110:

The tile at this site was intercepted before joining the drainage district tile and a 19-cm diameter inverted syphon, made of polyvinyl chloride (PVC) pipe, was installed to ensure that the tile section being monitored is full of water. At low flow velocities, only the stage measurement is used for calculating flow that is based on calibration curves from manually-measured, volumetric discharge rates.

Site 132:

At this site, a corrugated metal section of the tile line which emptied directly into the Walnut Creek stream channel was removed and replaced with a 19 cm-diameter PVC pipe. At the pipe outlet, a steel plate with a 30° v-notch weir was attached and a 50-cm length of the top half of the PVC pipe removed at a distance of 0.5 m from the end. The bottom of the v-notch was located approximately 2 cm above the bottom of the pipe to ensure that the flow meter sensor was always submerged. At low velocities, only the measured stage is used to calculate flow, based on rating curves developed for the v-notch. During high flows the v-notch does not restrict flow since water is free to exit the pipe through the removed top section.

Sites 122, 123, and 170:

These monitoring sites are currently being assessed for installation of discharge measuring devices.

<u>Small Basins</u>

Site 210:

This site monitors the district tile draining subbasin 1. There are no provisions for extending the measurement range below the limits of the velocity sensor.

Site 220:

The district tile at this site drains subbasin 2. The original corrugated metal pipe was lined with a smooth-walled PVC pipe which was sealed to the outer culvert with an inflatable inner-tube. Stream sediment has further sealed the inner tube so that no leakage is observed between the two drain pipes. Flowtote flow measurements are supplemented by manual measurements during low flows, using a 7.6 cm wide portable Parshall flume or a pygmy current meter, where the tiles discharge water into an open channel (Rantz, 1982).

Site 230:

Due to the large area drained by the 91-cm diameter tile that drains basin 3 at this site, velocities have been consistently within the flow meter range. Low flow measurements are taken similarly to those at site 220.

At sites where flow is measured, automated ISCO water samplers have been installed and are triggered by Flowtote flow meters to collect 350-ml samples on a flow proportional basis. The flow meter sends an electronic pulse to the sampler after it has measured a predetermined volume of water. Samplers consist of peristaltic pumps that draw water samples from the tile stream via Teflon™ coated tubing and discharge into clear glass bottles. The sampler purges the line with water prior to and after drawing the sample volume. Samplers at sites 110 and 132 initially were set up to take time-composite samples. Each composite contained four sub-samples, each sub-sample taken every two hours. This was changed during the course of monitoring to flow-weighted samples, one sample per sample bottle. Automatically-collected samples are retrieved from each station every two days or after a major rainfall event.

In addition to automated collection, water samples are collected manually, on a weekly basis, at each site by dipping (sterilized) amber glass bottles into stream flow.

Water samples collected from tile sites are labeled with site names, numbers and sample time and are delivered to the NSTL Analytical Laboratory where they are analyzed for metolachlor, alachlor, metribuzin, atrazine and nitrates. Section 5-S of this report provides information on sample storage and analytical procedures.

Observation Schedule

Tables 3 and 4 list field basin and small basin tile sites, along with starting dates for flow measurements and water quality sampling.

Table 3. Field basin tile sites in Walnut Creek Watershed. Site numbers are provided along with starting dates for flow measurements and water quality (WQ) sampling.

Site Number	Discharge	WQ Weekly Manual	WQ Event Automatic	WQ Composite Samples
110	12/27/91	12/11/91	04/27/92	07/24/92-04/10/93
122	N/A	06/17/92	N/A	N/A
123	N/A	03/04/92	N/A	N/A
132	06/02/92	03/11/92	07/16/92	07/16/92-04/23/93
170	N/A	04/29/92	N/A	N/A

N/A = Measurements not made

Table 4. Small basin tile sites in Walnut Creek Watershed. Site numbers are provided along with starting dates for flow measurements and water quality (WQ) sampling.

Site Number	Discharge	WQ Weekly Manual	WQ Event Automatic
209	05/13/91-11/07/91	12/31/91-06/03/92	N/A
210	07/10/92	06/10/92	05/21/93
220	07/12/91	06/22/90	08/14/91
230	06/05/92	05/21/92	05/03/93
241	N/A	06/10/92-03/09/94	N/A
242	N/A	06/10/92-03/09/94	N/A
243	N/A	05/21/92-03/09/94	N/A

N/A = Measurements not made

Quality Assurance and Quality Control

On a weekly basis each Flowtote flow meter is checked to ensure that the battery voltage is sufficient for operation and that the instrument is functioning properly.

The ISCO samplers used to collect water quality samples are recalibrated when sample volumes spill over the top of sample bottles or do not fill bottles completely. Samplers and flow meters are replaced when they are not functioning properly.

Data Format and Processing

Each Flowtote has an internal datalogger that records time versus five-minute averages of stage, velocity and flow measured once every minute. This information is downloaded to a lap-top computer biweekly using Floware communications software. At the NSTL, data is converted to ASCII files using Floware software, then adjusted for the time drift caused by inaccurate Flowtote clocks based on a linear drift between download dates. Stage, velocity, and flow data is then automatically screened for out-of-bound values (negative stages, velocities, or flows) and flagged. Screening rules are listed for each site in Table 5. A final screening of the data is done manually where suspect data and outliers are flagged. Outliers result from debris snagging on the flow sensor or cold temperatures affecting the meter electronics. The ASCII files are then loaded into the NSTL Statistical Analysis Systems (SAS) database.

Within the database, five-minute flow values are used to compute four hour averages, six values for each day. Missing data are interpolated to allow for complete records of four-hour data. Interpolation is done by relating flow at each site to flow within the stream, primarily main stream site 310. Four-hour flow data is then flagged to indicate whether it is computed from measured five minute flow data or interpolated.

Table 5. Data screening rules for tile monitoring sites.

Site	Max flow rate	Min stage	Max stage	Stage calculation threshold
	(m^3/s)	(cm)	(m)	(cm)
110	0.017	28	2.5	<32
132	0.074	0	2.5	<5
210	0.388	38	2.5	not est.
220	0.323	25	2.5	not est.
230	2.09	0	2.5	not est.

Herbicide and nitrate analytical results from the NSTL Analytical Laboratory are provided in hardcopy files to NSTL staff. Chemical concentration graphs are plotted with hydrographs to check for outliers. These outliers are checked by lab personnel for data entry error and corrected if needed. Data are saved in ASCII files and loaded into the NSTL SAS database. Herbicide and nitrate loading rates are being calculated, in the SAS database (Bob Jaquis), based on discharge measurements and herbicide and nitrate concentrations.

References

Marsh-McBirney, Inc. 1989. Portable open channel flow meter systems installation and operations manual. 47 p.

Rantz, S.E. 1982. Measurement and computation of stream flow: U.S. Geological Survey Water-Supply Paper 2175, 631 p.

Section 5-I Stream and Runoff Toxicological Assessments

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Site Locations

Toxicological assessments were conducted at four sites in Walnut Creek Watershed. Sample sites were selected to provide a longitudinal gradient of conditions within the watershed. Two edge-of-field sites were sampled: the "Pothole" site is located near tile flow and water quality monitoring station 110 (description provided in Section 5-H) and the Hilton site is located near tile flow and water quality monitoring station 220 (description provided in Section 5-H). Stream station sites were located near stream gaging and water quality stations 310 and 330 (descriptions are provided in Section 5-F). Site locations are shown in Figure 1.

Sampling Techniques

Toxicological sampling was conducted concurrently with stream and runoff sampling conducted by the National Soil Tilth Laboratory (NSTL) to ensure comparability of toxicity data with herbicide data from streams and runoff. Composite 20-L samples were collected as 1-L grab samples from each site and stored in acid-washed 20-L polyethylene cubitainers. Immediately after collection, samples were mailed in a cooler with ice to the National Fisheries Contaminant Research Center (NFCRC), National Biological Survey (NBS), Columbia, Missouri. At the Laboratory they were refrigerated at 4°C until toxicity analyses were performed on the samples.

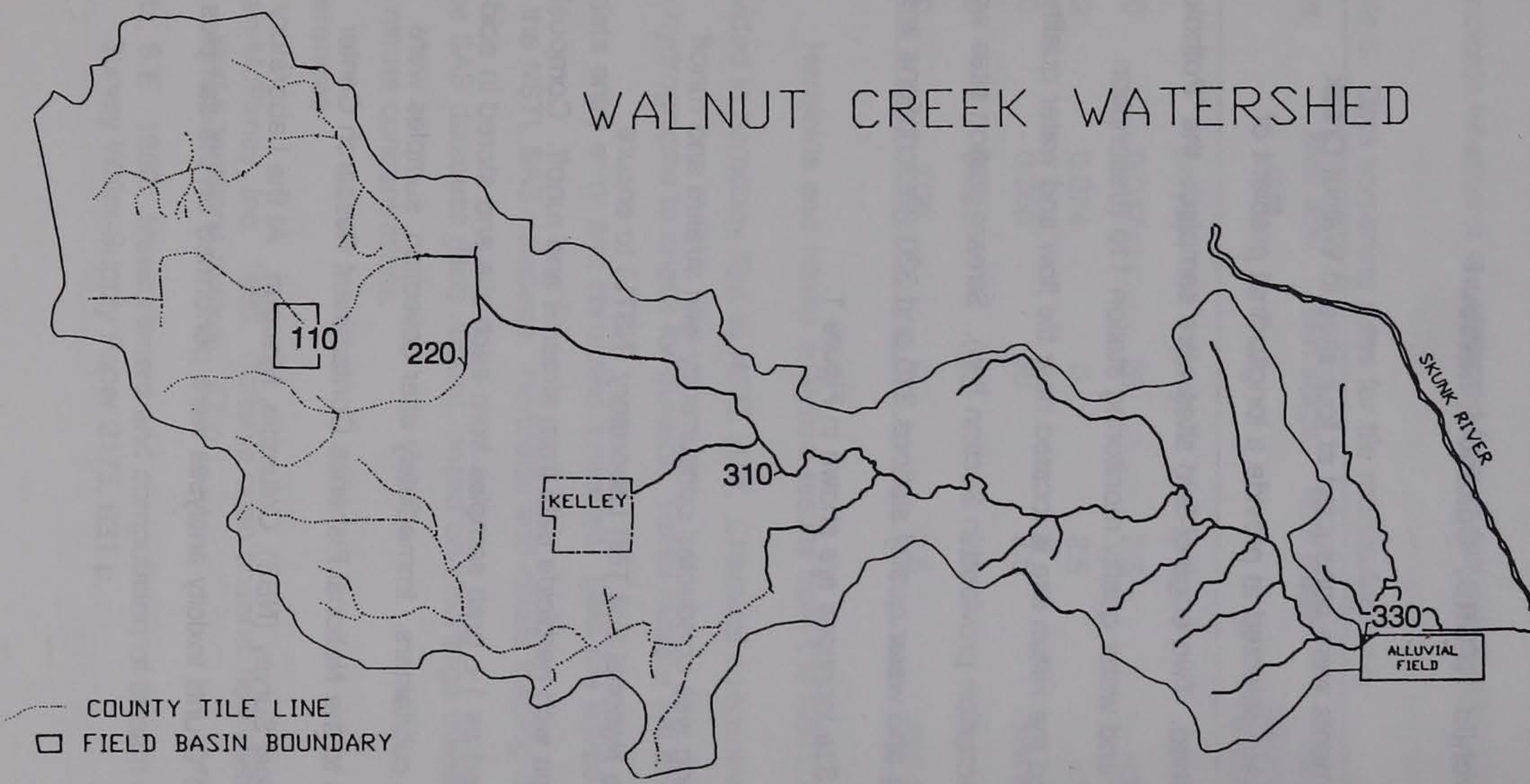

Figure 1. Stream toxicological study sites in Walnut Creek watershed.

Water samples collected by NSTL staff were delivered to the NSTL Analytical Laboratory (details are provided in Section 5-O of this report).

Samples were analyzed by NFCRC staff for pH, alkalinity, hardness, conductivity, temperature, dissolved oxygen, and turbidity using standard methods (APHA, AWWA, and WPCF, 1985). Ammonia-nitrogen, nitrate- and nitrite-nitrogen, and soluble reactive phosphorus were also determined using a Technicon Auto-analyzer (Technicon Industrial Systems, 1976).

Sample splits (one-L) were sent to the Patuxent Wildlife Research Laboratory, United States Fish and Wildlife Service (USFWS), Laurel, Maryland and analyzed for organophosphate and carbamate insecticides. Samples were extracted using a modified version of Section 10 of United States Environmental Protection Agency (U.S.EPA) Test Method #608 (U.S.EPA, 1982). A 1000-ml water sample was extracted three times using methylene chloride. Extracts were combined with three methylene chloride container rinses, dried using sodium sulfate, and concentrated using a rotary evaporator. Residues were quantified using gas chromatographic methods similar to those described by Belisle and Swineford (1988). Gas chromatography specifics are as follows: for organophosphates a 30-m megabore capillary column containing 7% phenyl cyanopropyl polysiloxane was used with flame photometric detection and analytical detection limits of 1 ug/L (ppb); for carbamates a 30-m megabore capillary column containing 5% phenyl methyl polysiloxane was used with nitrogen-phosphorus detection and analytical detection limits of 2 ug/L (ppb).

Toxicity tests using two species of aquatic plants (Selenastrum capricornutum and Lemna minor), one species of fish (Pimephales promelas), and one species of invertebrate (Ceriodaphnia dubia) were performed at NFCRC on water samples to determine the bioavailability and toxicity of agricultural effluents. Tables 1 and 2 provide a summary of experimental conditions used for plant and animal toxicity tests. Test organisms were obtained from NFCRC culture facilities.

Observation Schedule

Runoff and stream samples for toxicity assessment were collected on April 15, April 22, May 13, May 27, July 8, July 15, and July 29 of 1992. Sample dates corresponded to regularly scheduled NSTL stream and runoff sampling events. Sample weeks were selected to span conditions ranging from base-flow to peak-flow.

Quality Assurance and Quality Control

Studies were conducted as described in NFCRC Protocol 92-20038-24-03, entitled: "Bioavailability and Toxicity of Agricultural Chemicals in Runoff from MSEA Sites: Potential Impacts on Non-target Aquatic Organisms". Protocols are based on good scientific practices described within the Good Laboratory Practice (GLP) outlined in the Federal register (160.120; 40 CFR Chapt. 1; 7/1/85 edition; subpart G - "Protocol for and conduct of a study"). Procedures involving live organisms were conducted in accordance with the NFCRC Animal Welfare Plan, adopted by the Animal Care and Use Committee based on the Animal Welfare Act (Proposed Rules 9 CFR, Part 2, Subpart C, Section 2.35, Federal Register Volume 52, No. 62, March 31, 1987).

Table 1. Experimental conditions and procedures used in toxicity tests performed in Walnut Creek watershed.

Condition	Test			
	Selenastrum[1]	Lemna[2]	Ceriodaphnia[3]	Pimephales[4]
Temperature (°C)	25	25	25	25
Light source	fluorescent cool-white	fluorescent cool-white	ambient	ambient
Light intensity (fc)	400	400	50-100	50-100
Photoperiod	continuous	continuous	16L:8D	16L:8D
Test chamber	125-mL Erlenmeyer	250-mL beaker	30-ml beaker	1-L beaker
Water volume (mL)	50	200	15	750
Organisms stocked (#)	20,000 cells/mL	12 fronds	5	10
Replicates	3	3	4	2
Media	ASTM	10X ASTM/soil	N/A	N/A
Test duration (h)	96	96	48	96
Water renewal	no	no	no	no
Endpoint	population growth	frond production	mortality	mortality

[1] modified from ASTM (1991).
[2] modified from Taraldsen and Norberg-King (1990).
[3] modified from U.S.EPA (1985) and ASTM (1990).
[4] modified from U.S.EPA (1985).

Table 2. Parameters, frequency of calibration, calibration method, and methodology used for water quality analyses performed on water samples collected in Walnut Creek watershed.

Parameter	Frequency Calibration	Calibration	Method; NFCRC SOP
pH	daily	2-pt	Orion; SOP B4.41
alkalinity	daily	1-pt	titration; SOP B4.16
conductivity	daily	1-pt	YSI Model 35; SOP B4.15
temperature	annual	single pt	YSI Model 54; SOP 4.46
oxygen	daily	single-pt	YSI Model 54; SOP B4.46
TN	daily; every 10 samples	4-pt curve	Technicon; SOP B5.18
NH_3	daily; every 10 samples	4-pt curve	Technicon; SOP B5.19
NO_2NO_3	daily; every 10 samples	4-pt curve	Technicon; SOP B5.20
TP	daily; every 10 samples	4-pt curve	Technicon; SOP B5.18
PO_4	daily; every 10 samples	4-pt curve	Technicon; SOP B5.19
DOC	daily; every 10 samples	4-pt curve	Technicon; SOP B5.21
chlorophyll	annually	4-pt curve; daily single-pt coproporphyrin standard	fluorometry; SOP B5.37

This study addressed in part the objectives outlined in the Work Unit Plan 20038, "Fate and Effects of New Generation Chemicals on Fish and Aquatic Organisms". The Standard operating procedures (SOP's) used in the protocol are cited in Table 3; copies of the Protocol and SOP's are available on request. Precision of toxicity tests were determined based on replicate samples (n=2 or 3 depending on species) (Table 1). The SOP's for these procedures are cited in Table 3.

Water quality parameters, methods, calibration frequency, and calibration methods are provided in Table 2. Standards and samples were analyzed in duplicate. Duplicates and standards were used to monitor the accuracy and precision of analytical procedures.

Insecticide analyses were based on three-point standard curves using standard reference materials. Duplicates, spikes, and blanks were used to monitor the accuracy and precision of analytical procedures and analytical recoveries. Detection limits for organophosphate and carbamate insecticides were 1 and 2 ug/L (ppb), respectively.

Data Format and Processing

Hardcopies of all data (toxicity tests, water quality, and insecticide analyses) are maintained in the Ecology Laboratory in Building C-5 at the NFCRC. All herbicide data is stored and maintained at the NSTL (Sections 5-F and 5-G). Data is entered from hardcopy to either Lotus 1-2-3 spreadsheets or Statistical Analysis Systems (SAS) files by NFCRC technicians. Data is verified following entry and reviewed by NFCRC

Table 3. Standard operating procedures used in toxicity tests.

B5.53	Dissolved Nutrient Sample Preparation
B5.52	Procedure for Sample Collection of Water for Nutrient Analysis on the Technicon Auto Analyzer II
B5.20	Determination of Nitrate and Nitrite in Water with the Technicon Autoanalyzer AAII (Adapted from Technicon Industrial Method No. 158-71W)
B5.19	Technicon Autoanalyzer AAII Determination of Ammonia Nitrogen and/or Orthophosphate (SRP) in Water
B4.41	Operating the Orion Model 811 pH Meter
B4.16	Alkalinity: Burette Method
B4.42	Turbidity Sampling in Water Using the Hach Model 2100A Turbidimeter
B5.37	Extraction and Analysis of Chlorophyll and Pheophytin a from Water
B4.46	YSI Model 54 Dissolved Oxygen Meter and Probe-Ecology
B4.43	Measurement of Photosynthetically Active Radiation Using the Li-Cor Lamda Meter
B5.63	Storage, Handling, and Retrieval of Hand Written Material
B4.40	Calibration Procedure for Turner Designs Model 10 Fluorometer
B5.165	Acclimation of Fish to Research Waters
B5.dft	Collecting, Shipping, Receiving, and Storing of Grab-samples Collected from Field Waters
B5.dft	Procedure for Testing the Acute Toxicity of Effluents to the Fathead Minnow (Pimephalespromelas) Under Static Conditions
B5.dft	Algal 96-h in-vivo Fluorescence Bioassay
B5.dft	Procedure for Ceriodaphnia dubia Acute Toxicity Dilution Test
B5.dft	Toxicity Testing Using Lemna minor
B5.160	Reporting Deficiencies in Animal Care and Treatment
B5.148	Humane Disposal of Fish
B5.95	Hardness
B5.13	Procedures for Keeping Fish Culture and Acclimation Records
B5.16	Glassware Washing Procedure for Analytical Biology Section (Rm. 40)
B5.154	Humane Procedures for Anesthetization and Handling of Fish for Sampling Purposes
B4.62	Orion Model EA 940 Expandable Ionanalyzer
B5.237	Conductivity Determination with the Orion Model 140 S-C-T Meter
B4.58	Reference Electrode, Double Junction; Orion Model 90-02 Preparation, Maintenance, and Storage
B4.12	Determining Chloride Ion Concentration in Aqueous Samples
B5.192	Ammonia Determinations Using the Orion 95-12 Ammonia Electrode and Orion Ionanalyzers
B5.27	Culturing Selenastrum capricornutum

researchers. Verified data is stored on disk at two separate locations, the Ecology Laboratory and the Computer Facility at NFCRC. Hard-drive computer files are backed up by the Information Transfer Section of the NFCRC on a weekly basis. At the termination of this study, data will be transferred to the NFCRC archived database.

Data is analyzed statistically using Lotus 1-2-3 and SAS. Statistically, the effective concentration resulting in 50% growth inhibition (plant tests) or mortality (animal tests) will be determined. Replicate concentration series will allow comparisons of no-effect (NOEC), lowest observable effect (LOEC), and effective concentrations causing 50% mortality (EC-50) values using analysis of variance (ANOVA).

Data derived from this study will be provided to the U.S.EPA Environmental Research Laboratory (ERL), Duluth, Minnesota and NSTL on request. Data will be used to perform an ecological risk assessment of the impacts of non-point agricultural pollution on aquatic communities of the Midwest. Risk assessment results will be transferred to the scientific community via publication in a peer-reviewed journal.

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Section 5-J Stream Characterization

Section 5-J.1 Stream Biology

R. Carlson ERL-Duluth, Minnesota

Site Locations

Stream biological survey stations were established in the Walnut Creek watershed at four locations and at seven additional sites in other small, central Iowa streams. Survey stations in addition to those at Walnut Creek were established to permit comparisons of habitat features, water chemistry profiles, and types of biological communities. Descriptions by Larimer (1957) were used to position the comparative stream sites.

The four Walnut Creek stations are located at Management System Evaluation Area (MSEA) water quality monitoring sites: station #1 is located near tile site 220 and surface runoff site 223; station #2 is located near tile site 132 and surface runoff site 133; station #3 is located near stream gaging station 320; and station #4 is located near stream gaging station 330 (Reference to other sections in this report-Section 5-G: runoff stations; Section 5-H: tile flow stations; and Section 5-F: stream gaging stations). Figure 1 shows the locations of the stream biological survey sites. Of the seven additional stations, three are located in Bear Creek in Story and Hamilton Counties, two are located in Squaw Creek in Hamilton and Boone Counties, one site is located in Montgomery Creek, Boone County, and one site is located in Crooked Creek, Hamilton County.

Walnut Creek Watershed, IA

Management System Evaluation Area

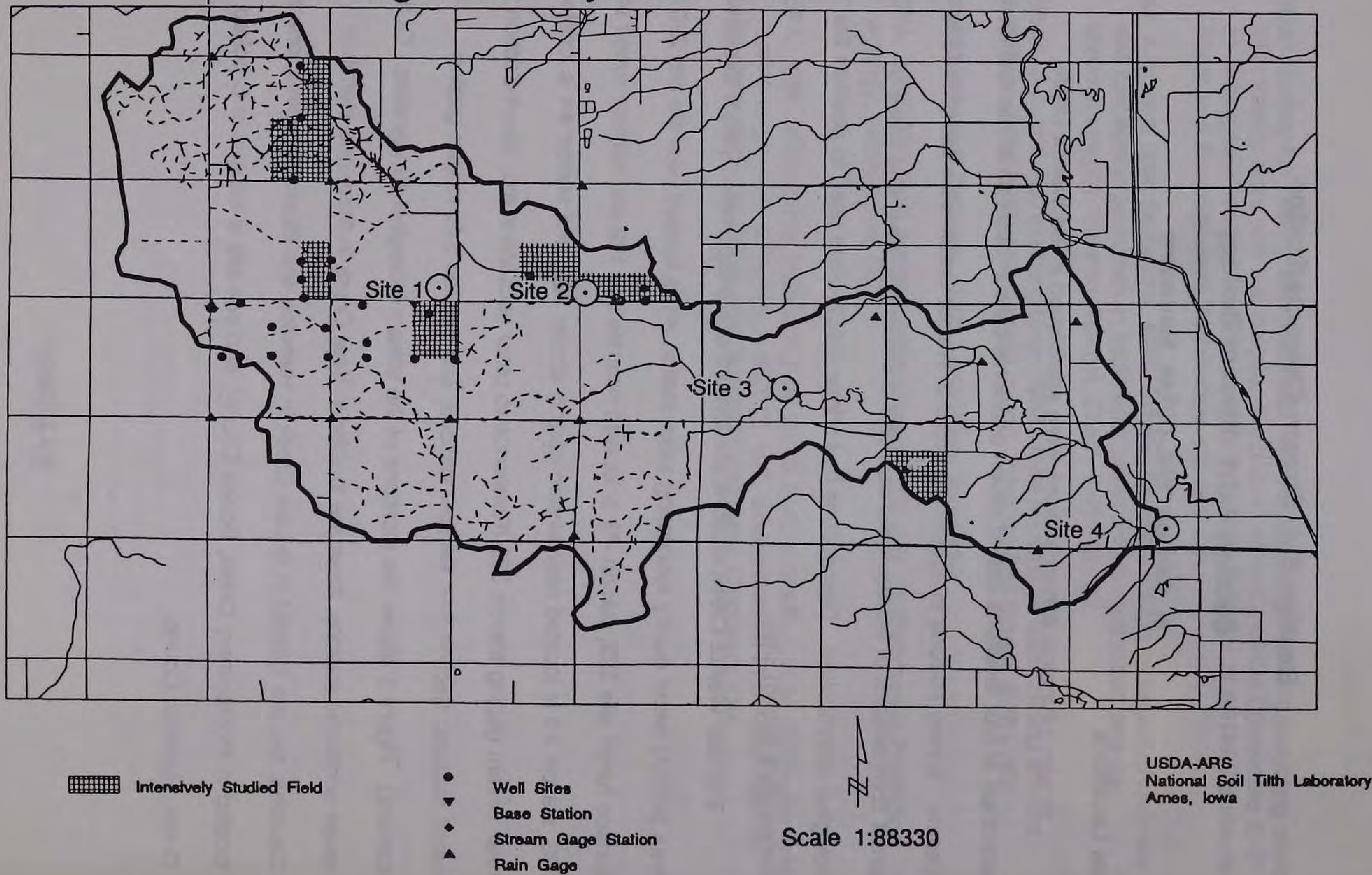

Figure 1. Locations of stream biological stations in Walnut Creek Watershed.

Sampling Techniques

Water quality, sediment, and habitat quality were evaluated at each station along with an assessment of macroinvertebrate and fish communities. Samples were collected by U.S. Environmental Protection Agency (EPA), Environmental Research Laboratory (ERL)-Duluth staff. Water grab samples were collected away from shoreline disturbances by immersing polyethylene bottles at mid-depth and midstream. Sediment samples were collected away from the shoreline influences using a petite Ponar dredge at three representative locations and contents were composited into polyethylene bottles. Immediately after collection, water and sediment samples were stored on ice in coolers for transportation back to the U.S. EPA ERL Duluth, Minnesota.

After samples arrived at the ERL-Duluth, they were logged-in by station identification number and frozen until analysis. Prior to freezing, sediment pore water samples were prepared by centrifuging sediment samples in a rotor at 2500 X gravity for 20 minutes in a refrigerated centrifuge, and decanting off the supernatant, pore water. Sediment pore water samples were stored in polyethylene bottles.

Water and sediment pore water samples were analyzed at the ERL-Duluth for ammonia-nitrogen (NH_3-N), nitrite- and nitrate-nitrogen (NO_2+NO_3), phosphates (PO_4), total phosphorus (TP), and total nitrogen (TN). A Lachat QuikChem AE automated ion analyzer was employed using Lachat (1988) procedures. Samples were analyzed for total organic carbon with a DC-80 Dohrmann instrument using U.S. EPA (1983) procedures. Alkalinity, conductivity, and total suspended solids analyses were also performed on samples using standard analytical procedures (APHA, AWWA, and WPCF, 1980).

Sediment pore water samples were used for standardized *Ceriodaphnia dubia* toxicity tests (U.S. EPA, 1989). Daphnids used for toxicity tests were from cultures of known parentage obtained from ERL-Duluth and were approximately 24-hours old when 7-day tests were initiated. One daphnid was placed into each of ten, one ounce cups containing 15 ml of sample water. The same procedures were repeated for a set of 10 replicate controls containing dilute mineral water solutions. Daphnids were fed daily, test solutions changed at days 2 and 4 of the 7-day test and monitored for significant survival and reproductive differences from controls ($P < 0.05$) using a pair-wise multiple range comparison based on a modification of Tukey's HSD procedure; additional details are given in Lewis et al. (1992).

Stream macroinvertebrates were sampled qualitatively using sweep nets, substrate kicking, and shoreline picking and quantitatively using Hester-Dendy masonite sampler (Plafkin, 1989; Klemm et al., 1990). Sweep net and substrate kick samples were collected by disturbing the stream bottom and positioning an A-frame dip net downstream to collect the dislodged organisms. Masonite samplers were placed at each location for durations of 7 to 8-weeks. Samples were strained through a 40-mesh sieve prior to preservation with 10% formalin. At the laboratory, the benthos were counted and identified to the genus level.

Fish populations were sampled using a 6.1 m bag seine (approximately 10 mesh) using procedures developed by Klemm et al. (1993). The longitudinal reach seined at each station was generally 61 to 122 m long. A blocking net was placed in the stream at the upper end of the seined reach to prevent fish escapement. Fish were removed from the net and preserved in 10% formalin. At the ERL-Duluth, fish were counted, identified and sorted into size classes. Abdominal cavities of larger fish specimens (> 10-15 cm long) were opened to ensure more thorough preservation. The total weight of all fish collected at a site was also obtained.

A systematic appraisal of habitat quality was conducted at each sampling location. Habitat assessment techniques, as described by the Ohio Environmental Protection Agency (1987), were used. This procedure includes a calculation of a Quantitative Habitat Evaluation Index (QHEI), and provides an empirical evaluation of stream quality. Seven metrics were used for computation of the QHEI index and included: substrate type/quality, instream cover, channel morphology, riparian zone/bank erosion, pool/riffle-run, gradient, and drainage area. The total QHEI score was computed by adding together the individual metric scores, the best attainable score being 100. Substrate embeddedness was also determined at each site.

Substrate embeddedness was determined at each site. Representative surficial substrate samples (up to 10-15 cm in depth) were collected with a scoop and the proportions of finer particles (< 2.4 mm) were determined by volume displacement using a large graduated cylinder.

Observation Schedule

Stream sampling events occurred during May, June, August, September, and November 1992 and April, June, August, and October 1993. Two additional sampling events are planned for 1994.

Quality Assurance and Quality Control

The ERL-Duluth uses standard operating QA/QC protocols as outlined in ERL-Duluth (1992 and 1993). Chemical analyses are performed using known standards. A taxonomic library has been established for comparison of macroinvertebrate and fish collections to ensure uniform taxonomic identifications.

Data Format and Processing

All raw, unformatted biological and chemical data are retained on bench sheets by the analysts at the ERL-Duluth. Data is further summarized and transferred onto Lotus spreadsheets in a central computer prior to statistical analyses. The ERL-Duluth and University of Minnesota-Natural Resources Research Institute will eventually transfer the data to ARC-Info files for GIS applications. Data will also be compared to riparian zone data collected by the Kansas Biological Survey throughout 15 cornbelt sites in the United States, including Walnut Creek, and used to create landuse riparian zone diagnostic models.

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5-J.2 Stream Chemistry

W.G. Crumpton and J.L. Owens ISU

Overview

The water quality of Walnut Creek is monitored at several locations in Walnut Creek watershed. Submersible water quality monitors are used to measure stream dissolved oxygen and temperature. Additionally, water samples and sediment cores are collected and used to determine nitrate concentrations and denitrification rates.

Site Locations

In 1991 and 1992, water quality monitors were placed in-stream near stream gaging stations on Walnut Creek located at sites 310, 320, and 330. These sites are described in section 5-F of this report.

In 1993, water quality was monitored at eight sites in Walnut Creek between the bridge on county road R38 and the stream gaging station at site 310 . Figure 1 shows the locations of these sites in Walnut Creek watershed. This section of Walnut Creek represents a portion of the stream without much diversity in stream habitat. Downstream of site 310, the riparian habitat becomes more wooded and less agricultural. Sediment cores were collected from forty sites in Walnut Creek at 100-m intervals between Gauge 310 and County Road R38, except for a stretch immediately upstream of a beaver dam where water was too deep to collect samples (Fig. 1).

Sampling Techniques

The in-stream, water quality monitors were installed at the 1991, 1992, and 1993 stream sampling sites. These battery-operated, submersible systems are placed in the

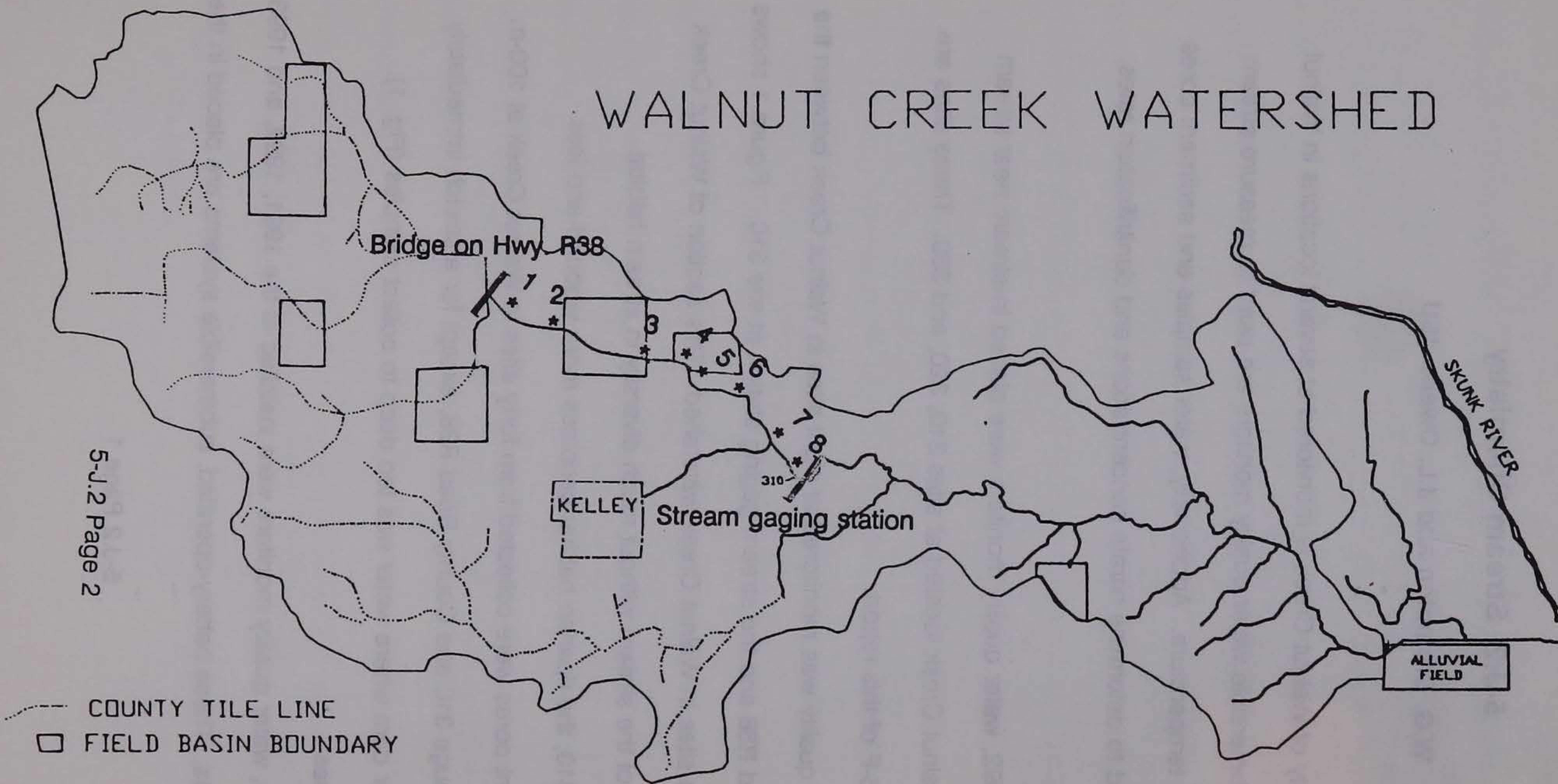

Figure 1. Walnut Creek watershed stream and sediment sampling sites located between the bridge on county road R38 and stream gaging station 310. Stream sampling sites are shown as astericks (*).

center of the deepest part of the stream, near the stream bottom and measure dissolved oxygen and temperature at selected sampling intervals. The electronics are housed in a cylindrical watertight case with removable end caps. Dissolved oxygen and temperature sensors are mounted through the bottom end-cap. Dissolved oxygen is measured using a Clark-style electrode which is insensitive to flow, and temperature data were collected with either a type-K thermocouple or a thermistor. Data are stored in monitor memory and downloaded to a personal computer at a later time.

In 1993, water samples were collected in triplicate at stream sampling sites directly from the stream using 20-ml plastic syringes and transferred to 20-ml plastic vials that contained 0.02 ml of H_2SO_4. Samples were delivered to the Iowa State University Aquatic Ecology wet laboratory where they were analyzed for nitrate-nitrogen using second-derivative spectroscopy (Crumpton et al., 1992). A Perkin Elmer Lambda 3b model UV-visible scanning spectrophotometer with a spectral band-width of 1 nm was used for nitrate-nitrogen determinations. The spectrophotometer is interfaced with a microcomputer used to calculate derivatives from absorbance.

Sediment cores were collected from forty stream sites in 1993. Cores were collected by pushing 15-cm long, 5.5-cm diameter plexiglass tubes, with bevelled bottom edges, into the stream sediment. Rubber stoppers were placed at the bottom of the tubes after they were extracted from the sediment. The cores were delivered to the same laboratory mentioned above, and used for nitrate loss experiments. Cores were put in plexiglass chambers and dosed with stream water that contained 8-10 mg/L nitrate-nitrogen. Samples (2 ml) were collected, using a pipette, from the supernatant in each chamber over a period of several days and were transferred to acidified vials. Samples were then analyzed for nitrate-nitrogen using methods described earlier.

Observation Schedule

In 1991 and 1992 stream monitors were installed in Walnut Creek near each stream gaging station in May and were removed in late October. In June 1993, monitors were installed at stream sampling sites located between stream gaging station 310 and the bridge on county road R38 and they were removed in October. Each monitor was programmed during 1991, 1992, and 1993 sampling periods to record dissolved oxygen and temperature measurements every six minutes. Monitoring units were serviced on a weekly basis by a graduate student and lab technician. Servicing entailed downloading data to a personal computer, collecting reference values, and cleaning and checking sensors for damage. Stream monitors were repaired or replaced if they were not functioning properly.

Stream samples for nitrate-nitrogen analyses were collected, in 1993, from stream sites approximately 3 times per week during the summer and weekly during the fall. Stream sediment samples were collected during one sampling event in November 1993.

In 1994, stream monitors will be installed at the same stream sampling locations used in 1993. Stream and sediment samples will most likely be collected at the same stream sites used in 1993 and will be analyzed for nitrate-nitrogen using the methods described earlier.

Quality Assurance and Quality Control

Temperature

Temperature measurements are made with either a type-K thermocouple or a thermistor that are calibrated prior to being installed at stream monitoring sites using a two point calibration based on one low temperature and one high temperature. Temperature sensors are calibrated only once per year because measurement drift was low. Reference temperature measurements are made manually, one to three times per week, using two mercury thermometers and were recorded to the nearest 0.1° C.

Dissolved Oxygen

Dissolved oxygen probes are calibrated using field reference values. Water samples are collected in triplicate from each monitoring site and assayed for dissolved oxygen using the Winkler method (APHA, AWWA, and WPCF, 1989). Analytical results are averaged and used as field reference values to calibrate the probes.

Nitrate-nitrogen Analyses

Nitrate samples are collected in triplicate and are acidified to stop all biological activity. The spectrometer used for nitrate-nitrogen analysis is calibrated prior to analysis of each sample set using standards prepared by serial dilution.

Data Format and Processing

Data are downloaded from stream monitors using a personal computer and stored in binary files. Data are analyzed using a computer program designed for use with stream monitor data in binary file format. The program uses stream monitor data to estimate productivity and community respiration using diurnal oxygen curve analysis (Owens, 1974). This program also calculates hourly averages of parameters collected and is capable of providing statistical and graphics outputs. Data generated by this program, including graphs, can be output as ASCII files.

Nitrate-nitrogen analytical results from stream samples and nitrate loss experiments using sediment cores are entered into Microsoft Excel files where they are statistically analyzed.

References

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TERRESTRIAL ECOLOGY RESEARCH

Section 5-K Terrestrial Ecology

Bird Censuses and Landscape Features

L.B. Best and T.M. Bergin ISU

K. Freemark U.S. EPA Corvallis, Oregon

Overview

This project was developed to fulfill part of the Midwest Agricultural Surface/Subsurface Transport Effects Research (MASTER) Strategic Research Plan coordinated by the United States Environmental Protection Agency (U.S.EPA), Environmental Research Laboratory (ERL), Corvallis, Oregon to determine the effects of agrichemicals and other farming practices on the terrestrial ecosystem. Specifically, this project fulfills Task 1 of the Strategic Plan, to investigate the importance of landscape structure to terrestrial biota in Walnut Creek watershed and to define a landscape model for evaluating potential benefits from alternative land uses, management practices, and habitat manipulations.

A landscape ecology approach is needed to preserve or enhance the ecological features of agricultural landscapes in the Midwest. This approach is used to understand how changes in the composition and quality of habitat types and their spacial arrangements affect environmental quality, ecological processes, and species composition and abundance (Freemark, 1988; Fry, 1991). Because landscapes are often hierarchically structured, investigation of landscape patterns and processes profit from sampling at different spacial scales (Legendre and Fortin, 1989; Turner and Gardner, 1991). This hierarchical approach provides a broad, theoretical framework for investigating the distribution and abundance of species within agricultural landscapes (Turner and Gardner, 1991; Bergin, 1992).

Site Locations

Bird abundance was characterized in 12 sections (1 census block/section) in Walnut Creek watershed in 1993. Figure 1 shows the locations of census blocks in the watershed and Attachment I is a key to this figure. Watershed boundaries in this figure were generated by Iowa State University's (ISU) Geographical Information System (GIS) (based on Kansas Biological Survey delineations) (Fig. 2). Whereas, boundaries used for maps in other sections of this report were generated by the United States Environmental Protection Agency (U.S.EPA) GIS in Las Vegas, Nevada (Fig. 2).

Table 1. Bird census block locations in Walnut Creek watershed (1993).

Location	ASCS Tract
W 1/2, Sec 25, T83N, R25W, Boone County	3021
SW 1/4, Sec. 30, T83N, R24W, Story County	1968
NE 1/4, Sec. 29, T83N, R24W, Story County	1969
NW 1/4, Sec. 32, T83N, R24W, Story County	9496, 2709
NW 1/4, Sec. 33, T83N, R24W, Story County	9493, 9495
E 1/2, Sec. 34, T83N, R24W, Story County	9114
E 1/2, Sec. 35, T83N, R24W, Story County	2774
E 1/2, Sec. 36, T83N, R24W, Story County	2754, 2384
NW 1/4, Sec. 6, T82N, R24W, Story County	1929
SE 1/4, Sec. 5, T82N, R24W, Story County	2750
NW 1/4, Sec. 4, T82N, R24W, Story County	9055, 1848, 1972
E 1/2, Sec. 1, T82N, R24W, Story County	9461

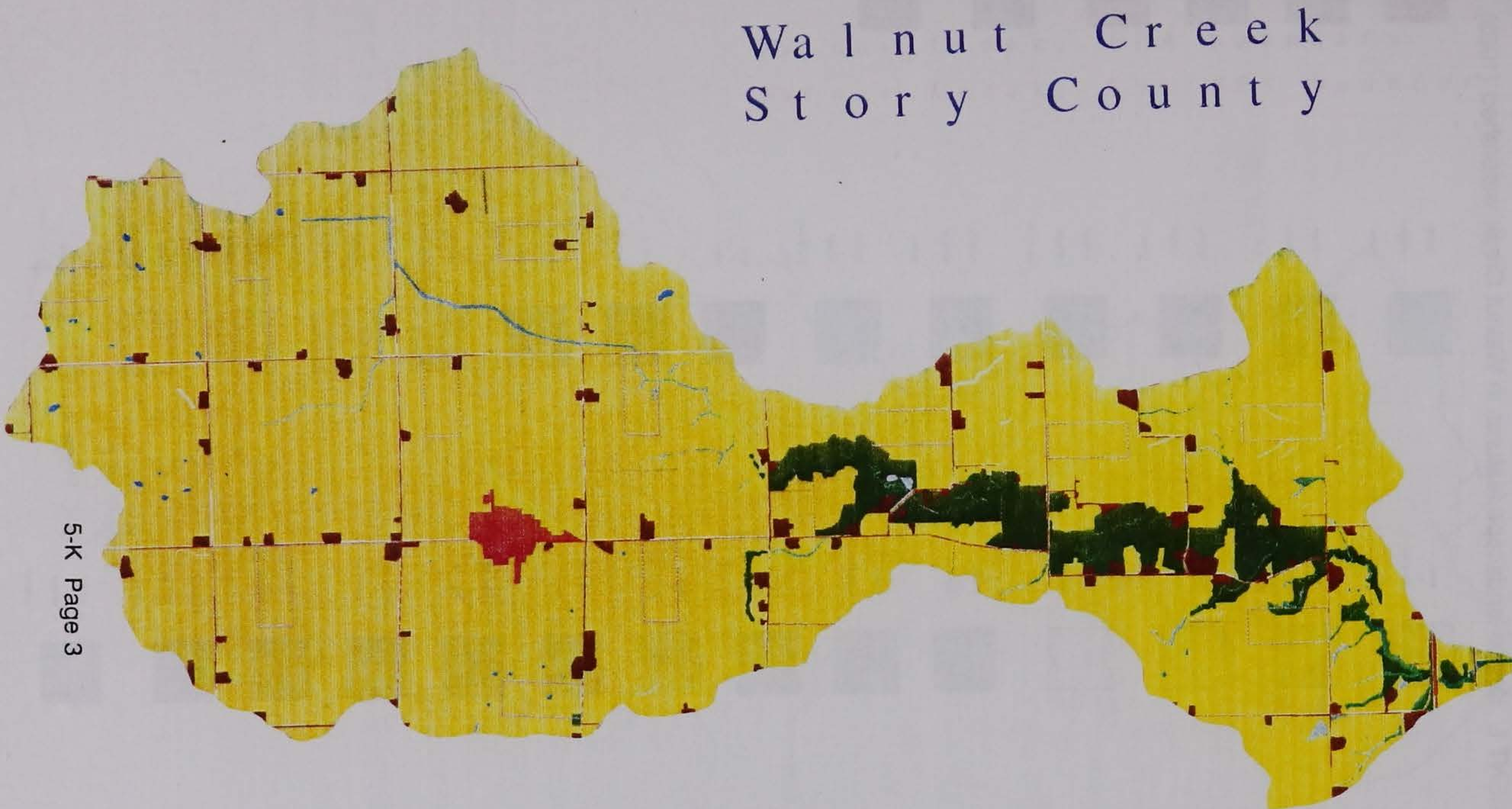

Figure 1. Landscape features and locations of bird census blocks in Walnut Creek watershed (1993). Attachment 1 provides a key to the features on this GIS-produced figure.

ATTACHMENT I. Key to landscape features in Walnut Creek watershed (1993).

- woodland closed
- woodland open
- savannah
- shrubland dense
- shrubland moderate
- shrubland sparce
- row crops
- forage pasture
- farmstead
- pond
- residential industrial
- fencerow dense
- fencerow moderate
- fencerow sparce
- fencerow herb

- grass waterway dense
- grass waterway moderate
- grass waterway sparce
- grass waterway herb
- terrace dense
- terrace moderate
- terrace sparce
- terrace herbaceous
- railroads dense
- railroads moderate
- railroads sparce
- railroads herbaceous
- upland stringer dense
- upland stringer moderate

- upland stringer sparce
- upland stringer herb
- riparian stringer dense
- riparian stringer moderate
- riparian stringer sparce
- riparian stringer herbaceous
- river dense
- river moderate
- river sparce
- river herbaceous
- roadside dense
- roadside moderate
- roadside sparce
- roadside herb

- road paved
- road gravel
- water
- undefi (code 47)
- undefi (code 48)
- (code 0
- 1993 bird survey block

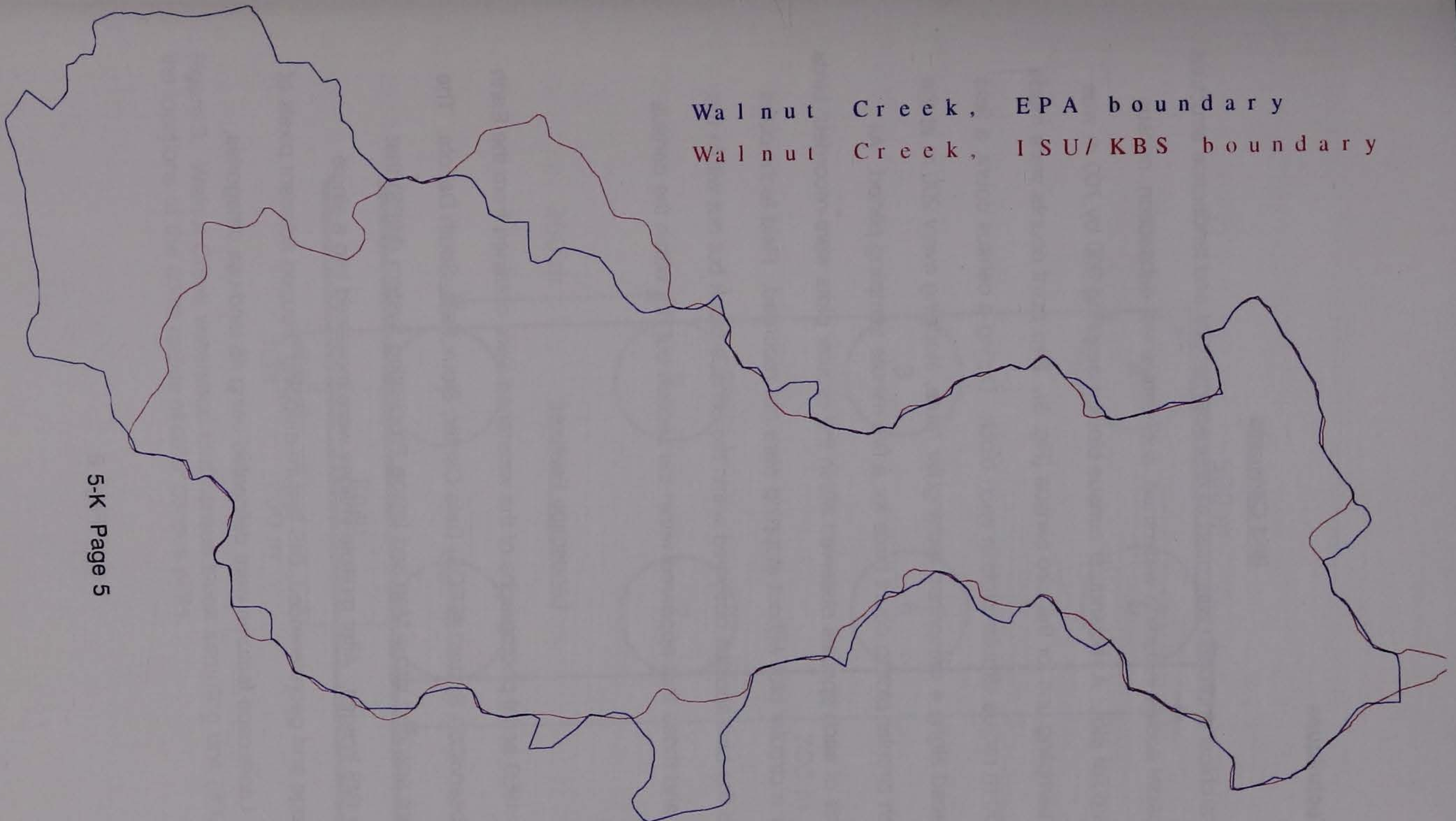

Figure 2. Walnut Creek watershed boundary differences between U.S.EPA and ISU and Kansas Biological Survey GIS-generated maps.

Sampling Techniques

Bird Censuses

A hierarchical approach was used to characterize bird and landscape structure at several spacial scales including watershed, sub-watershed, subsection, census block, and circular plot. A rectangular census block measuring 300 by 700 m was used as the sampling unit for the bird census (Fig. 3). Bird point counts were made within eight 50-m radius circular plots in each block. During a census count, a field technician paced along a prescribed rectangular route, stopping every 200 m at the center of each circular plot to count birds for a five minute sampling period. All individual birds of each species observed within the circular plots were recorded; birds that flew over a circular plot without stopping were not recorded. Field technicians also recorded the bird species observed within the census block but not within the circular plots and those that appeared within the section but not within the census block.

Landscape Features

Spring 1990 aerial photographs of the watershed were obtained from the Earth Resources Observation System (EROS) Data Center, Sioux Falls, South Dakota. The air photos were scanned into a Map and Image Processing System (MIPS) that created raster GIS images. After multiple images were mosaiced into a single watershed image and georeferenced, GIS feature-mapping grouped adjacent pixels of similar value. Landscape features were delineated using 46 land-use categories,

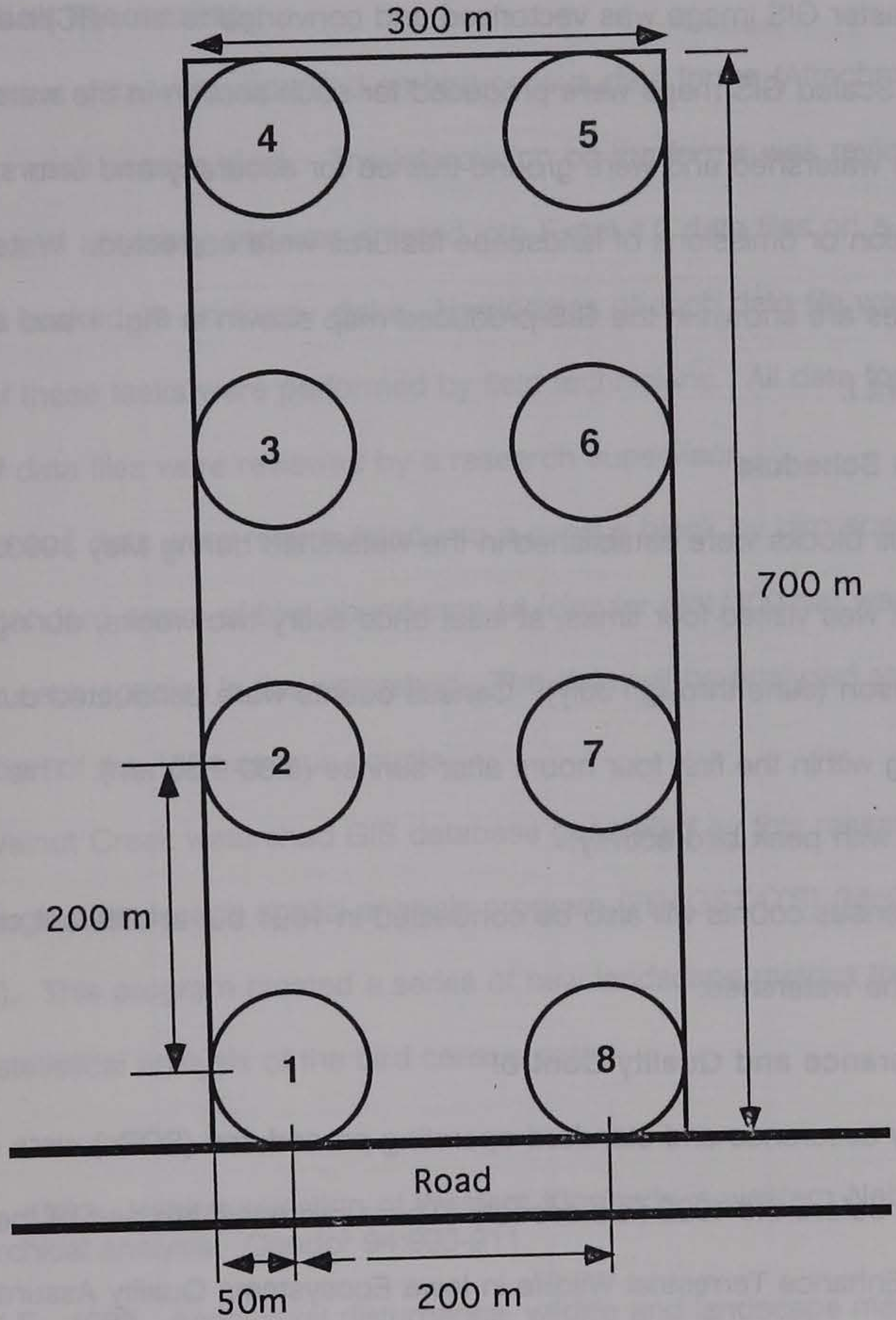

Figure 3. Walnut Creek watershed bird census block sampling unit (300 x 700 m) with the locations of the 50-m radius circular census plots.

including block cover such as woodland, shrubland and rowcrops and strip cover such as roadsides, fencerows, grassed waterways and riparian watercourses.

The raster GIS image was vectorized and converted to an ARC/INFO vector GIS image. Scaled GIS maps were produced for each section in the watershed and for the entire watershed and were ground-truthed for accuracy and errors; misidentification or omissions of landscape features were corrected. Watershed land-use categories are shown in the GIS-produced map shown in Fig. 1 and are defined on Attachment I.

Observation Schedule

Census blocks were established in the watershed during May 1993. Each census block was visited four times, at least once every two weeks, during the peak breeding season (June through July). Census counts were conducted during the early morning within the first four hours after sunrise (5:30-9:30 am). This time span corresponds with peak bird activity.

Bird census counts will also be conducted in 1994 but at different census block locations in the watershed.

Quality Assurance and Quality Control

Quality assurance and standard operating procedures (SOPs) were developed for this study before the 1993 field season. These protocols are part of the Landscape Structure to Enhance Terrestrial Wildlife in Iowa Ecosystems Quality Assurance Project Plan (QAPP) submitted to U.S.EPA in December 1993. The QAPP includes SOPs for

GIS database development, census block location, bird censusing, data entry and verification, and ground-truthing.

Data Format and Processing

Bird census data were recorded on bird census data forms (Attachment II) during visits to each census block. The information on the forms was reviewed for completeness and accuracy and was entered into Excel 4.0 data files on a MacIntosh computer and backed-up on floppy disks. Hardcopies of each data file were also verified. All of these tasks were performed by field technicians. All data forms and hardcopies of data files were reviewed by a research supervisor.

Bird census data were reformulated into a census block by bird species matrix. Means and standard errors of bird abundance (#/circular plot/100 ha) were calculated for each species in the watershed. The data will be analyzed statistically after completion of the 1994 census counts.

The Walnut Creek watershed GIS database generated by this research project was run through a landscape spatial analysis program (FRAGSTATS) (McGarigal and Marks, 1993). This program created a series of new landscape metrics that will be used in the statistical analysis of the bird census data.

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ATTACHMENT II. Bird census data form.

Surveyor:	Reviewed by:
Watershed:	Date:
County:	Time:
Township:	Temperature:
Section:	Wind Speed:
	Precipitation:

Location	Species Names	Species Code	# Observed	Notes

Fry, G.L.A. 1991. Conservation in agricultural ecosystems. pp. 415-433 In: J.F. Spellerberg, F.B. Goldsmith, and M.G. Morris (eds.). The scientific management of temperature communities for conservation. Blackwell Scientific Publ., Oxford, UK.

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Section 5-L Groundwater Monitoring Well Network

R. Buchmiller USGS Iowa City, Iowa

Site Locations

Groundwater monitoring wells were installed by the United States Geological Survey (USGS) at selected locations within the Walnut Creek watershed for the Management System Evaluation Areas (MSEA) initiative and on the flood plain of the South Skunk River for the Midwest Agricultural Surface/Subsurface Transport Effects Research (MASTER) initiative. Thirty-eight well nests with a total of 106 wells were installed in the watershed for the MSEA initiative and six wells including four multi-level wells with a total of 37 sampling ports were installed on the floodplain of the South Skunk River for the MASTER initiative. Well locations are shown in Figure 1 and descriptions are provided in Table 1. Wells are used to monitor groundwater elevations and water quality and to determine aquifer hydraulic characteristics.

Well sites for the MSEA initiative were selected topographically downgradient and upgradient from fields with specific crop and soil management systems. In Iowa the water table in most glacial deposits typically follows the contour of the land surface. Downgradient well sites were located at the edges of fields and should represent groundwater originating from beneath the upgradient management system. Groundwater elevations in upgradient and downgradient wells are used to determine groundwater flow gradient and direction. When topographic gradients were not obvious, well sites were located at the edges of surrounding fields.

Walnut Creek Watershed, IA

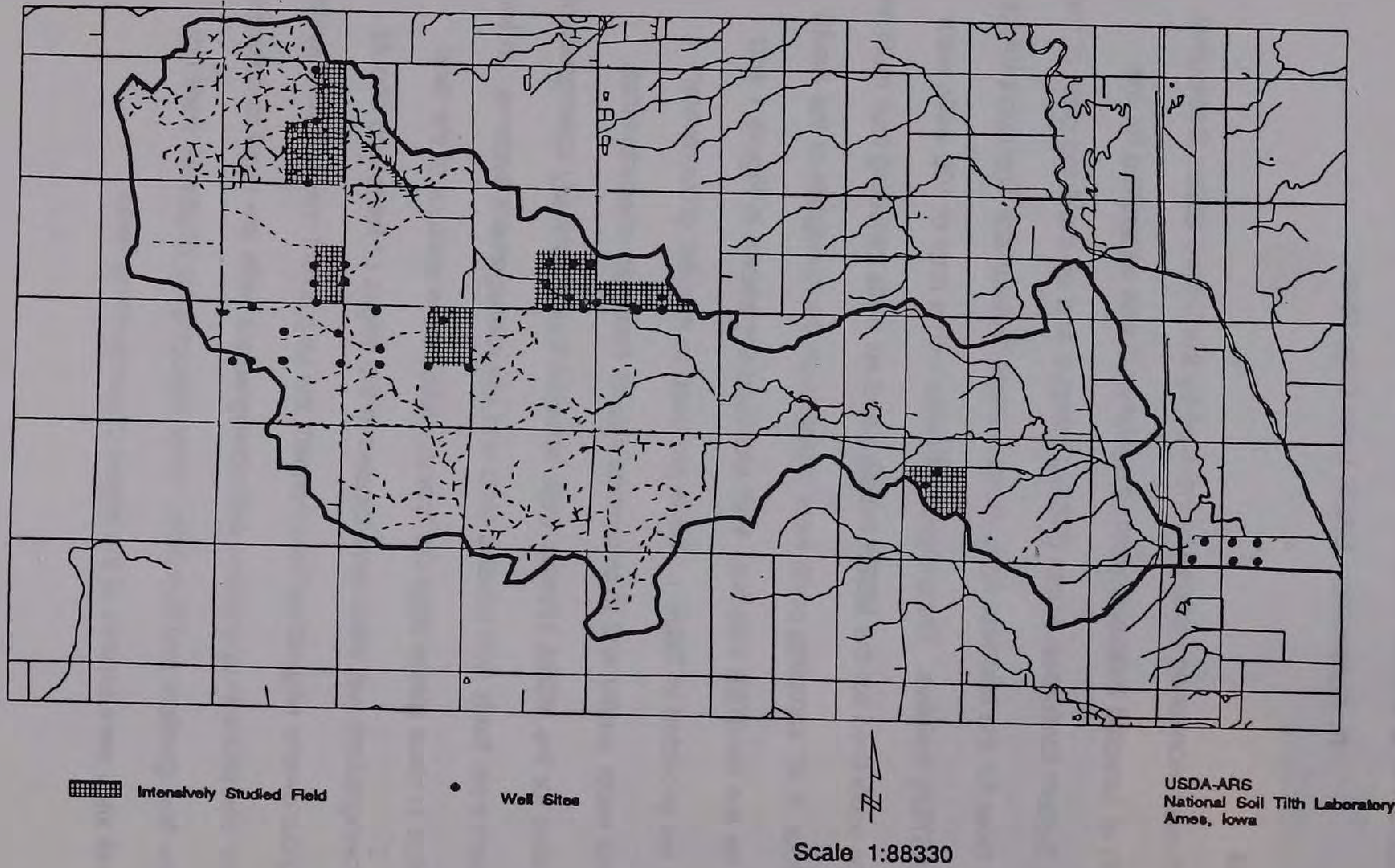


Figure 1. Well locations in Walnut Creek watershed and on the flood plain of the South Skunk River.

Table 1. Groundwater monitoring network well nest numbers and locations in Walnut Creek watershed. (a)

Well Nest #/# Wells per Nest	ASCS Tract	Location
WC-1/3	T8999	SE 1/4, Sec. 28, T83N, R24W, Story Co.
WC-2/5	T8999	SW 1/4, SE 1/4, SW 1/4, Sec. 28, T83N, R24W, Story Co.
WC-3/3	T8999	SE 1/4, SE 1/4, SW 1/4, Sec. 28, T83N, R24W, Story Co.
WC-4/5	T2672	NW 1/4, NW 1/4, Sec. 31, T83N, R24W, Story Co.
WC-5/2	T3010	SW 1/4, SE 1/4, SE 1/4, Sec. 25, T83N, R25W, Boone Co.
WC-6/2	T2802	NE 1/4, NE 1/4, Sec 31, T83N, R24W, Story Co.
WC-7/4	T3010	NE 1/4, SE 1/4, SE 1/4, Sec. 25, T83N, R25W, Boone Co.
WC-8/2	T3012	SE 1/4, NE 1/4, Sec. 36, T83N, R25W, Boone Co.
WC-9/3	T3010	SE 1/4, NE 1/4, SE 1/4, Sec. 25, T83N, R25W, Boone Co.
WC-10/3	T3010	SW 1/4, NE 1/4, SE 1/4, Sec. 25, T83N, R25W, Boone Co.
WC-11/3	T3010	NW 1/4, SE 1/4, SE 1/4, Sec. 25, T83N, R25W, Boone Co.
WC-12/2	T902	NE 1/4, NE 1/4, Sec. 36, T83N, R25W, Boone Co.
WC-13/3	T2802	SE 1/4, NE 1/4, Sec. 31, T83N, R24W, Story Co.
WC-14/3	T2802	SW 1/4, NE 1/4, Sec. 31, T83N, R24W, Story Co.
WC-15/3	T9002	NE 1/4, SE 1/4, SE 1/4, Sec. 29, T83N, R24W, Story Co.
WC-16/2	T4234	SW 1/4, NW 1/4, NW 1/4, Sec. 36, T83N, R25W, Boone Co.
WC-17/4	T9002	SE 1/4, SW 1/4, SE 1/4, Sec. 29, T83N, R24W, Story Co.

Table 1. Continued (b)

Well Nest #/# Wells per Nest	ASCS Tract	Location
WC-18/1	T2802	SW 1/4, SE 1/4, NW 1/4, Sec. 31, T83N, R24W, Story Co.
WC-19/4	T9002	NW 1/4, SE 1/4, SE 1/4, Sec. 29, T83N, R24W, Story Co.
WC-20/2	T4234	SW 1/4, SE 1/4, NW 1/4, Sec. 36, T83N, R25W, Boone Co.
WC-21/2	T4234	SW 1/4, SW 1/4, NW 1/4, Sec. 36, T83N, R25W, Boone Co.
WC-22/2	T4234	NE 1/4, NW 1/4, NW 1/4, Sec. 36, T83N, R25W, Boone Co.
WC-23/2	T3012	SW 1/4, SW 1/4, NE 1/4, Sec. 36, T83N, R25W, Boone Co.
WC-24/2	T3012	NW 1/4, SW 1/4, NE 1/4, Sec. 36, T83N, R25W, Boone Co.
WC-25/1	T2802	NW 1/4, SE 1/4, NW 1/4, Sec. 31, T83N, R24W, Story Co.
WC-26/3	T8999	NE 1/4, SE 1/4, SW 1/4, Sec. 28, T83N, R24W, Story Co.
WC-27/3	T2012	NE 1/4, SW 1/4, NE 1/4, Sec. 2, T82N, R24W, Story Co.
WC-28/3	T2012	SE 1/4, SW 1/4, NE 1/4, Sec. 2, T82N, R24W, Story Co.
WC-29/3	T9002	NW 1/4, NW 1/4, SE 1/4, Sec. 29, T83N, R24W, Story Co.
WC-30/3	T9002	NW 1/4, NE 1/4, SE 1/4, Sec. 29, T83N, R24W, Story Co.
WC-31/2	T9002	NE 1/4, NE 1/4, SE 1/4, Sec. 29, T83N, R24W, Story Co.
WC-32/3	T9002	NW 1/4, SW 1/4, SE 1/4, Sec. 29, T83N, R24W, Story Co.
WC-33/2	T9002	SE 1/4, SW 1/4, SE 1/4, Sec. 29, T83N, R24W, Story Co.

Table 1. Continued (c)

Well Nest #/# Wells per Nest	ASCS Tract	Location
WC-34/3	T9002	SW 1/4, SW 1/4, SE 1/4, Sec. 29, T83N, R24W, Story Co.
WC-35/3	T9002	SE 1/4, SW 1/4, SE 1/4, Sec. 29, T83N, R24W, Story Co.
WC-36/3	T3016	SE 1/4, Sec. 24, T83N, R25W, Boone Co.
WC-37/3	T3016	SE 1/4, NE 1/4, Sec. 24, T83N, R25W, Boone Co.
WC-38/3	T3016	NE 1/4, NE 1/4, Sec. 24, T83N, R25W, Boone Co.
SR-1/7	T2449	SE 1/4, SW 1/4, SE 1/4, Sec. 6, T82N, R23W, Story Co.
SR-2/8	T2449	SE 1/4, SW 1/4, SE 1/4, Sec. 6, T82N, R23W, Story Co.
SR-3/2	T2449	SE 1/4, SE 1/4, SE 1/4, Sec. 6, T82N, R23W, Story Co.
SR-4/2	T2449	NE 1/4, SE 1/4, SE 1/4, Sec. 6, T82N, R23W, Story Co.
SR-5/10	T2449	SW 1/4, SE 1/4, SW 1/4, Sec. 5, T83N, R25W, Boone Co.
SR-6/8	T2449	NW 1/4, SE 1/4, SW 1/4, Sec. 5, T83N, R25W, Boone Co.

Wells were also installed in a small sub-basin of Walnut Creek watershed at the edges of fields on an approximate 0.25-mile grid spacing in the sub-basin. The grid arrangement of wells provides a more detailed view of the water table and groundwater movement within a small drainage area in the watershed. Water-level data from this area will be used to create potentiometric contour maps of the water table throughout the sub-basin.

Wells installed in the watershed were nested; each nest consisted of two or more wells, one per borehole. Wells in each nest were installed at different depths in close proximity, approximately 6 feet from each other.

Glacial till deposits in the Walnut Creek watershed can be divided into oxidized and unoxidized till. Oxidized till is tan to brown and is typically mottled indicating fracturing or preferential water movement in these sediments. Unoxidized till is dark gray with little to no evidence of mottling. Both till units contain sand lenses of various sizes, however there are indications of a zone of sandy material that is present at many of the well site locations at a depth of between 1.5 and 3.0 m below land surface. Well depths were based on depth to the interface between oxidized and unoxidized till. One well of each nest at a field management system site in the watershed was completed several feet into the gray unoxidized till. Other nested wells were completed at discrete depth intervals above the oxidized-unoxidized interface. Well nests installed in the small sub-basin in the watershed generally consist of two wells per nest; one well being in the upper part of the unoxidized till and one well being in the more permeable part of the oxidized layer.

Well sites on the South Skunk River alluvium were selected so that they would provide information on the three-dimensional movement of groundwater near the point where Walnut Creek enters the floodplain of South Skunk River. Six wells were installed to assess groundwater flow direction in the alluvial aquifer near Walnut Creek.

Well Installation Techniques

Wells in Walnut Creek watershed were drilled using solid-stem, continuous-flight augers. These augers created a 9.0-cm diameter borehole which typically stood open after removal of the augers due to the cohesive nature of till materials. A string of 5-cm diameter, Schedule 40, flush-threaded polyvinyl chloride (PVC) well casing consisting of a 0.76-m long, slotted well screen and attached riser pipe was lowered into the borehole. The screened interval was packed with washed and sorted sand appropriate to the 0.05-cm slot size of the well screen. Sand pack extended to about 30-cm above the well screen. The remainder of the borehole was backfilled with bentonite pellets to prevent vertical movement of water within the borehole and to prevent infiltration of surface runoff.

Wells on South Skunk River floodplain were drilled using 10-cm hollow-stem augers. Polyethylene tubing (1-cm diameter) was attached at several depths to the outside of well casings installed in four of the boreholes. The bottom 10 cm of the tubing was slotted and screened with fiberglass fabric. The tubes provide multiple sampling ports at discrete depth intervals at each well site. Well casing (materials similar to Walnut Creek watershed well casing) was installed inside auger flights after the target depth for each well had been reached and then the augers were removed. This allowed the sand and gravel to collapse around the well casing and form a natural sand pack. The top 5 feet of these boreholes were backfilled with bentonite pellets to prevent infiltration of surface runoff to the aquifer.

Sampling Techniques

Depth to groundwater in monitoring wells in the watershed and South Skunk River floodplain are measured with an electronic water-level sensor. Depths are measured prior to sampling and the sensor is rinsed with distilled water between monitoring wells.

Prior to sampling, monitoring wells in the watershed are bailed dry with a stainless-steel bailer; this purges the well and sand pack of stagnant water. The water level in the well is allowed to recover for one day and is sampled using a stainless-steel bailer. Samples are stored in 1-liter amber glass bottles that prior to sampling are baked in an oven at 350°C to remove organic contaminants. Samples are maintained at 4°C until analyzed at the National Soil Tilth Laboratory (NSTL) Soil Analysis Laboratory. Sampling equipment is rinsed with distilled water between monitoring wells.

A minimum of three well volumes of water are bailed out of each well in the Skunk River floodplain prior to sampling to purge the well of stagnant water. Water is then pumped out of each well with a peristaltic pump until pH, temperature, and specific conductance stabilize. Electrodes connected to digital meters are used to monitor the three parameters. Samples are collected from the pump discharge and stored in 1-liter amber glass bottles that have been decontaminated using procedures described above. Samples are maintained at 4°C until analyzed at the NSTL. Sampling equipment is rinsed with distilled water between monitoring wells.

Groundwater samples collected from the Walnut Creek watershed and South Skunk River floodplain are analyzed for atrazine, alachlor, metolachlor, metribuzin, and nitrates using methods that are referenced in Section 5-S of this report.

Observation Schedule for Groundwater Monitoring

Groundwater samples were collected by NSTL staff once per month from May 1991 to March 1993 from monitoring wells in Walnut Creek watershed wells at specific management system field sites. The sampling schedule was changed after March 1993 to twice yearly, once before planting and once after harvest. Wells installed on the South Skunk River floodplain were sampled by USGS staff approximately once every six weeks from June 1992 to August 1993. Water levels are measured by NSTL staff twice per month in the wells installed on the Walnut Creek watershed and monthly for the wells on the South Skunk River floodplain.

Data Format and Processing

Well installation reports (Attachment I) and site, file description forms (Attachment II) have been completed for some of the monitoring wells. Depth to groundwater data are entered into the USGS Ground-Water Site Inventory (GWSI) database and at the NSTL the data are entered into a SAS database. Descriptive logs of materials penetrated during drilling have been completed by USGS staff for each well (Attachment III). The information on these logs is not in a database. Groundwater monitoring well water quality data are currently stored in ASCII files at the NSTL and must be screened and prepared for import into a GIS.

Quality Assurance and Quality Control

During each groundwater sampling event a duplicate sample is collected randomly from one of the wells once per day.

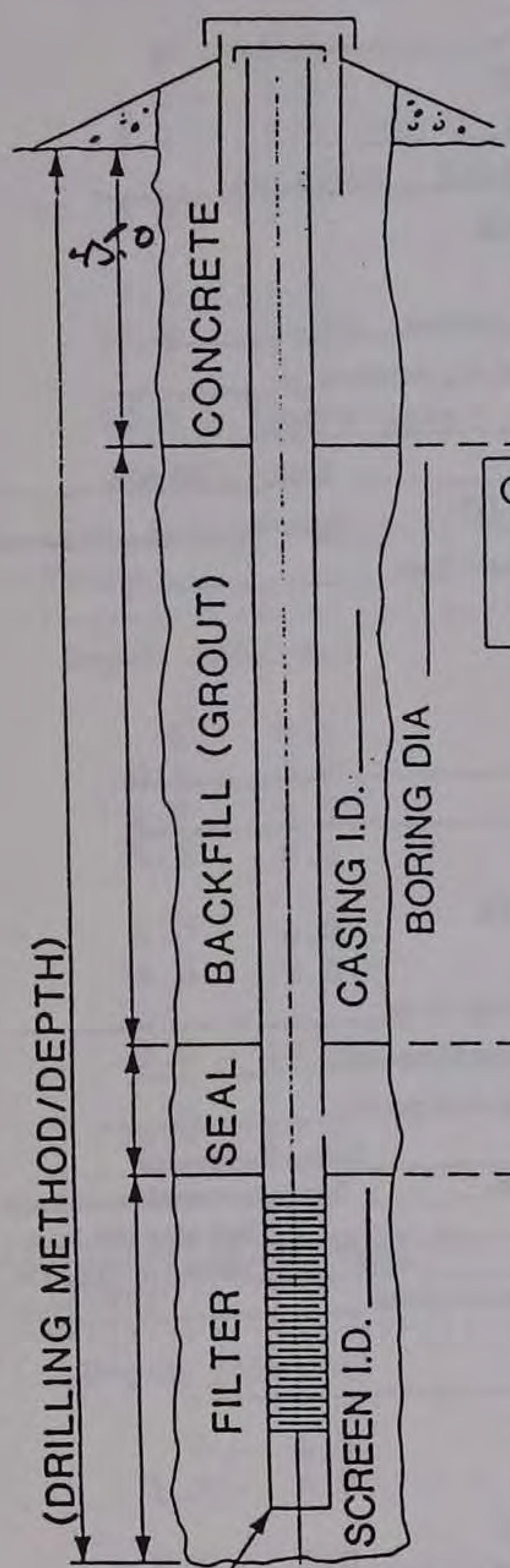
A well sampling quality check sheet (Attachment IV) is completed during each sampling event and documents the working conditions of the water level indicator, conductivity, pH, and temperature meter and bailer. Sampling equipment is thoroughly cleaned with distilled water after each sampling event.

Note:

Groundwater monitoring wells have also been installed in the watershed by Sally Logsdon and Dan Jaynes at the NSTL and Bill Simpkins, Geology and Atmospheric Sciences Dept., ISU. Please refer to sections 5-N.1, 5-M.1, and 5-M.2 for information on these wells.

ATTACHMENT I

WELL INSTALLATION REPORT
(SATURATED ZONE MONITORING WELL)



PROJECT Mesa
WELL NO. WC-4-46
DATE WELL STARTED 11-18-92
DATE WELL COMPLETED 11-18-92
CASING TOP ELEVATION ____
SURFACE ELEVATION ____
CONCRETE MIX ____
QUANTITY INSTALLED ____
CASING VENTED ? ____
WELL ENCLOSURE LOCKED ? ____

CASING LENGTH : TOP OF CASING TO TOP OF SCREEN 45.0
CASING INSIDE DIA. 2.0
CASING MATERIAL PVC

BACKFILL (GROUT) DESCRIPTION cutting mixed w benseal 41 to 5

MIX RATIOS (BY WEIGHT) ____

INSTALLATION METHOD ____

QUANTITY INSTALLED ____

SEAL DESCRIPTION holeplug 44 to 41
INSTALLATION METHOD ____
QUANTITY INSTALLED ____

FILTER DESCRIPTION # 2 well pack 47.5 - # 1 well pack 41.5 ...

INSTALLATION METHOD ____

QUANTITY INSTALLED ____

SCREEN LENGTH 2.5
SCREEN DESCRIPTION AND MATERIAL PVC
SCREEN OPENING .020

DENSE PHASE CUP ____ LENGTH ____
WELL NO. ____ REPORT BY ____
FIELD PROJECT MGR. ____ DATE

SITEFILE DESCRIPTION FORM

STATION NO. (8 or 15 digit) 415752093413105
Site established by PBL Data Reliability: (C) L M U
Date established 3-8-93 Project Number 06700
Site Name 083N24W31BABB 1992USGS WC-4-46

GENERAL SITE DATA

District Code 19 State Code 19 FIPS County Code 169 County Name Story
Latitude Longitude 41° 57' 52" 093° 41' 31" Lat-Long Accuracy S
Land-Net NW 1/4 NW 1/4 NE 1/4 NW Sec. 31 T 083N R 24W
Location Map Slater 7½' Scale 1:24,000
Elevation 1,042 Method of Measurement: A L (M) Accuracy ± 5
Hydrologic Unit Code 07080105 Drainage Basin Code ______
Topographic Setting: A B C D E (F) G H K L M O P S T U V W
Agency Use: (A) I O Station Type: GW/well
Data Type: GWL/QW Interm. (A) I O
Instruments at Site: ______
Remarks ______

SURFACE-WATER SITES

Base Discharge
Drainage Area ______ Contributing Drainage Area ______
Crest-Stage Gage: Upstream Elevation ______ Downstream Elevation ______
Gage Height at Zero Flow ______ *Punches per day ______
Location: ______ National Forest, ______ Indian Reservation, ______ National Park. Tributary to ______. At ______ feet (upstream/downstream) from (bridge/culvert) on (U.S./State/County) Highway ______. ______ feet upstream from mouth, ______ feet (upstream/downstream) from tributary. ______ miles ______ (direction: NE, NW, etc.) from ______ (town) and ______ miles ______ (direction) from ______ (other pertinent landmarks).
Location with respect to established gaging stations: ______
If a spring, does it flow directly into a stream?

GROUND-WATER SITES

Site type: C D E H I M O P T (W) X Use of Site: A C D E G H M (O) P R S T U W X Z
Date of Construction: 11-18-92 Primary Aquifer: 112PLSC Aquifer Type: (U) N C M X
Hole Depth: 47.5 Well Depth: 47.5 Casing Interval: 2" PVC cased 0-45'; 2" slotted PVC 45 to 47.5
Name of Contractor: USGS

Well Identification: WC-1-14
County: Story
Date: 2/25/91
Location: T83NR24W Sec 28 SW1/4

Depth Interval	Description
0 - 1.0	Topsoil, black, organic, frozen
1.0 - 3.0	Topsoil, black, clayey, cohesive
3.0 - 7.0	Clay, medium brown, oxidized, sandy, cohesive
7.0 - 7.5	Clay, brown to gray, very sandy, mottled appears fractured, water saturated
7.5 - 10.5	Clay, as above, less sand, very cohesive
10.5 - 12.5	Clay, medium to dark gray, sandy, pebbles, unoxidized, very cohesive
12.5 - 15.0	Clay, as above.

Well Identification: WC-2-21
County: Story
Date: 2/26/91
Location: T83NR24W Sec 28 SW1/4

Depth Interval	Description
0 - 0.5	Topsoil, black, organic, frozen
0.5 - 2.0	Topsoil, black, organic
2.0 - 5.5	Soil, medium brown, clayey, cohesive
5.5 - 6.0	Clay, mottled brown-gray, very sandy, pebbles
6.0 - 8.0	Clay, bluish-gray, wet
8.0 - 9.0	Clay, blue-gray, pebbles, appears dry, very stiff
9.0 - 18.0	Clay, blue-gray grading to dark gray with depth, pebbles, stiff, cohesive
18.0 - 22.0	Clay, dark gray, stiff cohesive

Well Identification: WC-3-11
County: Story
Date: 2/26/91
Location: T83NR24W Sec 28 SW1/4

Depth Interval	Description
0 - 1.5	Topsoil, black, organic
1.5 - 6.0	Sand, medium brown, clayey, cohesive, oxidized
6.0 - 7.0	Clay, medium brown to gray, mottled, sandy, pebbles, cohesive, oxidized
7.0 - 12.5	Clay, medium gray, dense, slightly sandy, some pebbles, cohesive

Iowa MSEA Project
WELL SAMPLING
Quality Check

Date	Initials	Time	Electronic Tape		YSI			Bailer	Comments
			Battery	Clean	Cond	pH	Temp		

GROUNDWATER RESEARCH

Section 5-M Groundwater Studies

Section 5-M.1 Groundwater Characterization

W. Simpkins ISU

Overview

Groundwater studies in Walnut Creek watershed that are being conducted by the Department of Geological and Atmospheric Sciences at Iowa State University (ISU) are focused in five major areas of research:

I. Characterization of the geology and hydrogeology of the basin and region;

II. Determination of the hydrogeochemistry and redox constraints in till aquitards and aquifers;

III. Determination of the age of groundwater in till aquitards and bedrock aquifers;

IV. Determination of the origin and distribution of methane in groundwater and its relationship to nitrate concentrations in groundwater;

V. Determination of the magnitude and quality of groundwater discharge to Walnut Creek and the influence of the creek on groundwater flow.

I. GEOLOGICAL AND HYDROGEOLOGICAL SETTING OF CENTRAL IOWA AND THE WALNUT CREEK WATERSHED (Simpkins)

Overview

The Paleozoic and Pleistocene geology of central Iowa was examined in order to determine the spatial relationships between aquifers and confining units that underlie Walnut Creek watershed. Attachment I provides detailed information on this subject that was compiled from continuous cores collected during stratigraphic drilling in the watershed; well logs for private wells in the watershed; discussions with well drillers; and bedrock, surficial deposits, and landforms maps, diagrams of central Iowa.

Site Locations and Sampling Techniques

During the period of January 29th through February 3, 1993, continuous cores of the glacial sediments at Bassett's conventional-till "pothole" field and at Black's conventional-till (east) field within Walnut Creek watershed were collected for the purpose of refining the glacial stratigraphy at those sites (Figure 1). Drilling methodologies are provided in Simpkins et al. (1993). Cores were described in detail and portions of each were analyzed for organic carbon, water content, nitrate-nitrogen (NO_3-N) and ammonium-nitrogen (NH_4-N). Water content, NO_3-N, and NH_4-N analyses were performed at the National Soil Tilth Laboratory (NSTL) Soil Analysis Laboratory (refer to Section 5-S of this report). Samples were analyzed for organic carbon using a Carlo-Erba dry combustion analyzer (model NS1500, Cambardella Laboratory).

Maps and diagrams that are included in Attac. ıment I were extracted from various unpublished sources. Figures 1 and 2 in Attachment I were prepared by a researcher using AUTOCAD v.12.

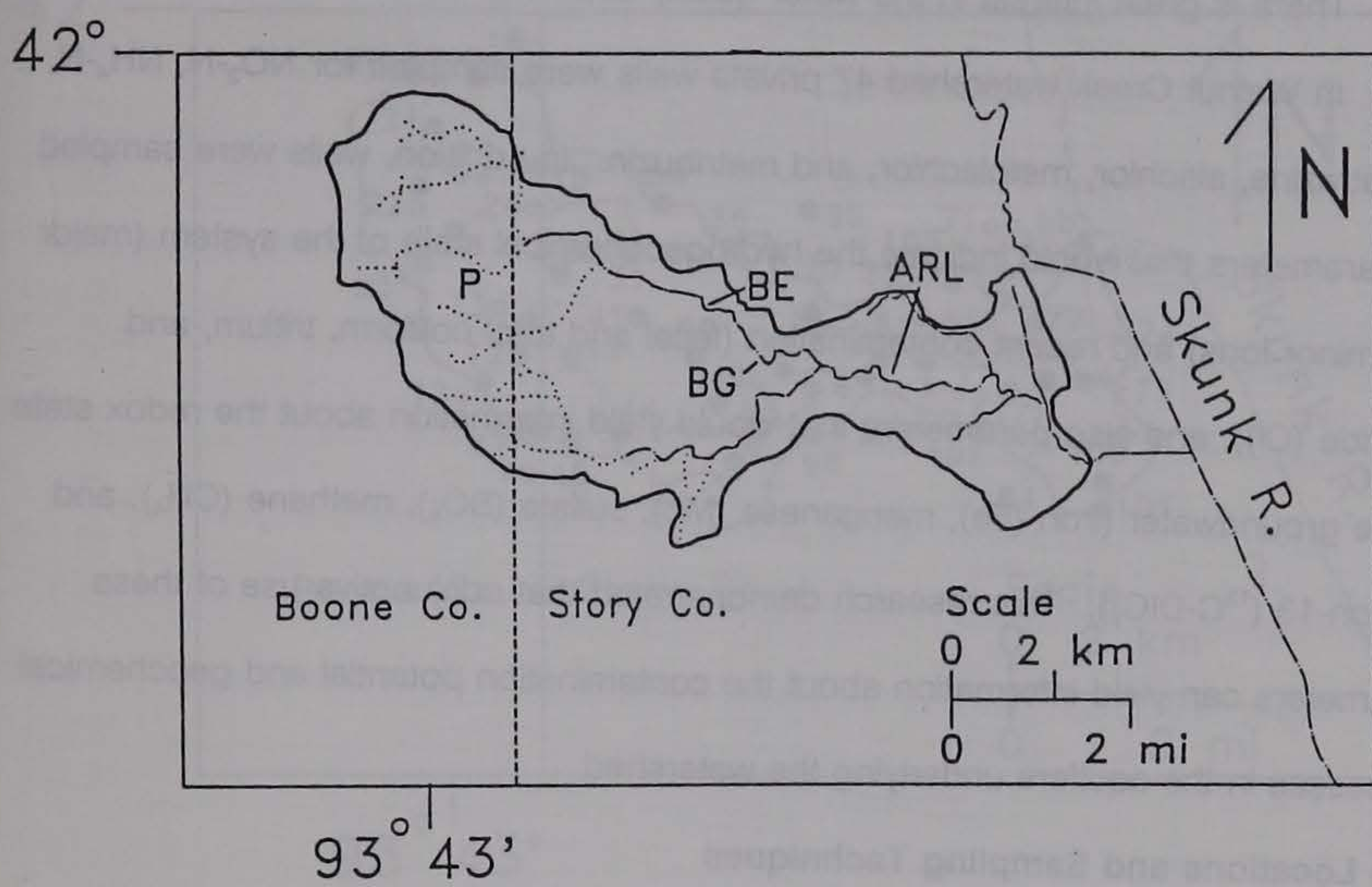


Figure 1. Locations of stratographic drilling sites in Walnut Creek watershed; P = "pothole field" and BE = Black's conventional-till (east) field. Black's gaging station (BG) and the Animal Resources Laboratory (ARL) are the locations of piezometer transects.

II. HYDROGEOCHEMISTRY AND WATER QUALITY IN PRIVATE WELLS WITHIN THE WALNUT CREEK WATERSHED (Simpkins)

Overview

There is great interest in the water quality of private wells in agricultural areas of Iowa. In Walnut Creek watershed 47 private wells were sampled for NO_3-N, NH_4-N, and atrazine, alachlor, metolachlor, and metribuzin. In addition, wells were sampled for parameters that would indicate the hydrogeochemical state of the system (major and minor ions) and recent contamination (fecal and total coliform, tritium, and chloride (Cl)), and also parameters that would yield information about the redox state of the groundwater (iron (Fe), manganese (Mn), sulfate (SO_4), methane (CH_4), and carbon-13 (δ^{13}C-DIC)). This research demonstrated that conjunctive use of these parameters can yield information about the contamination potential and geochemical processes in the aquifers underlying the watershed.

Site Locations and Sampling Techniques

In the watershed, 47 private wells were selected for intensive groundwater monitoring. Well construction reports were obtained for many of these wells. Well locations are shown in Figure 2. Well identification numbers are provided in Table 1 along with the geologic formation that the well is terminated in and well depth. Questionnaires were distributed to landowners in 1992 to determine well construction, production interval, and ambient water levels. Groundwater was sampled after temperature and specific conductance had stabilized and after the water supply pressure tank had been drained. Conductance was measured using a YSI

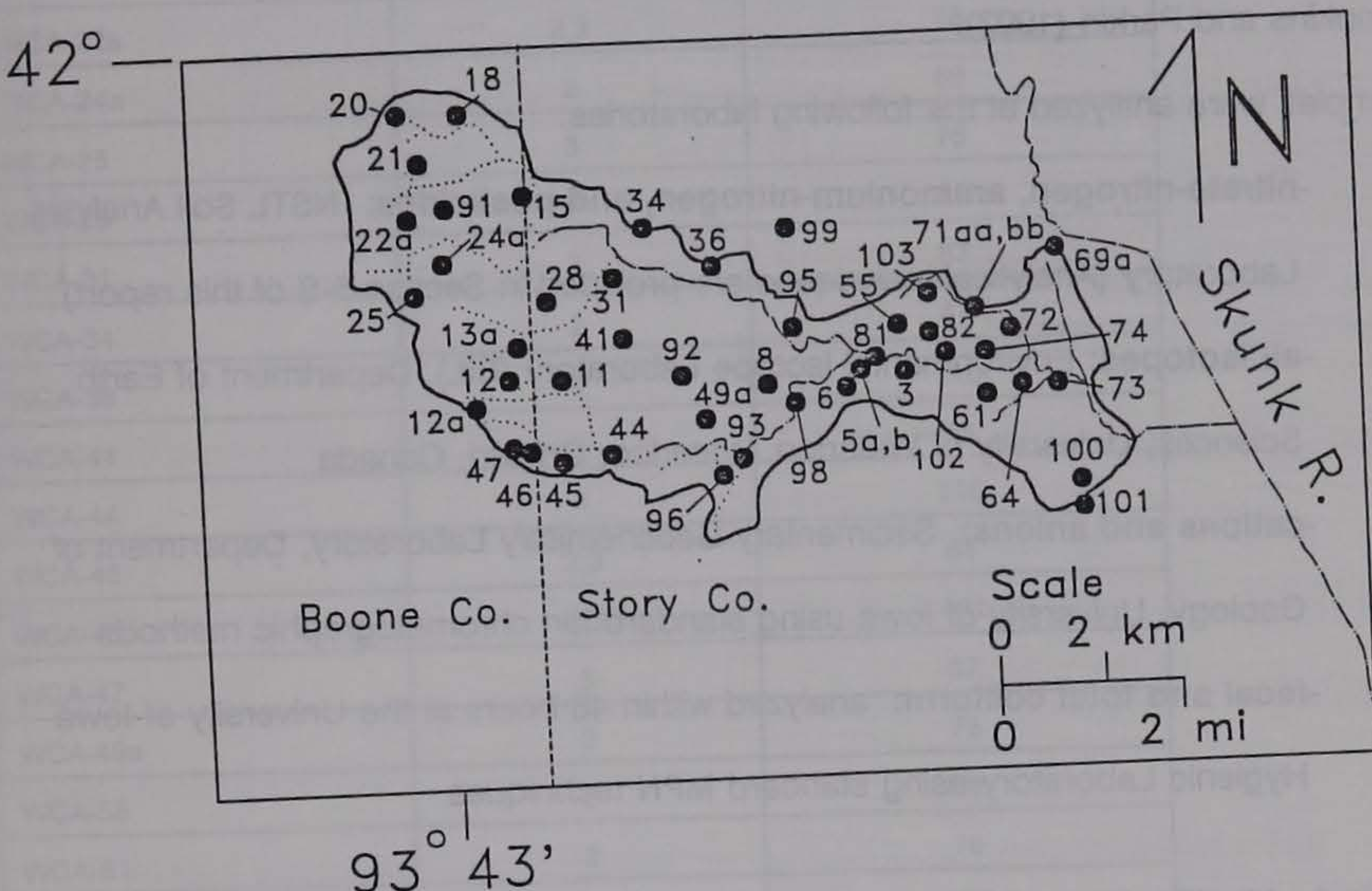


Figure 2. Locations of private wells sampled for water quality in Walnut Creek watershed.

temperature compensating probe that was lowered down into the well. A Fisher VU meter was used for measuring the pH of in-situ groundwater samples. Specific groundwater sampling techniques and analytical methodologies are described in Simpkins and Parkin (1993).

Samples were analyzed at the following laboratories:

- **nitrate-nitrogen, ammonium-nitrogen, and pesticides:** NSTL Soil Analysis Laboratory (Analytical techniques are provided in Section 5-S of this report)
- **all isotopes:** Environmental Isotope Laboratory (EIL), Department of Earth Sciences, University of Waterloo, Waterloo, Ontario, Canada
- **cations and anions:** Sedimentary Geochemistry Laboratory, Department of Geology, University of Iowa using standard ion chromatographic methods
- **fecal and total coliform:** analyzed within 48 hours at the University of Iowa Hygienic Laboratory using standard MPN techniques

Table 1. Identification numbers, geologic units and depths for private wells sampled in Walnut Creek watershed.

Well Number	Geologic Unit	Well Depth (m)
WCA-3	4	110
WCA-5a	1	31
WCA-5b	1	40
WCA-6	2	55
WCA-8	1	31
WCA-11	1	38
WCA-12	2	73
WCA-12a	2	49
WCA-13	2	65

WCA-15	2,3	~64
WCA-18	2,3	64
WCA-20	4	79
WCA-21	4	79
WCA-22a	2,3	78
WCA-24a	2	69
WCA-25	3	76
WCA-28	2	68
WCA-31	2	67
WCA-34	2	67
WCA-36	4	110
WCA-41	2	58
WCA-44	4	116
WCA-45	2,3	61
WCA-46	2,3	~61
WCA-47	3	87
WCA-49a	3	73
WCA-55	2	58
WCA-61	2	76
WCA-64	3	~76
WCA-69a	4	85
WCA-71a	2,3	70
WCA-71ab	4	90
WCA-72	3	87
WCA-73	4	79
WCA-74	2	51
WCA-81	2	41
WCA-82	4	127
WCA-91	2	67
WCA-92	2	66
WCA-93	2	67

WCA-95	1	50
WCA-98	2,3	87
WCA-99	4	135
WCA-100	3	78
WCA-101	4	92
WCA-102	2,3	69
WCA-103	1	34

Geologic Units:
1 = upper Pre-Illinoian sand and gravel
2 = lower Pre-Illinoian gravel
3 = Pennsylvanian/Mississippian sandstone
4 = Mississippian limestone

Observation Schedule

Samples for all constituents were collected in the summer and fall of 1992. Samples for NO_3-N, NH_4-N, CH_4 and pesticides were sampled again in June and July of 1993. No further sampling is warranted at this time.

III. AGE OF GROUNDWATER IN AQUIFERS AND CONFINING UNITS IN CENTRAL IOWA (Simpkins)

Overview

Determining the age of groundwater is important in order to understand why contaminants are detected in some samples and not in others. In this study tritium (^3H) and carbon 14 (^{14}C) (dissolved inorganic carbon) were examined as the primary indicators of groundwater age. Deuterium (δD) and $\delta^{18}O$ were used to estimate the temperature of the water when it entered the system. They can be used as proxy climate indicators.

Site Locations and Sampling Techniques

Groundwater samples for ^{3}H, ^{14}C, δD, and $\delta^{18}O$ analyses were collected from the following private wells in the watershed: WCA-3, WCA-36, WCA-44, WCA-72, WCA-81, WCA-82, WCA-91, WCA-92, WCA-93, WCA-95, WCA-99, WCA-100, WCA-102, and WCA-103. Well locations are shown in Figure 1 and well geologic units and depths are provided in Table 1.

Groundwater samples were collected for ^{3}H, ^{14}C, δD, and $\delta^{18}O$ using methods described in Simpkins and Parkin (1993) and Qui (1993). The parameters ^{3}H, δD, and $\delta^{18}O$ were analyzed at the Environmental Isotope Lab at the University of Waterloo and ^{14}C-DIC was analyzed on a Tandem Accelerator Mass Spectrometer (TAMS) at IsoTrace Laboratories at the University of Toronto and at Beta Analytic, Inc. in Coral Gables, Florida.

Observation Schedule

Most of these samples were collected during the summer and fall of 1992. Samples from WCA-102 and WCA-103 were collected in July 1993.

IV. ORIGIN AND DISTRIBUTION OF METHANE AND ITS RELATIONSHIP TO NITRATE CONCENTRATIONS IN GROUNDWATER (Simpkins, Parkin)

Note: Major portions of this section were extracted from a manuscript prepared by Parkin and Simpkins and submitted to the Journal of Environmental Quality on April 26, 1994.

Overview

Studies at the Ames Till Hydrology Site (located northwest of Walnut Creek watershed) have shown the presence of CH_4 in groundwater at high concentrations (Simpkins and Parkin, 1993). Low redox conditions that are favorable for CH_4 production are also not favorable for the persistence of nitrate. The purpose of this study is to determine whether CH_4 is being produced today in the late Wisconsinan till and loess and also to determine the fate of NO_3-N, specifically denitrification, under low redox conditions.

Site Locations and Sampling Techniques

Piezometers at the Ames Till Hydrology site (located northwest of the watershed), Walnut Creek watershed transect piezometers, and USGS-installed piezometers are sampled for CH_4 and nitrous oxide (N_2O) using methods detailed in Simpkins and Parkin (1993). Figure 3 shows the locations of the Ames Till Hydrology and USGS-installed piezometer sites. The Ames Till Hydrology site piezometers were sampled on an irregular basis from 1991-93 and the USGS-installed piezometers were sampled only once in August 1992. Walnut Creek transect piezometers were sampled in March-April 1994 and will be sampled monthly during the growing season. In addition, continuous cores were obtained, with the help of the United States Environmental Protection Agency (U.S. EPA), in June 1993 from the Ames Till Hydrology Site and from the Walnut Creek watershed piezometer transects in the summer and fall of 1993. The cores were wrapped in cellophane and aluminum foil in the field and were subsampled under anaerobic conditions at the NSTL. Laboratory

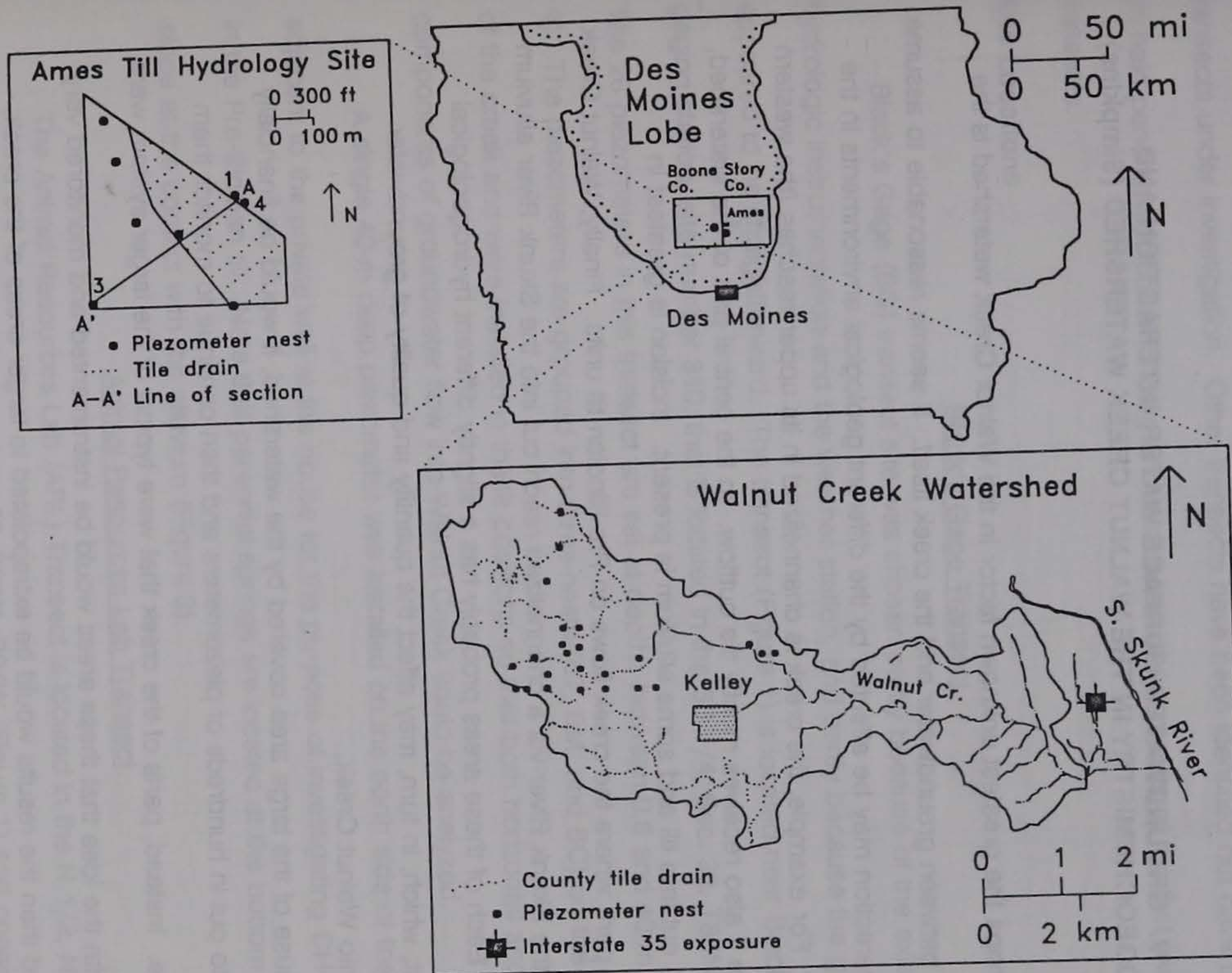


Figure 3. Locations of Ames Till Hydrology and USGS-installed piezometer study sites.

procedures for estimating CH_4 production rates and denitrification potential are detailed in Parkin and Simpkins (in review at the J. of Env. Qual.).

V. GROUNDWATER/SURFACE WATER INTERACTION AND HYDROGEOCHEMISTRY IN THE WALNUT CREEK WATERSHED (Simpkins)

Overview

Perhaps the greatest unknown factor in the Walnut Creek watershed is the interaction between groundwater and the creek itself. It seems reasonable to assume that this interaction may be affected by the different geological environments in the watershed. For example, the creek is channelized in its upper reaches (the western part), where it also receives mostly tile outflow. In the central part of the watershed, the creek is cut into till and some alluvium is present. Incision is greatest in the eastern part, where the creek flows on Pre-Illinoian till units. Finally, Walnut Creek enters into the Skunk River via a channelized reach cut into the Skunk River alluvium (Figure 1). Each of these areas probably has a slightly different hydrogeological environment, which, in turn, may affect the quantity and quality of groundwater discharge into Walnut Creek.

Because of the large area covered by the watershed, it would be financially impractical to put in hundreds of piezometers and then continue to monitor them through time. Instead, parts of the creek that were typical of the larger system were identified, with the idea that these areas would be instrumented and monitored very intensely and then the results would be extrapolated to larger areas of the creek. Several transects have been identified in the watershed that would be used for research sites during the next few years of study. Presently, the Black's Gage site (26 piezometers) and the Animal Resources Lab site (30 piezometers) are the only transects under investigation. Other transects have been identified but have been put on hold pending additional funding and evaluation of the results of the first two transects.

Site Locations

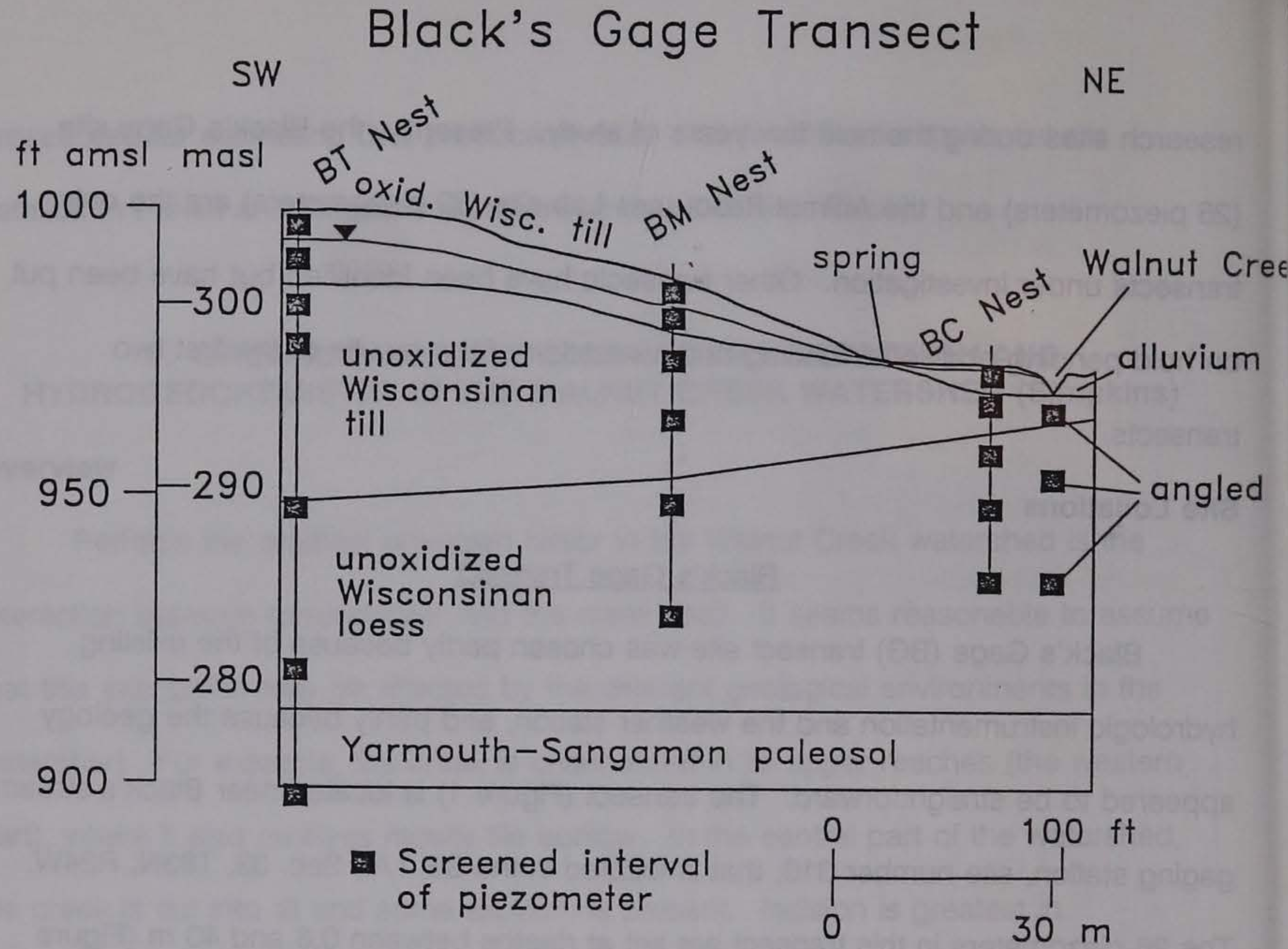
Black's Gage Transect

Black's Gage (BG) transect site was chosen partly because of the existing hydrologic instrumentation and the weather station, and partly because the geology appeared to be straightforward. The transect (Figure 1) is located near Black's stream gaging station, site number 310, that is located in the SE 1/4, Sec. 33, T83N, R24W. The 26 piezometers in this transect are set at depths between 0.6 and 40 m (Figure 4). The piezometers are grouped into three nests (BT, BM, and BC) on the south side of the creek and were installed in these positions so that both horizontal and vertical components of groundwater flow into Walnut Creek could be analyzed.

A single 40-m deep piezometer was installed on the north side of the creek adjacent to the private well at the house for the purpose of investigating CH4 transport in the Pre-Illinoian till. Note that perennial springs are located at the bottom of the slope at the contact with the alluvium (Figure 3).

Animal Resources Lab Transect

The Animal Resources Lab (ARL) Transect is located in the N 1/2, NE 1/4, Sec. 2, T82N, R24W and the SE 1/4, Sec. 35, T83N, R24W (Figure 1) and consists of 30



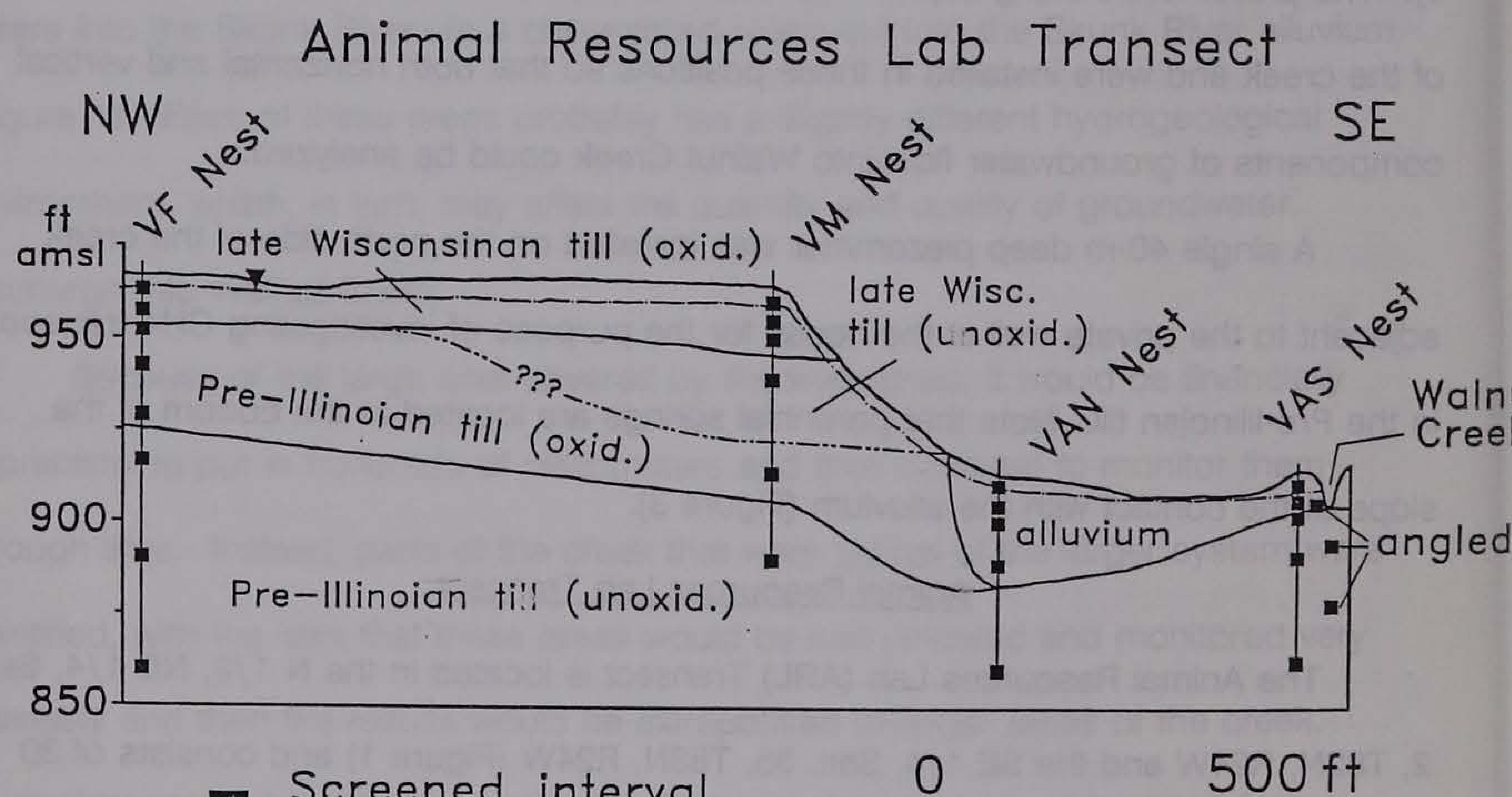


Figure 4. Stratigraphic cross-sections for Black's gage (BG) and the Animal Resources Laboratory (ARL) transects.

piezometers at depths between 0.3 and 30 m and in a more deeply incised portion of Walnut Creek. The piezometers are grouped into the VF, VM, VAN, and VAS piezometer nests (Figure 4). The stratigraphy here is quite different and consists of mostly weathered and fractured Pre-Illinoian till at a very shallow depth. No wood chips or Wisconsinan loess were noted at this site. The late Wisconsinan till is very thin at this location and probably is thin from this point eastward to the Skunk River. Walnut Creek is flowing on unweathered Pre-Illinoian till.

Sampling Techniques

The piezometers were installed in November 1993 using non-traditional techniques to minimize contamination from the bentonite seal and avoid smearing of fractures in the screened interval (Simpkins et al., 1993). Twelve of the 56 piezometers were installed at 45° in order to intercept vertical fractures that may carry contaminants at faster velocities in the system. Most of the piezometers at both transects have been surveyed into absolute mean sea level. Hydraulic heads have been measured at monthly or bimonthly intervals using a Solinst flat tape water level meter (Solinst model 102) with a probe (model P4). Slug tests to determine hydraulic conductivity will be performed on the shallow units in the summer of 1994.

All piezometers were sampled in March/April 1994 for NO_3-N, NH_4-N, anions, dissolved organic carbon (DOC), and pesticides using methods described in Simpkins and Parkin (1993). These analyses, excluding the anions (same as above), are performed at the NSTL Soil Analysis Laboratory using methods described in Section 5-

S of this report. The DOC analyses were performed using the Dohrman wet combustion technique (Tom Moorman's Laboratory at NSTL).

Observation Schedule

Groundwater samples are collected quarterly from piezometers. Intensive sampling was conducted in April 1994 and then again in June 1994, which is the period that most of the contaminants move into groundwater.

Quality Assurance and Quality Control (All Studies)

Sample splits are included with each submittal to outside laboratories. Precision checks are conducted routinely at the laboratories used for analyses of samples.

Data Format and Processing (All Studies)

Analytical results are reviewed by a researcher and the data are entered into spreadsheets. Hardcopies and diskcopies of the data are stored in William Simpkins and Tim Parkin's offices. Data are also provided to graduate students.

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ATTACHMENT I

Extracted from a "Report of Activities, USDA Interagency Agreement 58-3625-2-134 with the U.S. EPA MASTER Program, June 7, 1994" prepared by W. Simpkins et al. Dept. of Geol. and Atmos. Sciences, ISU.

GEOLOGICAL AND HYDROGEOLOGICAL SETTING OF CENTRAL IOWA AND THE WALNUT CREEK WATERSHED

Introduction

As part of this contract, we examined the Paleozoic and Pleistocene geology of central Iowa in order to determine the spatial relationships between aquifers and confining units that underlie the Walnut Creek watershed. This section presents a summary of information complied from various sources and our own investigations.

The bedrock geology in central Iowa consists primarily of Pennsylvanian, Mississippian, Devonian, Silurian, Ordovician, and Cambrian age units. Bedrock units strike northwest to southeast and dip to the southwest and into the Forest City (structural) Basin. The topography on the bedrock surface in central Iowa (which may be on the top of either the Mississippian or Pennsylvanian rock) varies considerably in the region, and range from 198.2 m (650 ft) above mean sea level in the valley floors to 274 m (900 ft) above sea level on bedrock highs. The depth to bedrock (and thickness of Pleistocene sediment) in the region may vary anywhere from 30 to 100 m (100 to 330 ft).

Buried Bedrock Valleys

Central Iowa contains an extensive network of bedrock bedrock valleys (Figure 1) that have been identified and studied for nearly 100 years (Twenter and Coble, 1965; Hansen, 1985; Iowa DNR, unpublished). The exact placement of the valleys in the subsurface involves considerable geologic interpretation of scant well data; hence, the positions of the valleys are continuously updated as new data are received. Most recently, the buried valleys have been investigated as potential sources of groundwater for municipal supply. A large buried valley just south of Ames, comprising part of the Ames Aquifer, provides nearly 70 percent of the water supply for that city. The buried valleys were probably pre-glacial stream valleys that later served as meltwater channels during the Pre-Illinoian glaciations and, in some cases, late Wisconsinan glaciations. For example, the present course of Squaw Creek and the Skunk River within and just north of Ames lie within the bedrock valleys (Figure 1); these bedrock valleys are known as the Squaw and Skunk channels, respectively (Hansen, 1985). The two major bedrock valleys shown on Figure 1 are the Jordan Channel, which trends northwest-southeast across the Boone-Story county line, and the Skunk Channel, which officially begins south of Ames and then swings eastward towards the Story-Marshall county line. The Skunk Channel underlies the extreme eastern edge of the Walnut Creek watershed. The two channels appear to meet approximately 2 km northeast of the town of Huxley (Figure 1).

Although it is generally thought that most of the buried valleys contain coarse sand and gravel, in fact, they mostly contain thick sequences of Pre-Illinoian till. (Figures 2a-b). Two recognizable sand and gravel units occur within the Pre-Illinoian section generally at depths of 34 to 38 m about 69 to 76 m below the ground surface. The lowermost sand and gravel unit is closely associated and aligned with the buried bedrock valleys and it is usually absent on subsurface bedrock highs. The lateral continuity of the units suggest that they probably represent outwash deposits and outwash terraces. The uppermost sand and gravel unit shows very little relationship to the buried valleys and is more laterally discontinous; it may represent outwash deposits that have been subsequently eroded or that were deposited on a

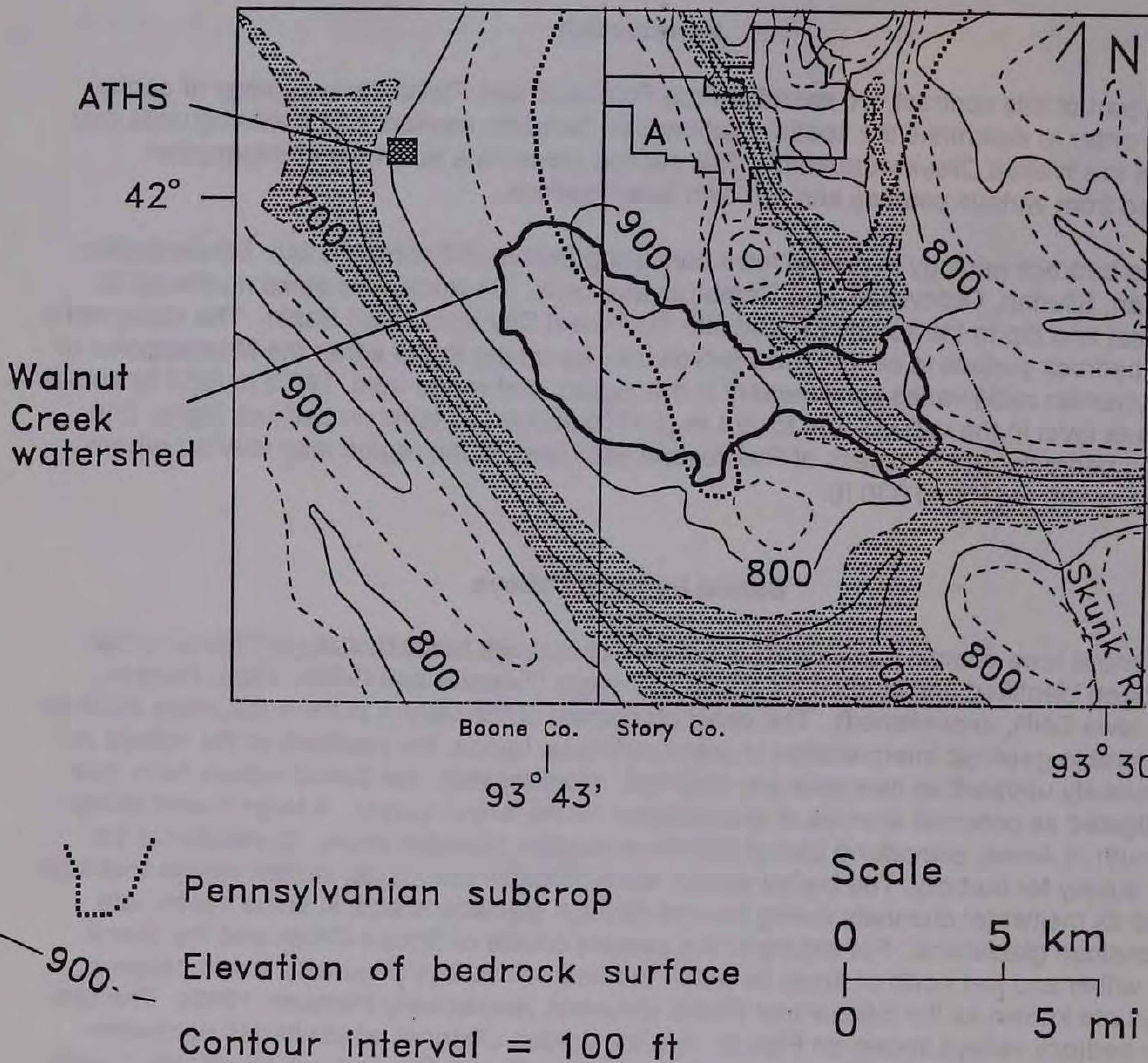
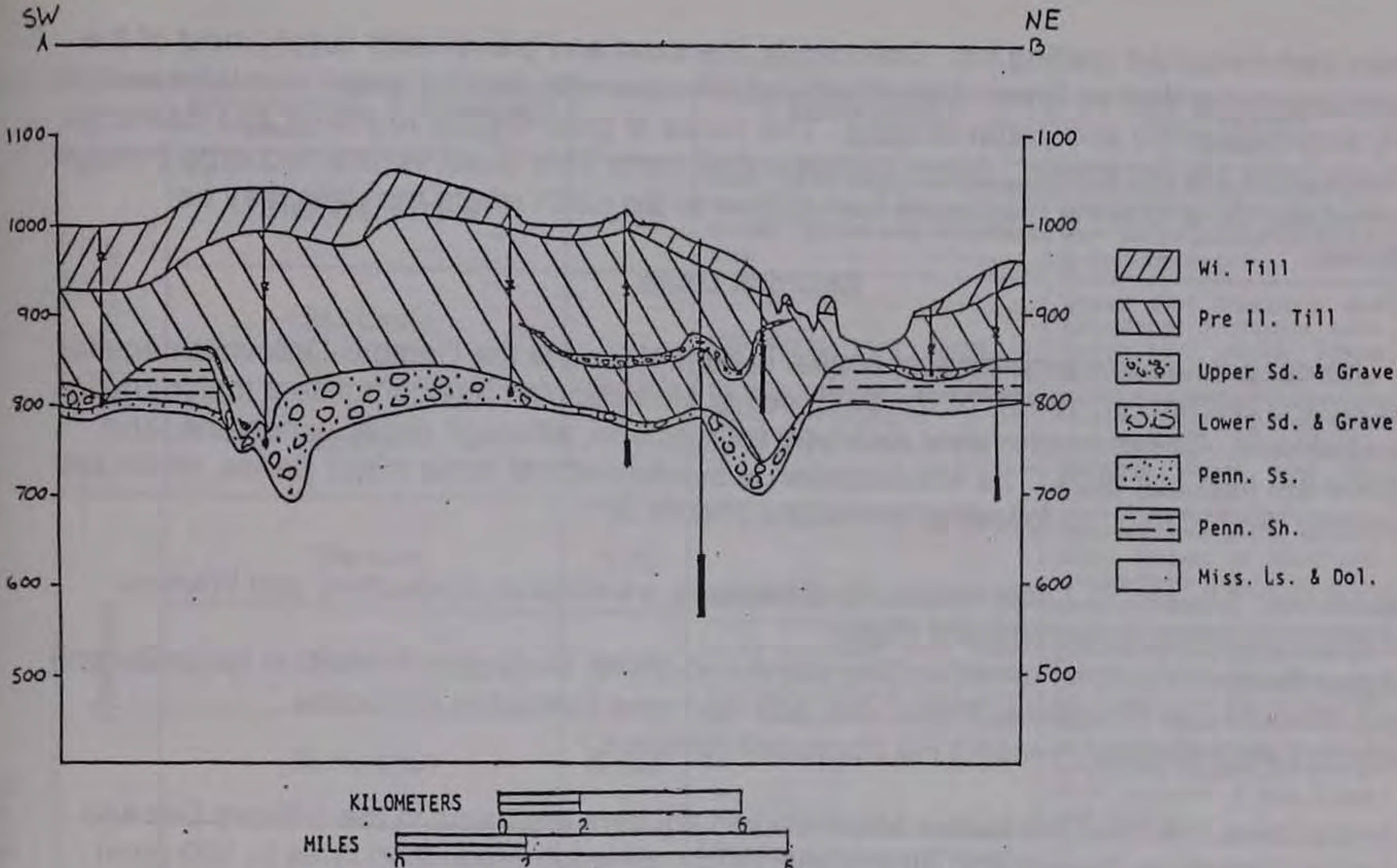
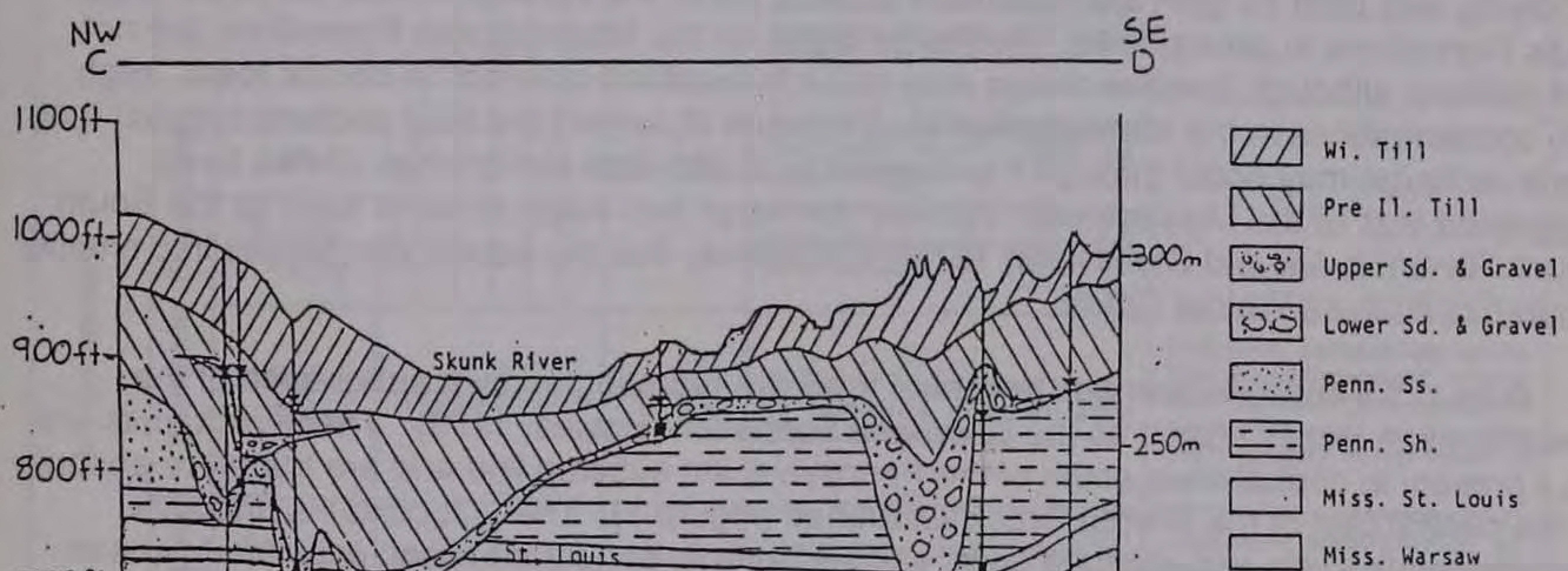


Figure 1. Bedrock topography and location of buried bedrock valleys (shaded regions) in central Iowa. Contour interval is 100 ft with supplementary contours at 50 ft. Map modified from the Iowa DNR *Bedrock Topography of Iowa* map (unpublished) and Hansen (1985).





Figures 2a-b. Preliminary cross-sections showing relationship of the bedrock valleys and sand and gravel units to bedrock units in central Iowa (from Gibbons, W., unpubl. M.S. thesis, Iowa State University).

surface that contained melting ice. Collectively, the sand and gravel units supply most of the landowners in the Walnut Creek Watershed and environs with drinking water (see later section on Hydrogeochemisty and Water Quality). The zones of groundwater recharge and discharge for these units are not known. Some recharge may come from direct vertical recharge through the overlying till, and some may come from further to the north where the units may be shallower.

Bedrock Units

The deepest usable groundwater source in central Iowa is the Cambro-Ordovician aquifer (Burkart and Buchmiller, 1990); however, rocks of Mississippian age comprise a major aquifer in central Iowa. The most prevalent rock type is limestone, although shale, sandstone, and siltstone are also common. The Mississippian is subdivided into three major Series, which are commonly divided into the following formations (Figure 3):

Meramecian Series: St. Louis Formation (limestone, sandstone, evaporites) and Warsaw Formation (dolomitic limestone and shale)
Osagian Series: Keokuk Formation (limestone and chert), Burlington Formation (dolomite and chert), Gilmore City Formation (limestone), and Hampton Formation (dolomite)
Kinderhookian Series: Prospect Hill Formation (siltstone)

In central Iowa, the most productive Mississippian aquifers are found in the Gilmore City and Hampton Formations (Horick and Steinhilber, 1973), although production rates (< 100 gpm) are still well below those from most alluvial aquifers (1000 gpm) in Iowa. Domestic wells supplying less than 10 gpm are commonly located within the Burlington-Keokuk and the St. Louis Formations in central Iowa. Recharge areas for the Mississippian Formations are not well defined, although some recharge may occur in localized outcrops in central Iowa. High SO_4 concentrations in the Mississippian aquifer south of Ames (see later section) suggest that some recharge may occur through Pennsylvanian shales and sandstones. It has been suggested that all the Mississippian aquifers discharge into major streams such as the South Skunk River (Horick and Steinhilber, 1973); it is unlikely that the aquifer discharges into smaller tributaries such as Walnut Creek.

Rocks of Pennsylvanian age in central Iowa are represented by a subdivision of the Desmoinesan Series known as the Cherokee Formation (Howes, 1993). These rock units are only present in central Iowa south of the Pennsylvanian subcrop line and are therefore absent in the central part of the Walnut Creek watershed (Figure 1). The unit contains primarily carbonaceous shale and siltstone units, and secondarily sandstone, coal, anhydrite/gypsum, and freshwater limestone units (Figure 4). The shale units in this Formation are an important regional confining unit (aquitard) and may isolate the limestone from signficant vertical recharge. Sandstone units provide water to some domestic wells in the area; however, high SO_4 concentrations and the non-contiguous nature of the channel sandstone deposits preclude its wide usage as an aquifer. In addition, the unit is absent in part of and to the north of the Walnut Creek watershed. The groundwater recharge and discharge areas for this unit are not well known.

Pleistocene Units

Three major ice advances of the Des Moines Lobe are recognized to have occured in Iowa during late Wisconsinan time (14,000 to 12,000 years B.P.): the Bemis, the Altamont,

System	Series	Group/Formation	North-central Iowa	Southeastern Iowa		North-central Iowa	Southeastern Iowa
MISSISSIPPIAN	Meramecian		Ste. Genevieve	Ste. Genevieve	0-85	Red, green and gray calcareous shales; minor limestones, dense and fossiliferous.	Limestone and greenish-gray shale; the limestone may be very dense locally. Commonly fossiliferous.
			St. Louis	St. Louis	0-135	Limestone, very dense in some zones, and dolomite, usually sandy; commonly much sandstone; minor chert, locally thin shale.	Upper part limestone and sandstone; limestone commonly very dense. Lower part dolomite, sandy, minor chert; also gypsum-anhydrite beds in parts of Dallas, Marion, Mahaska, Monroe, Appanoose, Davis, and Van Buren Counties.
			Spergen	Spergen			
	Osagean		Warsaw	Warsaw	0-75	Dolomite and limestone with much chert; locally contains shale in upper part; glauconite near top and base of Burlington. Many beds consist largely of fossil fragments.	Dolomite and shale; usually small amount of chert and chalcedony; geode zone locally at base.
			Keokuk	Keokuk	0-125		Limestone and dolomite containing much chert; glauconite usually at top and near base of Burlington. Many beds consist largely of fossil fragments. Upper part of Keokuk contains a thin shale unit locally.
			Burlington	Burlington	0-140		
	Kinderhookian		Gilmore City		0-160	Limestone, generally partly oolitic, but may be nearly all oolitic in some places; locally some beds consist predominately of fossil fragments; commonly very dense at top.	
		Hampton Formation	Iowa Falls		0-160	Dolomite, often calcareous; generally dense, may be saccharoidal.	
			Eagle City			Limestone, partly oolitic and very dense.	
			Maynes Creek	Wassonville	0-130	Dolomite, calcareous; usually contains considerable chert in lower part.	Dolomite, calcareous; or dolomite and limestone, cherty; thin oolite locally at top in northwest part of this district; usually minor chert in lower part.
		North Hill Group	Chapin	Starrs Cave	0-90	Limestone and dolomite, partly oolitic.	Limestone, locally oolitic, especially at base; commonly fossil fragments.
			Prospect Hill	Prospect Hill	0-95	Siltstone, dolomitic, and becoming more dolomitic toward the north.	Siltstone, dolomitic; some shale.
				McCraney	0-70		Limestone to dolomite, locally very dense.

Figure 3. Stratigraphic section for the Mississippian in central Iowa (from Anderson, 1983).

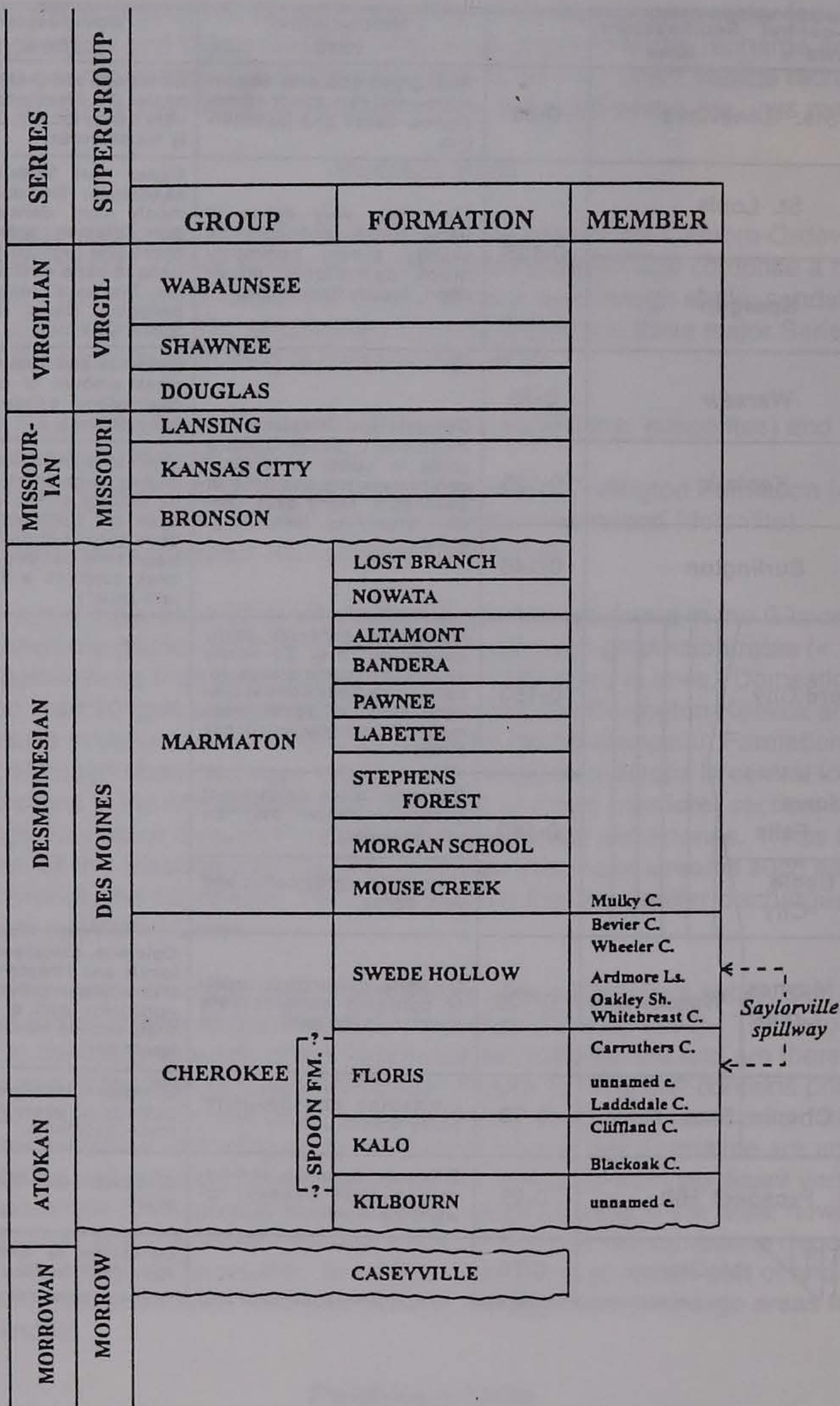


Figure 4. Stratigraphic section for the Pennsylvanian in central Iowa (from Howes, 1993).

and the Algoma (Figure 5). Till and associated glacial sediment are classified formally within the Dows Formation, which is primarily composed of two Members: the Alden Member (basal till) and the Morgan Member (supraglacial sediment)(Kemmis et al., 1981). Other members of the Dows Formation recognized in Iowa include the Lake Mills, Pilot Knob, and Noah Creek Formations (Kemmis et al., 1981; Quade, 1992). Supraglacial sediment of the Morgan Member is variable in composition and averages 44 percent sand, 42 percent silt, and 14 percent clay in Iowa. Where present, it is frequently the surficial unit on the landscape and may contain discontinuous sand lenses. The Alden Member is compositionally more uniform and averages 48 percent clay, 37 percent silt, 16 percent clay in Iowa (Kemmis et al., 1981). Most of this unit was deposited either by lodgement or melt-out processes. The thickness of this unit ranges from 4.5 to 25 m (15 to 80 ft). Both till units appear light yellowish brown (2.5 Y 6/4) where weathered (oxidized) to depths of about 4 m (13 ft) in upland areas - probably a result of water table lowering during the mid-Holocene. The weathered zone is absent in topographic lows and near creeks, partly to removal by erosion and also due to a lesser degree of Holocene weathering in lower topographic positions. Fractures containing precipitated iron oxides are commonly seen in the upper 4 m (13 ft) of the weathered till and show a preferred orientation approximately 30 to 45 degrees from the ice-flow direction (Lee, 1990). Unweathered (unoxidized) Alden Member till is dark gray (2.5 Y 4/0), and more cohesive and higher in bulk density than the weathered till above. It is primarily basal till. Fractures have been recognized to depths of 10 m in this zone.

The till landscape in central Iowa Iowa consists of low-relief (< 6 ft or 2 m high) arcuate-shaped ridges that are parallel to the former ice margin (ENE to WSW in this area) and to the end moraines (the Bemis moraine to the south near Des Moines and the Altamount moraine near Gilbert)(Figure 6). These features have been identified and described as corrugation ridges or minor moraines (Kemmis et al., 1981; Stewart et al., 1987). They were apparently formed from basal till and meltwater sediment squeezed into crevasses at the base of the ice. The numerous topographic lows ("Prairie Potholes") can be found in between these ridges and many drainages, such as Walnut Creek, probably formed parallel to the ridge trends during the Holocene. These topographic lows have been the locus of sedimentation during the Holocene for sand and silt deposits of colluvial origin (Walker, 1966). Most of these potholes were filled to capacity with water due to the abnormally high precipitation experienced in 1993, and many formed connected drainageways across the landscape.

The late Wisconsinan till in central Iowa overlies a Wisconsinan (Peoria) loess unit, deposited between 14,000 and 17,000 years B.P., which consists primarily of eolian silt and clay and is a maxium of 8 m (25 ft) thick in this area. Coring in association with both the Walnut Creek and Ames Till Hydrology Projects suggests that the contact between the loess and the till is often sharp and that an increase in silt is often noted near the bottom of the till and near the contact. Coring in the Walnut Creek watershed has suggested, however, that a zone of a interbedded diamicton, consisting of late Wisconsinan till, loess, and even Pre-Illinoian till, may exist at this contact. This material was incorporated as blocks of sediment when the ice overrode the landscape, and then was not homogenized, perhaps due to a short distance of transport. The loess unit also contains diamicton that is "till-like", suggesting that it may have been affected by mass movement on the landscape before final deposition. Another unique characteristic of the loess is that it has unusually large organic carbon percentages (near 1 percent). The carbon content is the result of a spruce forest that grew on the land surface prior to the advance of the Des Moines Lobe. The forest was buried and incorporated into the ice, which later deposited its debris as till.

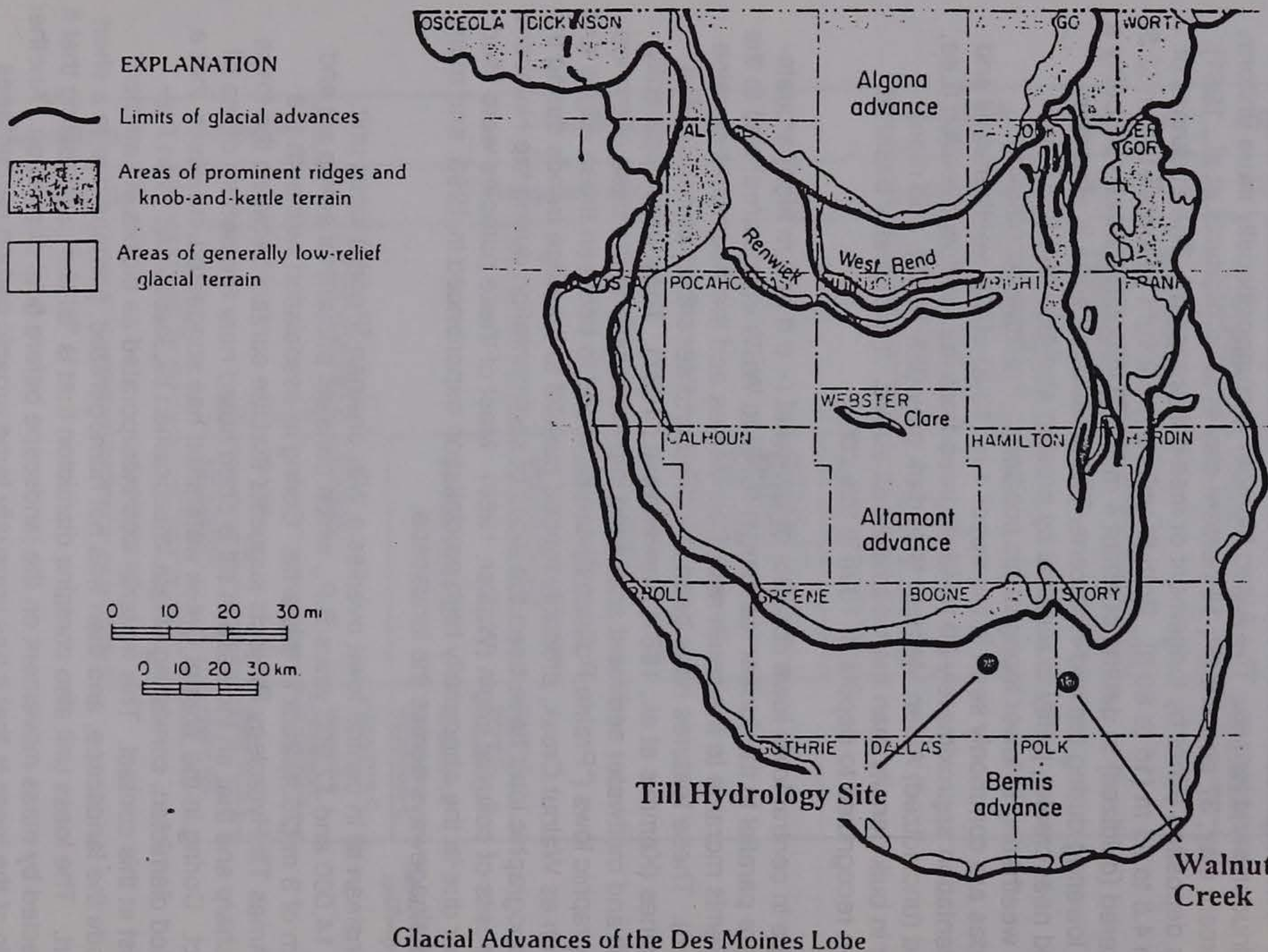


Figure 5. Extent of the Des Moines Lobe. The Ames Till Hydrology Site and the Walnut Creek Watershed are between the Altamont and Bemis moraines and in Boone and Story counties, respectively (from Prior, 1991).

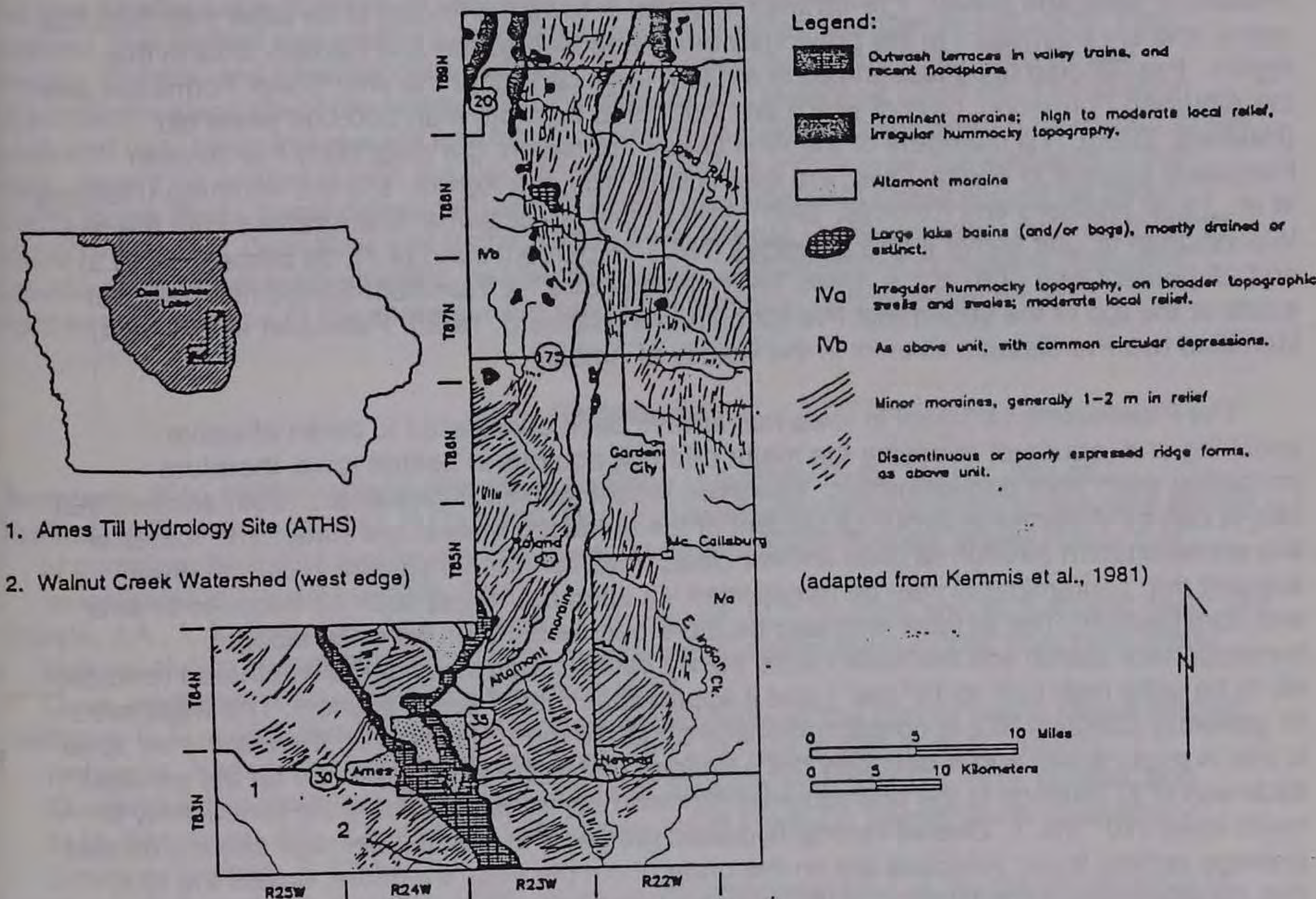


Figure 6. Map showing major and minor landforms of the Des Moines Lobe in central Iowa. Map adapted from Kemmis et al. (1981).

Beneath the loess unit is a thick (100m), Pre-Illinoian glacial sequence consisting of multiple till units and gravel. Pre-Illinoian deposits in Iowa are known to be older than 500,000 years, and are equivalent to the previously described Nebraskan and Kansan units in this region. Pre-Illinoian units recognized in eastern Iowa consist of the Wolf Creek Formation and the Alburnett Formation, both of which are thought to be more than 500,000 years old (Hallberg, 1986). Till members of the Wolf Creek Formation, the most likely Pre-Illinoian Formation present in central Iowa, are the Hickory Hills, the Aurora, and the Winthrop (Hallberg et al., 1984; Hallberg and Kemmis, 1986). The till unit is somewhat finer-grained than the late Wisconsinan till unit above it and averages (N=7) 36 percent sand (4.7), 39 percent silt (3.3), and 25 percent clay (3.6) at the Ames Till Hydrology Site. A Yarmouth-Sangamon paleosol exists at the top of the uppermost Pre-Illinoian unit (Hallberg, 1986). Palmquist et al. (1974) identified two Pre-Illinoian till units in the vicinity of Ames.

The Pleistocene sediment in Iowa has always been considered to be an effective confining unit (aquitard) overlying the major bedrock aquifers in central Iowa, therefore protecting them from contamination. However, recent studies (Kross et al., 1990) showed that NO_3-N can be detected in about 18 percent of the domestic wells in the state. The routes of this contamination through till units are not clear; however, recent studies in central Iowa suggest that contaminants may be transported via alternate routes such as fractures or poor well construction. The till itself may also be more permeable than we once thought. Heterogeneity (sand) and fractures cause the hydraulic conductivity of the weathered (oxidized till) to be quite high (10^{-3} to 10^{-5} ms^{-1}) and it approaches that of some aquifers. The weathered till generally contains NO_3-N concentrations of about 10 mg L^{-1}. However, the weathered zone is thin in many areas and is definitely not a uniform unit in the landscape. By far the greatest thickness of till belongs to the unweathered (unoxidized) till, and its hydraulic conductivity is much lower (10^{-8} ms^{-1}). Overall vertical hydraulic gradients in this unit average about 0.05 and average vertical linear velocities are on the order of cm per year; therefore, unless the till is thin, no significant contamination of underlying aquifers should occur within our lifetimes. The hydraulic conductivity of the Pre-Illinoian till is considerably less than the till units above and approaches the K values seen elsewhere only in shale (10^{-11} ms^{-1}). The bulk density of this material is generally greater than 2, probably a result of compression by later ice advances in the region and perhaps some diagenetic changes. Although vertical hydraulic gradients are large in this unit (> 1.0), velocities are less than 1 cm yr^{-1}. Redox conditions in this aquifer are also unfavorable for preservation of NO_3-N.

Holocene Units

The Holocene history of central Iowa is marked by a period of decreased rainfall, higher temperature, and increased prairie vegetation between about 8,000 and 3,000 years B.P. (Van Nest and Bettis, 1990; Dorale et al., 1992). Recharge decreased significantly during this interval, as evidenced by a decline in lake levels as much as 9 to 10 m below present levels in northwestern Iowa (Van Zant, 1979). Depth to the water table in central Iowa probably increased, perhaps to 5 m, allowing oxidation of minerals and organic carbon in the till. Following the dry period, rainfall increased and a period of erosion began at about 3,000 years B.P. which stripped sediment from the high points in the landscape and deposited them in the low points, such as in the numerous bogs and potholes in central Iowa (Walker, 1966; Ruhe, 1969). Tributaries such as Worrell Creek at the ATHS probably eroded headward during this period by taking advantage of existing low spots in the landscape.

Walnut Creek is a fairly recent arrival on the landscape of central Iowa. During wastage of the Des Moines Lobe at about 12,000 years B.P., the South Skunk River was a meltwater channel that incised and widened its valley through the Alden Member till unit, older Pre-Illinoian till units, and Mississippian bedrock. The channel has since been filled by late Wisconsinan (deposits of the Noah Creek Formation) and Holocene alluvium. The incision produced very steep valley walls and tributaries such as Walnut Creek eroded headward to the west. Based on analogies with the Buchanan Drainage, a tributary on the east side of the South Skunk River, basal dates in alluvial fill sequences in Walnut Creek should be about 10,000 years B.P. (Van Nest and Bettis, 1990); thus, Walnut Creek probably evolved through several episodes of entrenchment, headward erosion, and alluviation during the Holocene. Further modifications of the channel were made (by humans) during recent times.

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Section 5-M.2 Groundwater Quality As Affected By Landscape Position

D. Jaynes NSTL

Overview

Geologically, Walnut Creek lies within the area of the Des Moines lobe of the Wisconsin glacier that receded from central Iowa approximately 12,000 years ago. The glacier left behind a flat to gently rolling surface characterized by poorly drained soils and numerous closed depressions or potholes that remained as wetlands until drained by settlers after the 1900's (Hewes and Frandson, 1952). Although drained today, these depressions may still serve as foci of local surface and subsurface drainage (Richardson and Arndt, 1989). Thus, their influence on nitrate and herbicide fate and transport may be significant. As part of the Iowa Management System Evaluation Areas (MSEA) program, a field was selected within Walnut Creek that contained a well defined depression for extensive study. Objectives of this study are to determine the local topographic affects on soil moisture and on water quality of the shallow aquifer.

Site Location

The "Pothole field", ASCS tract 3010, was used for this study. The 30.4 ha (75.2 ac) field is located in the E ½, of the SE ¼, of Sec 25, Colfax Township, Boone County, Iowa. A corn-soybean rotation is used in this field with corn planted in the even years. The field is disk-tilled before planting soybeans and anhydrous ammonia is applied in the fall after soybean harvest.

Well and Neutron Tube Installation Techniques

Two transects were established across the southern half of the field, one aligned approximately east and west the other north and south. The transects intersect at a point within a large enclosed depression or pothole (Fig. 1). Along each transect, at approximately 60-m intervals, a well nest and an access tube for a neutron soil moisture meter were installed. In all, fourteen well nests and access tubes were installed in this field. All locations and elevations were measured with a total station and referenced to an United States Geological Survey (USGS) benchmark located in the southwest corner of the field.

Each well nest is composed of three wells - a shallow well screened from 0.30 to 1.07 m below the surface, an intermediate well screened from 1.07 to 1.83 m, and a deep well screened from 1.83 to 2.59 m.

Wells were bored using a tractor-mounted hydraulic soil coring device (Giddings Machine Co., Ft. Collins, CO). A string of 5.08-cm (2") diameter, 0.76-m (2.5') long sections of threaded plastic well pipe (TriLok brand, Brainard Kilman, Stone Mountain, Georgia) with a 0.76-m long slotted well screen was inserted into each 4.76-cm diameter borehole. All well pipe connections were sealed with rubber o-rings. Well pipes were installed with the top well pipe joint 0.30 m (12") below the soil surface. This allows for the removal of the top section of well pipe during field operations such as tillage, cultivation, planting, and harvest.

After installation, soil was excavated from around the well pipe at the 0.3 to 0.4 m depth and a concrete collar poured around the well pipe. The collar provides a water tight seal to prevent direct contamination of the well water by infiltration along the well pipe. Within the concrete collar, 0.3-m lengths of 0.95-cm diameter steel reinforcing rod were inserted to allow relocation of the well with a metal detector. Periodic relocation is required since the surface risers of all wells need to be removed for most field operations.

Neutron moisture meter access tubes were installed in the same manner as the wells. Access tubes consisted of 5.08 cm (2") diameter EMT tubing obtainable from any electrical supply company. Tubes were installed to a depth of 2.9 m or to a depth

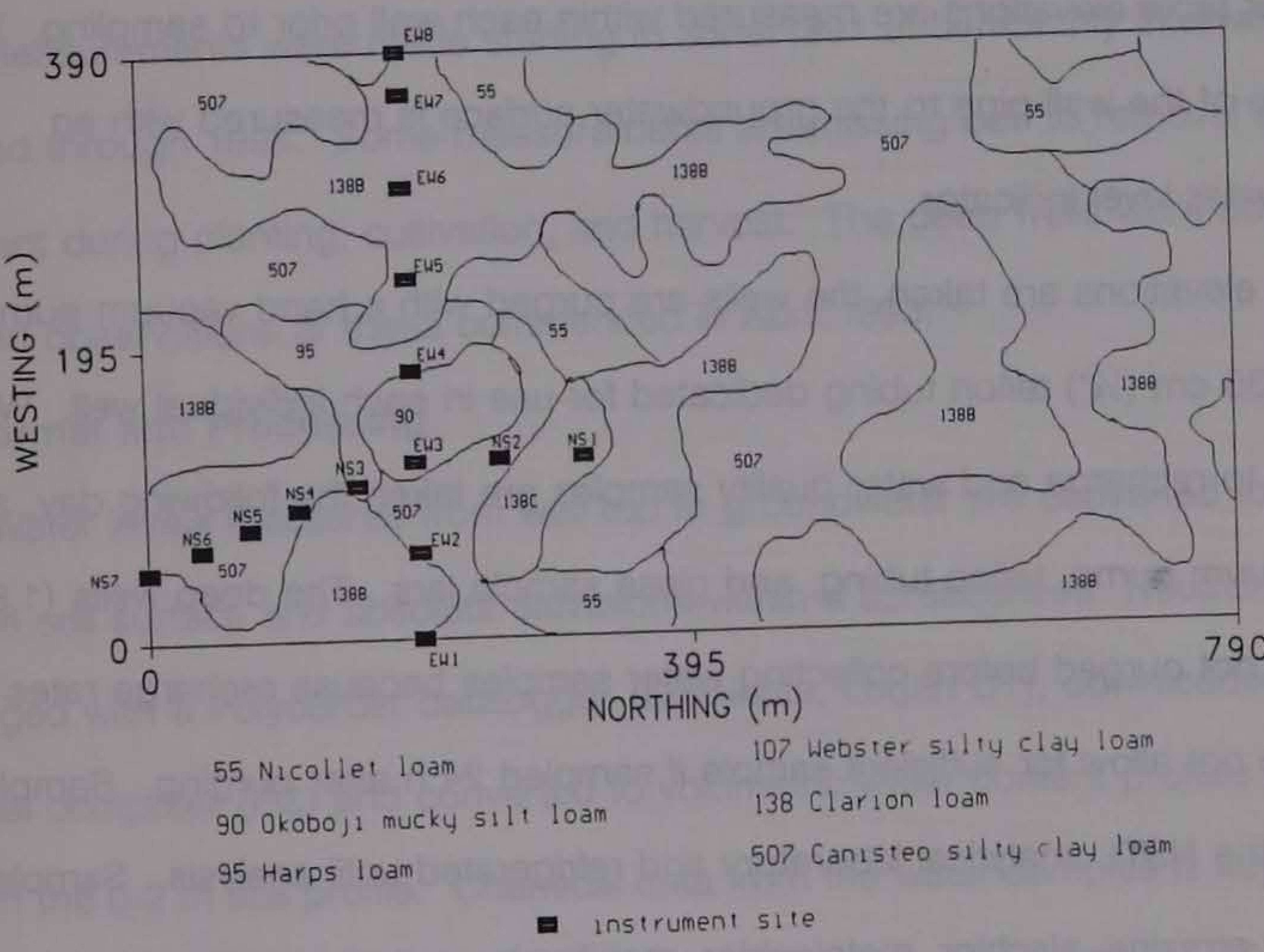

Figure 1. Well and neutron access tube locations (and location identification) with respect to soil type in pothole field.

where stones prevented deeper installation. A #11 rubber stopper was forced into the bottom of each access tube before installation to prevent groundwater from entering the tubes. After installation, #11 rubber stoppers are used to plug each tube when not in use to prevent rain from entering the tubes. Except for the field border locations, the access tubes are installed and removed each year to allow for field operations and as such are not located in the exact same field location every year. No cement collar is used around the access tubes. Instead soil is mounded around the tube at the soil surface to prevent water from running down the outside of the tube and influencing soil water content determinations.

Sampling Techniques

Water table elevations are measured within each well prior to sampling. Depth from the top of the well pipe to the groundwater surface is measured with an electronic water level indicator.

After elevations are taken, the wells are purged with a hand vacuum pump through 0.635 cm (¼") teflon tubing dedicated for use in each individual well. Wells are allowed to recharge and water quality samples are taken the following day, again using a vacuum pump, teflon tubing, and glass sample jars. The deep wells (1.83-2.59 m) are not purged before collecting water samples because recharge rates are slow and do not allow for sufficient sample if sampled 24 h after purging. Samples are returned to the NSTL analytical laboratory and refrigerated until analysis. Samples are analyzed for atrazine, alachlor, metolachlor, metribuzin, and nitrate-nitrogen. Analytical procedures are provided in Section 5-S of this report

Soil water contents are measured by neutron thermalization (Gardner, 1986) with a Campbell Scientific Neutron Moisture meter. Measurements are made starting 0.2 m below the surface in 0.2 m increments to the bottom of the access tube. Two standard counts are made when logging each access tube. A single calibration curve is used to convert the ratio of measured count to standard count to a volumetric water content. The calibration curve is based on the volumetric water contents of soil samples taken at the start of the project from three locations within the field and from the 0.2 to 2.8 m depth.

Observation Schedule

Shallow and intermediate wells and neutron access tubes were installed in May 1991. Measurements were made starting in June 1991 at bi-monthly intervals and continued through 1994. Some measurements are missing due to removal of equipment during planting, cultivation, and harvest. The deep wells were added in 1993 and observations of these commenced in April 1993.

Data Format and Processing

Water levels measured from well top to groundwater are converted to depths from the soil surface and absolute elevations within a spreadsheet. Neutron counts are logged with a Polycorder datalogger (Omnidata, Logan UT), downloaded into a personal computer (PC) and converted to volumetric water content profiles and total water in the 0-2 m soil profile. Chemical data from the water samples is keyed into a spreadsheet and combined with the water table elevation observations. All water table elevations, chemical concentration data, and water content information are contained within spreadsheet files independent of the watershed database.

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Section 5-M.3 Groundwater Quality from Well Water Geochemistry

T. Steinheimer NSTL

Objective

Overall objective is to determine the potential for pesticide leaching and runoff from an agricultural field during transition from conventional to no-tillage. This is accomplished by measuring concentrations of all pesticide-derived residues in runoff and shallow groundwater associated with the no-till practice, by placing added emphasis on the leaching-potential and degradation geochemistry of the relatively new and largely unstudied post-emergence herbicides, and by comparison of water chemistry data from the no-till field with a conventionally tilled field.

Approach

Overall approach is to assemble necessary water quality information (water chemistry, hydrology, agronomic practice) at the no-till field to develop a "water-quality profile." This conceptual model seeks to describe the water quality impacts of a given best management practice (BMP), defined in terms of tillage, cropping system and sequence, and chemical-based pest-control strategy. The water-quality profile describes the distribution of chemical residues, both parent and daughter, throughout the soil/surface water/groundwater environment as the legacy of a given BMP. It provides a tool for assessment of the integrated impact of many biogeochemical processes responsible for the environmental fate of pesticides. Emphasis is placed on the growing season, but monitoring continues throughout the year.

This study focuses on that component of groundwater issues that define groundwater quality in terms of dissolved- and suspended-phase chemical composition, with an emphasis on anthropogenic organic solutes. Other research addresses groundwater movement patterns, surface and subsurface responses to rainfall, and water table conditions as influenced by infiltration, all of which are determined by soil properties and conditions. Groundwater quality assessments require an integration of subsurface hydrology together with water chemistry.

A comprehensive hydrogeologic analysis of the flow system that is controlling chemical transport at the no-till field is lacking. In order to fully develop a "water-quality profile" of this field, more definitive information is needed regarding types, locations, and functions of field tiles; the fluctuation of the unsaturated zone-permanent saturated zone interface; the shallow groundwater movements, gradients, and magnitudes; responses of the water table to infiltration; reasonable estimates of groundwater flow velocity; and, the influence of elevation or landscape position on groundwater flow.

Site Locations and Groundwater Sampling

Fourteen groundwater sampling locations were established across the southern portion (approx. 65 ha.) of Bassett's no-till field in western Walnut Creek Watershed (location description is provided in Section 5-V of this report). Locations were selected on the basis of landscape topography, presumption of shallow groundwater flow patterns, and probability for surface ponding. Cropped acreage is approximately an equal split of corn and soybean (perhaps slightly greater on the west half); with the no-till west portion planted to corn and the no-till east portion planted to soybean in 1994. In 1993, the first year of no-till transition, cropping was reversed. This design of crop-rotation is significant in that it allows for quantitative evaluation of the groundwater-contamination potential on the same soil of new post-emergence herbicides, designed specifically for minimum-tillage corn and minimum-tillage soybean.

As presently configured, there are six locations in no-till east and eight locations in no-till west. At each location, paired wells are installed at two depths, presumably above and below the tile flow channels; screened approximately 1.2-1.8 m and 2.4-3.7 m below the surface. Installation of 5-cm inside diameter PVC casings followed standard National Groundwater Association protocols together with United States Geological Survey (USGS), Water Resources Division field practices. Sampling began in 1993, although flood conditions discredited most of the samples taken. Scheduled sampling frequency is monthly throughout the year. This is amended to include event-based sampling in response to infiltration.

Sampling and Analytical Techniques

Using hand bailers, each well to be sampled is purged 24-hr before sampling. Following establishment of hydrodynamic equilibrium with fresh-formation recharge one-day later, samples are taken. Water levels are recorded and full 4-L samples are withdrawn only after stability of measurement is observed during continuous monitoring of temperature, conductivity, and pH, using a water quality field station operating in a flow-cell mode. Samples are stored at 4°C in amber glass bottles prepared according to pesticide-analysis protocols. In the laboratory, additional measurements, prior to extraction of pesticides, include dissolved oxygen (oxygen selective electrode), dissolved organic carbon (DOHRMANN combustion infrared (IR)), and nitrate-nitrogen (LACHAT AE Quikchem, refer to Section 5-S of this report).

Groundwater samples are analyzed by residue-analysis methods developed by Steinheimer (1993, Attachment I) and Jayachandran et al. (1994, Attachment II). They utilize techniques considered to be state-of-the-science in environmental analysis; e.g., cartridge chemistry, chromatography, spectrophotometry, and spectrometry. These methods are component measurements in a Master Analytical Scheme under development which will permit multiple determinations to be made on a single water sample. This approach extends capabilities and addresses some of the co-occurrence questions. Currently, these methods can detect the active ingredients found in Aatrex, Accent, Banvel, Bicep, Bladex, Clarity, Dual, Extrazine II, Marksman, and Pursuit. In addition, other derived chemicals produced by herbicide breakdown and which have the potential to degrade water quality, also are determined in most samples. Depending on the volume taken for extraction, minimum detectability can be set between 250-50 ng L^{-1} (part per trillion). The laboratory protocols adhere to the Good Laboratory Practices (GLPs) specified by the American Chemical Society's Committee on Environmental Improvement, including recommended quality assurance and quality control (QA/QC) procedures to ensure data quality. Surrogate analytes are added to each sample, and their recovery determined, in order to flag gross sample processing errors. In addition, blanks, blinds, and reference-standard samples are routinely included in the sample table files required for instrumental determination.

Data Format and Processing

All measurements made to define the groundwater quality at the no-till field are collated into spreadsheets and stored as such on a Macintosh platform as Excel V4 or FileMaker Pro V4 files.

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ATTACHMENT I

HPLC Determination of Atrazine and Principal Degradates in Agricultural Soils and Associated Surface and Ground Water

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A method for the quantitative estimation of atrazine and its principal degradation products in agricultural soils and associated surface and ground water is described. Bonded-phase extraction through cyclohexyl cartridges is used to isolate two principal degradates of atrazine from both surface and ground water samples. Soil is first extracted with organic-free water followed by dilute hydrochloric acid under heated conditions in a microwave extraction system. Reversed-phase HPLC employing an acetonitrile–water gradient is used for separation of analytes on a stabilized C_{18} analytical column. Analytes are detected by monitoring multiple wavelengths using a photodiode array detector. Identification is by retention time and molecular absorption spectra matching against reference standards. Terbuthylazine serves as a surrogate analyte. Method validation involved determination of percentage recovery for all analytes from fortified soil material and from spiked water. Amendment levels ranged from 0.10 to 10.0 μg/L for water and from 100 to 10 000 μg/kg for soils. Nominal limit of detection is 0.4 μg/kL for water and 40 μg/kg for soils.

INTRODUCTION

Atrazine is one of the most widely used herbicides in agriculture in the United States. In 1982, the estimated total domestic usage exceeded 34 million kg (Gianessi and Puffer, 1991; Gianessi et al., 1985). Atrazine continues to be used for pre- and postemergent control of both grasses and broadleaf weeds in corn, wheat, sorghum, and many other crops throughout the Midwest and across the nation. Typical application rates for atrazine on corn have been 2.2–4.4 kg ha^{-1} of active ingredient depending upon soil properties, nature of crop, atmospheric conditions, and/or type of irrigation program (*Crop Protection Chemicals Reference*, 1990). In 1990, maximum application rates were reduced to 3.3 kg ha^{-1}. Since that time, maximum label-recommended application rates have been reduced further. For the 1993 growing season, rates are 2.7 kg ha^{-1} pre-emergence on highly erodible land with >30% residue cover and 2.2 kg ha^{-1} for highly erodible land with <30% residue cover. Rates for non-highly erodible land are currently at 2.7 kg ha^{-1}. In areas requiring a postemergence application, total atrazine may not exceed 2.7 kg ha^{-1} per calender year (Ciba-Geigy Corp., 1993). Currently, many Iowa farmers are using <1.7 kg ha^{-1}. During 1990, atrazine usage in Iowa exceeded 5.8 million lb.

During the past 15 years, much emphasis was placed on chromatographic methods for the determination of triazine herbicides. Several techniques using either packed or capillary column gas chromatography with a nitrogen–phosphorus selective detector (NPD) have been reported for residue determination of herbicides in water. The NPD is especially appropriate for the determination of triazine herbicides, all of which contain 5 mol of nitrogen/mol (35% nitrogen by weight). Most of these methods are for multiresidue determinations and used for detecting many triazines in a single extract (Pressley and Longbottom, 1982; Bradway and Moseman, 1982; Popl et al., 1983; Steinheimer and Brooks, 1984; Lee and Stokker, 1986). Each of these methods uses either liquid- or solid-phase extraction. Researchers using a more recent method describe the use of bonded-phase adsorbents together with high-resolution gas chromatography/mass spectrometry (GC/MS) for semiquantitative estimation of 21 pesticides (including 8 triazines) in ground water (Bagnati et al., 1988). Solvent extraction followed by GC/MS employing an ion-trap detector is applied to lower Mississippi River samples for a series of herbicides including several atrazine metabolites (Pereira et al., 1990). An enzyme-linked immunosorbent assay (ELISA) was compared with a GC/MS technique for determination of triazines, including atrazine metabolites, in water samples (Thurman et al., 1990). A novel approach using pressure devices to extract atrazine and dealkylated hydroxyatrazine congeners from plant tissues also has been reported (Nelson and Khan, 1989). High-performance liquid chromatography (HPLC) also is successful for separation of mixtures of triazine herbicides and other crop protection agents. Most commonly, detectors of choice are the spectrophotometer or the mass spectrometer. Many methods use reversed-phase mode of separation by employing methanol–water or acetonitrile–water as mobile phase (Paschal et al., 1978; Dufek and Pacakova, 1979; Subach, 1981; Binner, 1981; Beilstein et al., 1981; Lawrence, 1981; Williamson and Evans, 1981; Parker et al., 1982; Pacakova et al., 1988). Separation of dealkylatrazines and hydroxyatrazine by reversed-phase HPLC is described (Vermeulen et al., 1982). The simultaneous determination of 22 pesticides in both surface and ground water by HPLC using photodiode array detection has been reported (Reupert and Ploger, 1988). A detection limit of 50 μg/L is claimed for seven herbicides in 1-L samples. Reversed-phase HPLC separation of organic bases similar to atrazine degradates, specifically azaarenes and their hydroxy and methoxyl analogs, has been reported by Steinheimer and Ondrus (1986, 1990a,b). Recently, the determination of atrazine, hydroxyatrazine, dealkylatrazines, and other pesticides in water by bonded-phase extraction together with a radial-compression cartridge separation and photodiode array detection has been described (Steinheimer and Ondrus, 1990a,b; Schlett, 1990). HPLC is also applied to the determination of atrazine residues in soils. This method has been compared with a colorimetric method (Vickrey et al., 1980) and with a capillary column gas chromatographic method (Xu et al., 1986) for the parent herbicide and selected metabolites.

Paired-ion HPLC has recently been reported for atrazine and hydroxyatrazine determination in soils (Wenheng et al., 1991).

Rapid and inexpensive immunochemical assays for pesticide residues in environmental samples are a developing new technique for water-quality studies. A recent paper describes the first successful application of monoclonal antibody based ELISA determination of hydroxyatrazine and atrazine in soil and water (Schlaeppi et al., 1989).

This paper describes a rapid analytical method for simultaneous determination of atrazine, deethylatrazine, and deisopropylatrazine in agricultural soil and in associated surface and ground water. It incorporates bonded-phase extraction on reversed-phase sorbents. It is designed to serve as a tool for support of field-research conducted under the Iowa Management System Evaluation Area (MSEA) Program, a federal interagency/state cooperative study of Best Management Practices (BMPs) and Water Quality in the Midwest. BMPs are defined in the context of combinations of tillage, crop rotation or sequencing, and agrochemical usage. One objective is to characterize the biogeochemical fate of atrazine applied to croplands in the Midwest for weed control and to understand water-quality impacts by monitoring the distribution and movement of degradates.

MATERIALS AND METHODS

Reagents. Methanol and acetonitrile of pesticide residue quality and of HPLC optical purity were used. Millipore Milli-Q, or equivalent, organic-free water, free of ultraviolet absorbing compounds, as determined by blank-gradient HPLC, was used where water is required in stock standard solutions, mobile phases, and solutions for soil extraction. Purity certified crystalline standards were obtained from the Pesticide Repository, U.S. EPA (Research Triangle Park, NC), from Promochem, Ltd. (St. Albans, England), or from Crescent Chemical Co. (Hauppage, NY). All standard reference materials assayed at 96% or greater and were used without further purification. Triazine stock solutions having concentrations of 100 mg/L were prepared in methanol in glass-stoppered actinic volumetric glassware and stored in a freezer at −16 °C. Hydroxyatrazine stock solution (100 mg/L) was prepared in water by dropwise addition of reagent grade HCl and stored in a refrigerator at 4 °C. Standards were prepared by serial dilution of stock solutions with methanol or acetonitirile in glass-stoppered volumetric flasks. Stock solutions were added to water and soil samples to evaluate recovery efficiency and method sensitivity.

Apparatus. Samples were extracted using solid-phase extraction cartridges containing cyclohexyl-modified silica sorbent (Analytichem International, Harbor City, CA) on a VAC ELUT SPS-24 (Analytichem International) 24-port vacuum manifold. Soil–water mixtures were heated using a Model 2100, 950-W laboratory microwave extraction system (CEM Corp., Mathews, NC) configured with a 12-position carousel. This extractor is capable of both temperature- and pressure-controlled operation in open and sealed vessels. Supercritical fluid extraction of soil was performed using a Model 7680A SFE Module (Hewlett-Packard Co., Avondale, PA) with 7-mL stainless steel thimble tubes.

Equipment. HPLC analyses were performed on a Model 1090M Series II liquid chromatograph (Hewlett-Packard Co.) capable of ternary gradient separations and equipped with an autoinjection system, a thermostatically controlled column compartment, and a photodiode array detector. Instrumental system control was maintained through a Model 9000 Series ChemStation running LC-Pascal software (Rev. 5.22e). A built-in six-port column switching valve permitted two-column operation. Soil and water extracts were analyzed together in a single sequence, each on a column dedicated to that sample matrix.

Chromatography. Instrumental chromatographic parameters involved both ternary system pumping functions and flow programming. A LiChrospher 100 RP-18, 5 μm, 125 × 4 mm (H-P p/n 799250D-564) column was used. Photodiode array data were acquired at 220, 235, and 254nm, with a 4-nm bandwidth, and against a reference signal at 380 nm with a 40-nm bandwidth. Detector sensitivity was set at 20 mAU full scale. Spectral data were acquired between 200 and 400 nm with a sampling frequency of 640 ms. Injection volume was 25 μL. Channel A, acetonitrile; B, methanol; C, water. Gradient separation conditions:

time, min	channel A	channel B	channel C
0.10 (solvent)	10.0%	00.0%	90.0%
6.00 (solvent)	25.0%	00.0%	75.0%
21.00 (solvent)	65.0%	00.0%	35.0%
23.00 (flow)	1.50 mL/min		
23.00 (solvent)	100.0%	00.0%	00.0%
25.00 (solvent)	00.0%	100.0%	00.0%
27.00 (flow)	0.50 mL/min		
27.00 (solvent)	25.0%	00.0%	75.0%
30.00 (solvent)	10.0%	00.0%	90.0%

Procedure for Soil Extraction. Twenty-five milliliters of organic-free water was added to 10.0 g (field-moisture corrected)) of soil material contained in a 250-mL centrifuge bottle. The bottles are rotated on the carousel of a microwave oven while the samples are heated to 95–98 °C. The mixtures are centrifuged at 2300 rpm for 3 min, and the supernate is decanted into a 250-mL centrifuge bottle. The extraction is repeated once with organic-free water. Three additional extractions are done using 0.35 N HCl, combining the extracts in a separate centrifuge bottle, and the pH is adjusted to 7.0 using dropwise addition of either dilute (1:1) ammonium hydroxide or 0.2 N NaOH. The water extracts are combined with the neutralized acid extracts and centrifuged at 2300 rpm to remove precipitated metal hydroxides. Sample extracts are further clarified by filtration of the decantate through a Whatman No. 40 filter paper. The centrifuge bottle and filtration apparatus were rinsed with organic-free water. Bonded-phase extraction and elution are carried out on each soil extract (total volume of filtrate was about 125 mL) using the cartridge chemistry described in the procedure for water samples.

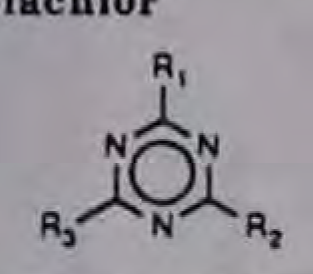
Soil Spiking Technique. Surface soil grab samples, collected in 1988, were taken from corn and soybean fields representative of agricultural land use at two locations within the Iowa MSEA program. Samples were collected from the shallow oxidized glacial till deposits of northeastern Iowa located at the Northeast Research Center, near Nashua, and from the deep loess deposits of silty loam found at the Deep Loess Research Station in southwestern Iowa, near Council Bluffs. Selected properties are given in Table I. All sampled fields at both locations have been under continuous corn production for many years. The soil samples were thoroughly mixed to ensure homogeneity. Stones, twigs, and plant residue were removed. Samples were not wet or dry sieved. All soils used for recovery studies were amended with atrazine congeners by weighing 10.0-g portions of well-mixed material into a 250-mL centrifuge bottle. An appropriate volume of spiking solution, 50–500 μL of methanolic solutions at 200 ppm concentration, was diluted into 25 mL of organic-free water, and the mixture was added to the sample bottle. This was stirred magnetically for several hours and evaporated to dryness overnight uncovered in a fume hood. These air-dried soils were used directly.

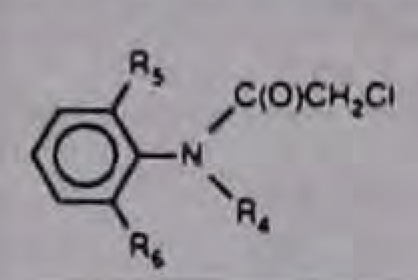
Table I. Selected Properties of the Loam (Nashua) and Silty Loam (Treynor) Soils Used for Recovery Studies

soil property	Nashua site	Treynor site
total organic carbon,[a] %	4.48	1.81
cation-exchange capacity,[b] mequiv/100 g	36.1	32.3
pH[c]	6.7	6.1
sand,[d] %	42.5	10.0
silt,[d] %	47.5	77.5
clay,[d] %	10.0	12.5

[a] Methods of Chemical Analysis of Water and Wastes, U.S. EPA, Method 415.1, 1979. [b] Methods of Soil Analysis, Agronomy No. 9, Part 2, Method 57-3, 1965; Sodium Saturation Method. [c] Recommended Chemical Soil Test Procedures for the North Central Region, Section 3, 1988. [d] Methods of Soil Analysis, Method 43-5.

Table II. Structures, Names, and Abbreviations for Atrazine, Hydroxyatrazine, Two Dealkylatrazines, and Related Compounds, along with Alachlor and Metolachlor





	R_1	R_2	R_3
deethyldeisopropylatrazine (DEDIA)	chloro	amino	amino
deisopropylatrazine (DIA)	chloro	ethylamino	amino
deethylatrazine (DEA)	chloro	amino	isopropylamino
hydroxyatrazine (HA)	hydroxy	ethylamino	isopropylamino
atrazine (A)	chloro	ethylamino	isopropylamino
terbuthylazine (TBA)	chloro	ethylamino	*tert*-butylamino
cyanazine (CYA)	chloro	ethylamino	2-methylpropionitrilamino

	R_4	R_5	R_6
alachlor (ALCLR)	methoxymethyl	ethyl	ethyl
metolachlor (MTLCLR)	2-methoxy-1-methylethyl	methyl	ethyl

Procedure for Water Samples. Water samples were filtered through 40 mm diameter organic-binder-free glass-microfiber depth filters in an all-glass vacuum filtration app· ·atus. Using a glass capillary digital micropipettor, 2.5–5.0 μL of a methanol solution of the surrogate compound, 100 mg/L TBA, was added to the sample. Volumes used for extraction ranged from 0.1 to 2.0 L. Larger volumes provide a greater level of enrichment but required longer extraction times and resulted in lower recoveries for certain analytes. Generally, 0.25–0.50 L was found to provide a reasonable level of enrichment with minimal loss during extraction. Before extraction, each water sample was adjusted to pH 7.0–7.5 by dropwise addition of dilute aqueous ammonia or phosphoric acid, as needed. Analytichem BondElut cartridges, 500 mg, of cyclohexyl specificity were activated by delivering not less than 12 mL (3 column volumes) of methanol followed by 12 mL (3 column volumes) of water through each cartridge with a glass syringe. The activated cartridges were positioned on the multiport vacuum manifold and fitted with adapters connected to glass 250-mL reservoirs. Using an applied vacuum of about 0.015 kPa, water samples were drawn through the cartridges at a nominal flow rate of about 20 mL/min. Following extraction, the cartridges were placed in 15-mL graduated centrifuge tubes and centrifuged for 1 min at 1500 rpm to remove residual water. Cartridges were then eluted by air displacement of 2.0 mL of acetonitrile (delivered from a volumetric pipet) into a clean, dry centrifuge tube. The cartridge is placed in the tube and centrifuged at 1500 rpm to ensure quantitative recovery of eluant from the cartridge. The total volume was vortexed, transferred to an autosampler vial, and sealed for instrumental analysis.

RESULTS AND DISCUSSION

Although atrazine has been studied extensively, the details of its many pathways to complete degradation and mineralization are not well understood. However, there is a general agreement that the first steps in major routes of degradation are biotic N-dealkylation and abiotic hydrolytic dechlorination (Somasundaram and Coats, 1991; Grover, 1989; Grover and Cessna, 1991; Kearney and Kaufman, 1969). These processes may occur simultaneously and perhaps competitively, depending upon the local soil environment. Chemical hydrolysis may proceed much more rapidly than metabolism, especially in acidic soils. Stabilization of these reactive intermediates through bioconjugation may also occur. Although the abiotic hydrolysis of field-applied atrazine occurs most rapidly, the N-dealkylation reactions are probably more important for water-quality studies because they occur in the soil where they are promoted by microorganisms and because these dealkylated congeners are more water soluble than either atrazine or hydroxyatrazine. Water solubility measurements in distilled water at room temperature show the following: deisopropylatrazine, 650 ppm; hydroxyatrazine, 7 ppm; deethylatrazine, 340 ppm; atrazine, 33 ppm; terbuthylazine, 8 ppm (personal communication from M. G. Ondrus).

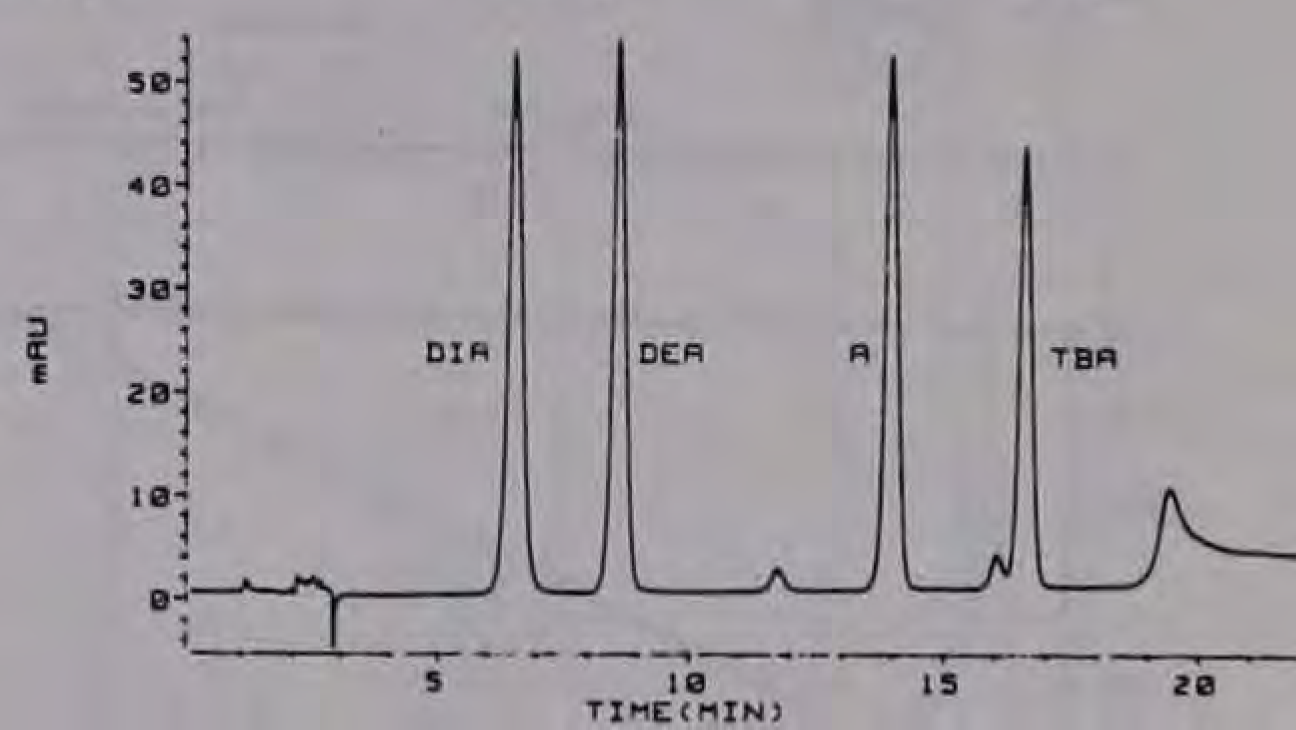


Figure 1. Chromatogram of DIA, DEA, A, and TBA, on a LiChrospher 100 RP-18 (5 μm) column (125 × 4 mm) using an unmodified acetonitrile–water gradient. Photodiode array detector was operated at 220 nm with sensitivity set at 20 mAU full scale (156-ng injection).

Table II shows structures, names, and abbreviations for atrazine, hydroxyatrazine, the two dealkylatrazine derivatives, and related compounds, along with alachlor and metolachlor. Terbuthylazine (TBA) serves as surrogate analyte because its chemical behavior mimics that for atrazine, it is inexpensive and commercially available at high purity, and it is well-resolved chromatographically from all other triazine peaks. TBA is not registered for agricultural purposes in the United States; therefore, its occurrence as a water contaminant is unlikely. The LC separation conditions were chosen so that all primary analytes and surrogate are resolved from each other and to the baseline within a 20-min analytical run cycle. The additional 10-min recycle time is necessary to flush the most polar of the chemical artifacts from the column; this is particularly important for sample sequences encompassing different types of soil. As shown in Figure 1, an end-capped *n*-octadecyl column under acetonitrile–water mobile phase provides a separation with excellent peak symmetry and without the necessity of ionic amendments to the solvent, such as dilute acids or bases, buffers, or counterions required for paired-ion separations. The use of these ionic agents on reversed-phase systems often diminishes the life of an analytical column and prevents its uses in other separation modes, while causing possible corrosion to stainless steel hardware components. The chromatogram in Figure 1 represents the response of 156 ng of each compound on column and was recorded at 220 nm at a photodiode array sensitivity of 20 mAU full scale. Signal-to-noise ratios for all analytes exceed 100.

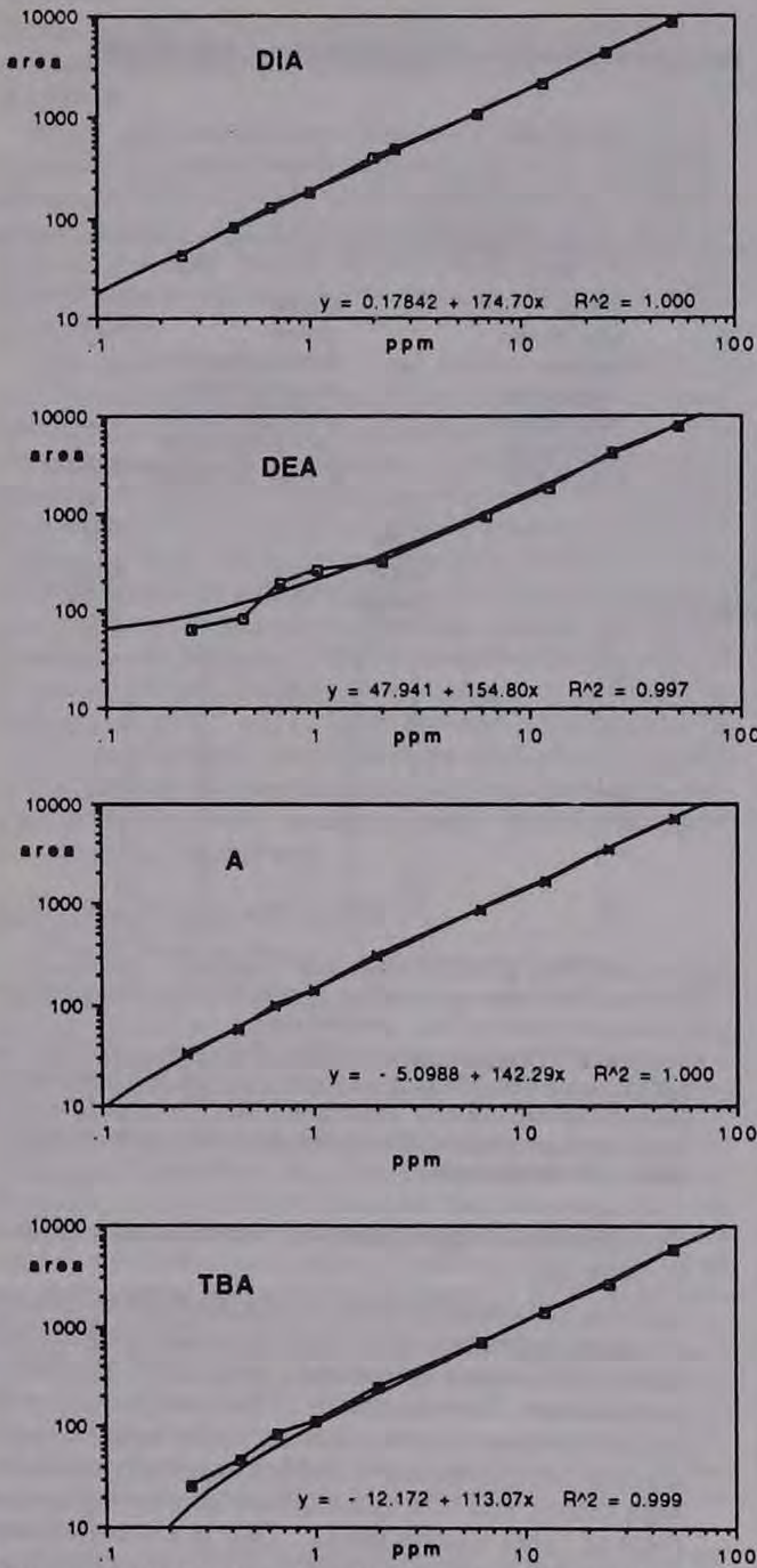


Figure 2. Multipoint calibration plots used for quantitation of DIA, DEA, A, and TBA.

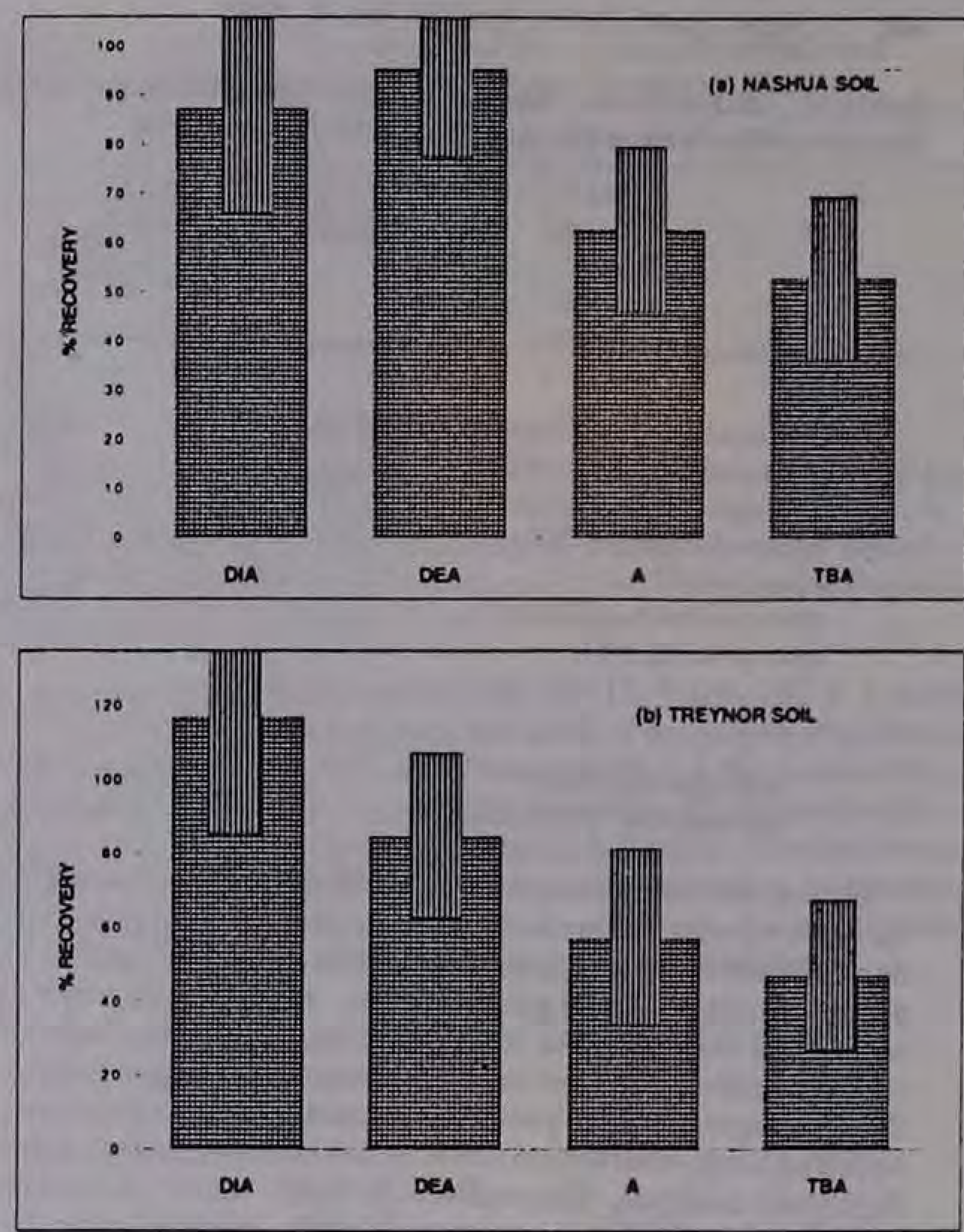


Figure 3. Recovery of analytes plus surrogate from soil amended at 1–2 ppm. Error bars are standard deviations from the mean of quadruplicate determinations. (a) Nashua; (b) Treynor.

Figure 2 illustrates typical nine-point calibration plots obtained for each analyte over a concentration range 6.25–1250.0 ng injected. These extended standard curves are necessary to accommodate the range of concentrations normally encountered in both soil and water samples. The instrumental software permits a peak-by-peak statistical evaluation for each peak of the chromatogram to establish the repeatability of instrument performance on repetitive injections before a long sequence or for assessing compliance within specified regulatory guidelines. Using this feature, the following variances are observed for this analytical separation: retention time, RSD <0.1%; area, RSD <10%; height, RSD <15%; width, RSD <10%. Pacakova et al. (1988) has studied the reversed-phase HPLC behavior of a series of triazines and their hydroxyl analogs in terms of mobile-phase composition and pH and concluded that the use of photometric detectors is preferred over electrochemical devices for low-level residue measurements. Weed-control agents, other than atrazine, are finding increasing usage in the corn and soybean rotations practiced by most Iowa farmers. Because of similarity of properties, several of these are likely to occur in water or sorbed to soil together with their corresponding degradates. Were they present in extracts, these chemicals would be distinguished on the basis of their retention time together with the respective UV absorption spectrum. Table III lists these properties for the primary analytes, several of their hydroxy analogs, and other herbicides and degradates with a probability of co-occurrence in agricultural field samples. For the most part, herbicides likely to be coapplied with atrazine do not break down to derivatives that would interfere with instrumental analysis.

The soil extraction procedure involves removal of atrazine and terbuthylazine by extraction with water heated to boiling point in a 950-W laboratory microwave digestor. DIA and DEA are removed by heating with dilute hydrochloric acid, which produces the protonated species, the corresponding triazinium ion, which is partitioned into the aqueous phase. In addition, extraction with aqueous solvents alone, as an alternative to the more commonly u.ed methanol–water or acetonitrile–water mixtures, appears to improve the partitioning process with respect to amounts of coextracted soil organic matter. This method seems to yield cleaner extracts and simpler chromatograms. For DIA and DEA, dilute acid may also catalyze hydrolysis of covalent bonds responsible for the chemisorption of these analytes to the complex soil organic matter. Furthermore, given the amphoteric and tautomeric nature of hydroxyatrazine, the acid extraction may release hydroxy analogs bound by other types of interactions by shifting the position of the tautomeric equilibrium. During method development, a series of experiments were conducted to determine the optimum concentration of dilute HCl required for maximum recovery of A and TBA commensurate with minimization

Table III. Retention Times Measured for Primary Analytes, Other Products of Initial Soil Degradation Processes, Most Probable Co-occurring HPLC Interferences, and UV Absorption Data for All Compounds

	R_t	UV, λ_{max}	intensity
atrazine-derived chemical			
deethyldeisopropylhydroxyatrazine	3.27	218, 258	high, low
deethyl,deisopropylatrazine	3.45	202, 230	high, medium
deisopropylhydroxyatrazine	5.15	210, 235	high, low
deethylhydroxyatrazine	6.15	210, 235	high, low
deisopropylatrazine	6.58	224, 262	high, low
hydroxyatrazine	7.65	204	high
deethylatrazine	8.65	224, 268	high, low
atrazine	14.00	218, 262	high, low
terbutylazine	16.63	224, 268	high, low
potential HPLC interferences			
diketometribuzin	8.72	202, 260	high, high
metribuzin	10.85	212, 228, 295	high, high, high
deaminodiketometribuzin	11.15	212, 228, 295	high, high, high
cyanazine	11.44	218	high
simazine	11.40	222, 268	high, low
carbofuran	12.32	210, 226, 278	high, low, low
alachlor	17.65	224, 268	high, low
metolachlor	18.65	224, 268	high, low

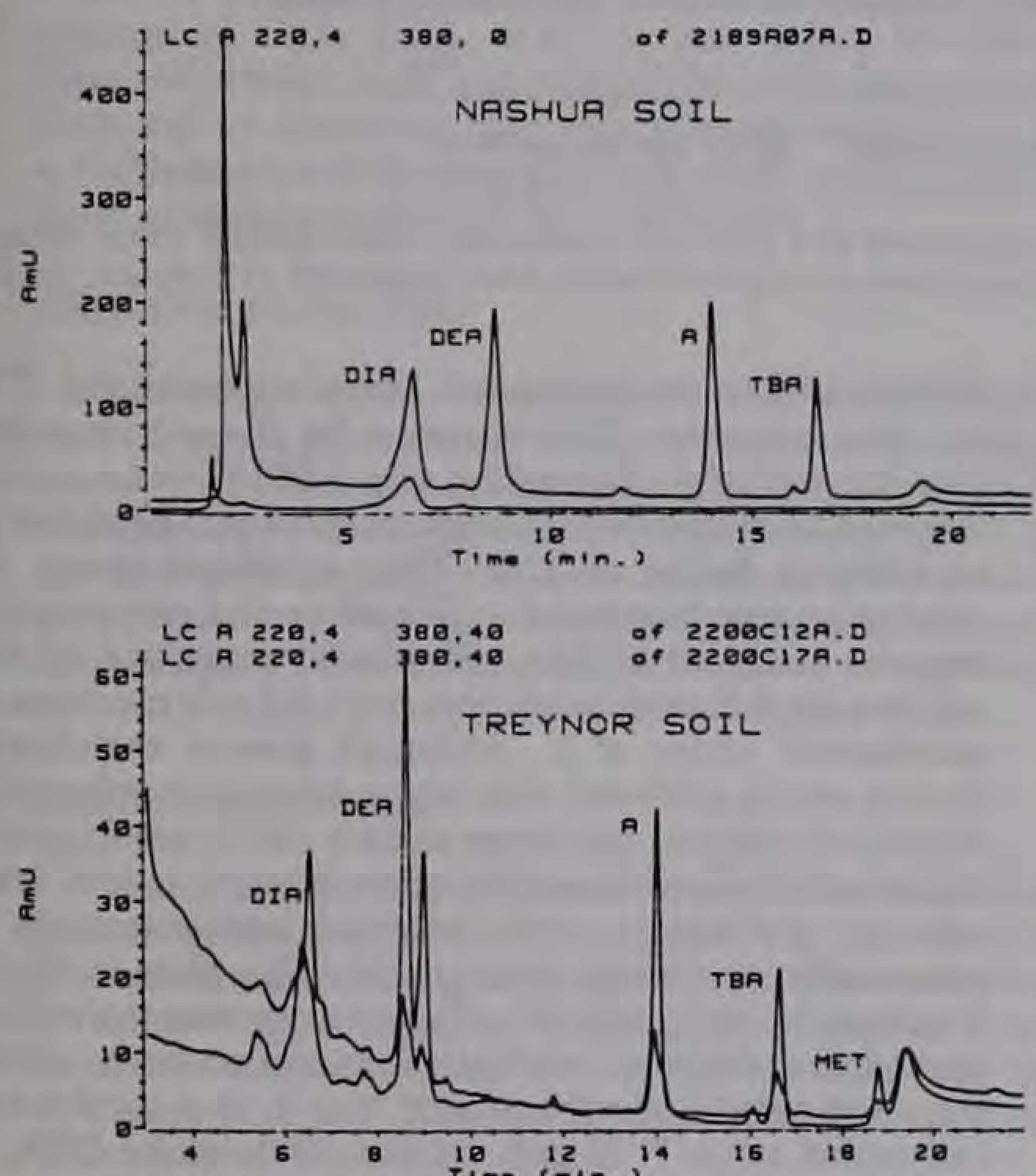


Figure 4. Chromatogram of extract from soil amended with analytes plus surrogate 1–2 ppm. (a) Nashua; (b) Treynor.

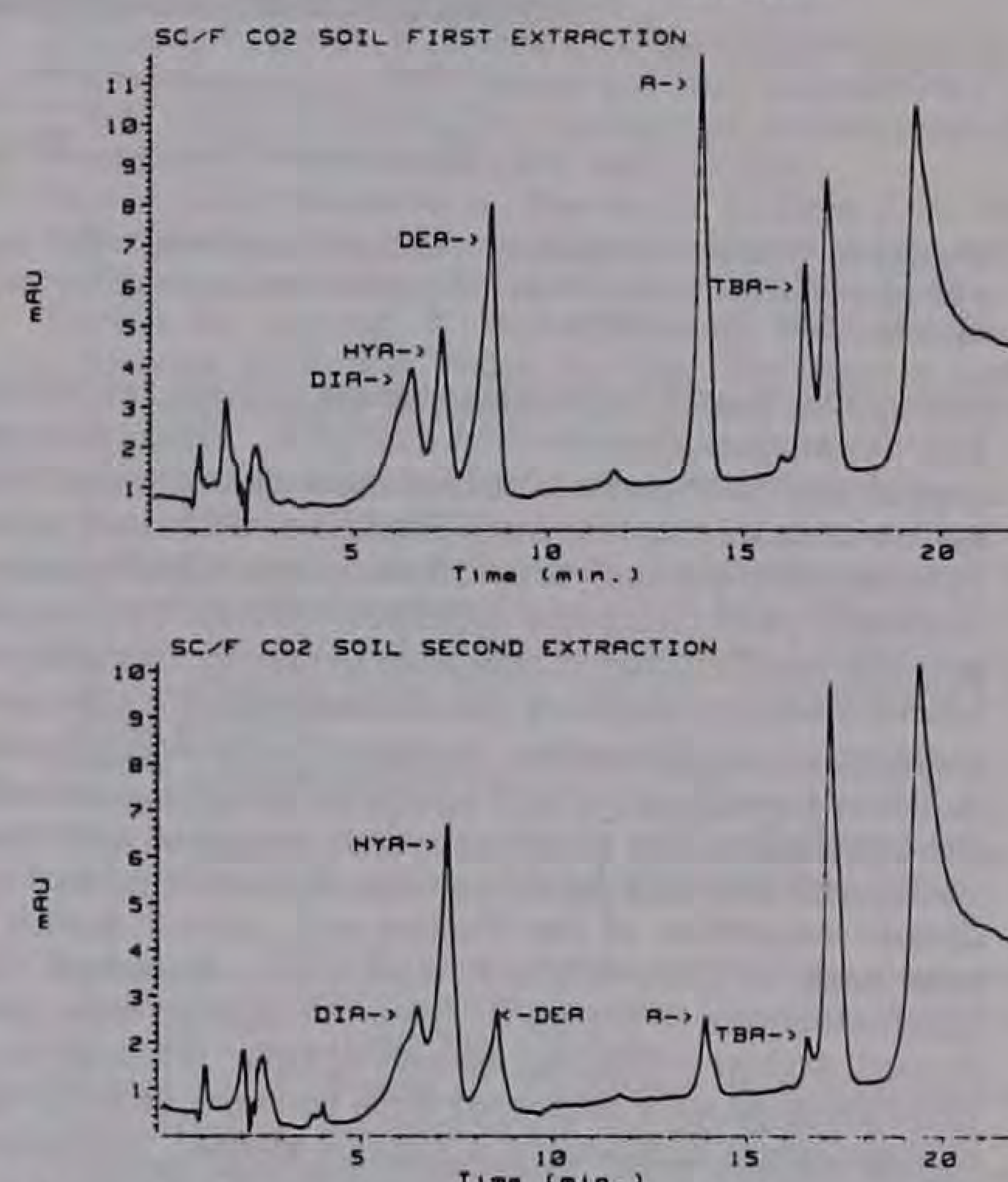


Figure 5. Chromatogram from extract of Nashua soil. Spike: 5 ppm each of DIA, DEA, A, and TBA. Sample: 10.0 g of soil amended with 10% water. (a) First extraction: CO_2 density, 0.3 g/mL at 121 bar; flow rate, 1.0 mL/min; T = 80 °C; equilibration time, 2 min; run time, 5 min. (b) Second extraction: CO_2 density, 0.9 g/mL at 350 bar; flow rate, 4.0 mL/min; T, 50 °C; run time, 20 min; other conditions unchanged.

of hydroxy analog formation. Extraction of Nashua soil with supercritical carbon dioxide (SFE) was also investigated with emphasis on recovery for DIA and DEA. Amendment of a 10.0-g sample with 1 mL of water resulted in measurable recovery for both metabolites, along with A and TBA.

Figure 3 plots typical recoveries obtained for each soil type when spiked within the range 1–20 ppm. DIA and DEA mean recoveries over the concentration range are 85–95% for the Nashua soil and 115–85% for the Treynor soil, respectively. A and TBA means are somewhat lower—65–55% for the Nashua soil and 55–50% for the Treynor soil, respectively. Error bars, showing the standard deviations from the mean of 25 replicate determinations, are approximately 30–40% for each analyte. Uncertainties of measurement associated with pesticide analysis of a soil matrix are much greater than those normally identified with a water matrix. Physical complexity, heterogeneous nature, and spatial and temporal variability of soil combine to yield larger variance. Both metabolites are extracted more efficiently from soil with dilute HCl than are the corresponding parent compounds. This is a direct result of their increased Brønsted–Lowry basicity associated with the primary amino group conjugated with an azaarene ring system. Recovery experiments with two tandem cartridges of identical surface chemistry show no evidence of first-cartridge breakthrough for either A or TBA, indicating that use of the 2.0-mL elution volume may be insufficient for full recovery. Studies are underway to assess the effect of a combination of larger elution volume, together with additional elutions of smaller volumes, for increased total recovery. In addition, other studies (personal communication from M. G. Ondrus) using only parent compounds as spiked analytes do not support the suggestion that the less basic A and TBA are more

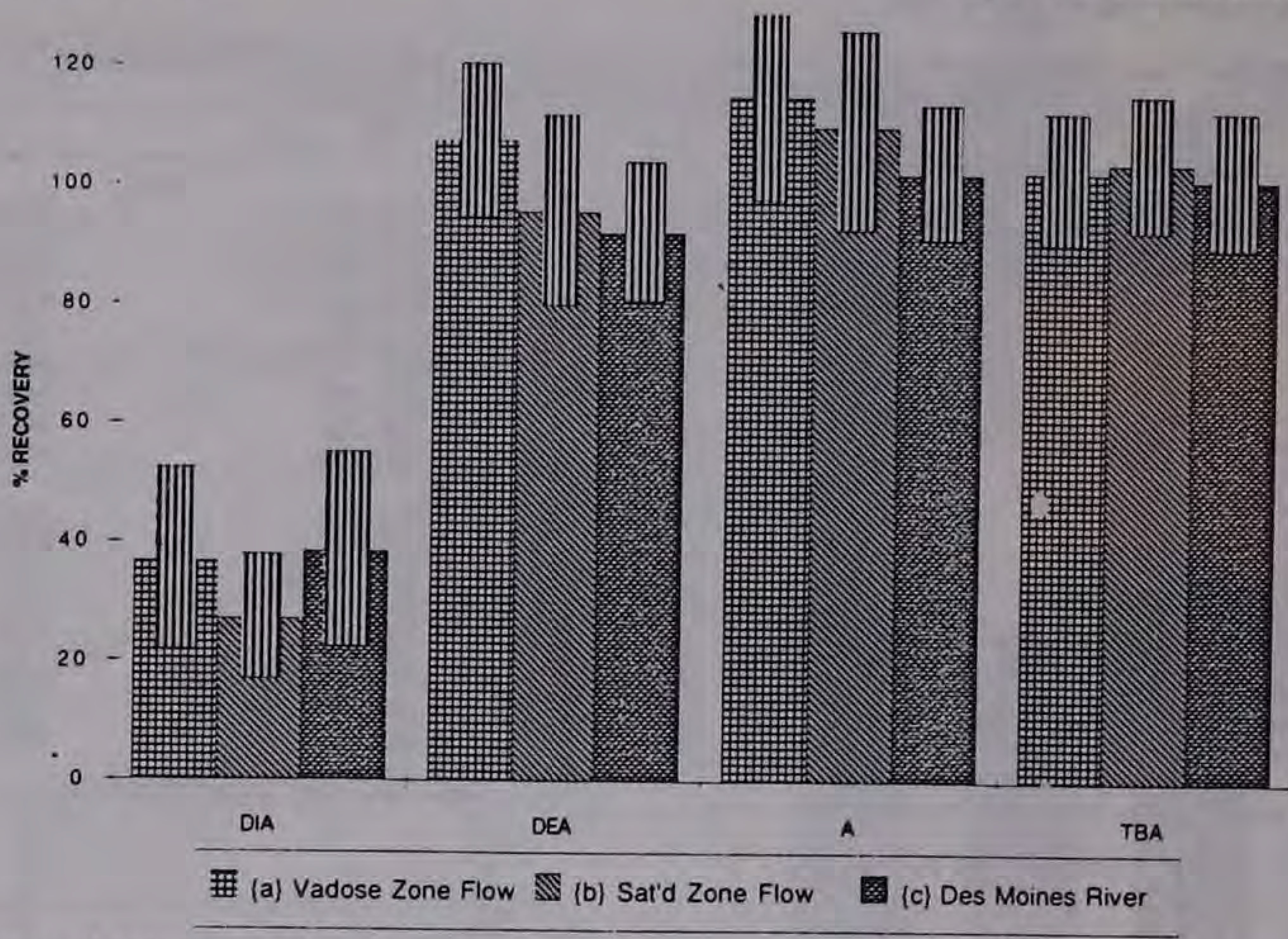


Figure 6. Recovery of analytes plus surrogate from water samples amended at 1 ppb. (a) Unsaturated-zone ground water beneath a 40-ha watershed under ridge-till continuous corn at Treynor. (b) Saturated-zone ground water from watershed at Treynor. (c) Des Moines River (June 1992).

susceptible to acid hydrolysis, leading to their respective hydroxy analogs, than are DIA and DEA. Figure 4 shows typical chromatograms obtained from the aqueous acid system as extractant for both Nashua and Treynor soils. Prominence of the analyte peaks, relative to the soil matrix, is apparent and illustrates the effectiveness of the sample preparation chemistry in reference to maximizing analyte recovery while minimizing the chromatographic effects of coextracted organic matter. As shown by the second trace in Figure 4, small amounts of additional analyte, especially the metabolites, are recovered when a stacked cartridge configuration is used for extraction. Supercritical carbon dioxide extraction of the Nashua soil, amended with 5 ppm each of DIA, DEA, A, and TBA, furnished the chromatograms in Figure 5. Two extractions were performed, each at a different density of CO_2. While all four spike analytes were recovered from the analyte trap, the chromatogram complexity is slightly greater, indicating larger amounts of coextracted organic matter or more rapid formation of hydroxy analogs than seen with the aqueous extractants. Additional experiments, which compare optimized extraction protocols directly, along with LC/MS characterization of each peak in the chromatogram, should resolve these issues.

Agricultural water samples are filtered and processed by solid-phase extraction on BondElut cartridges. Earlier studies demonstrated that the cyclohexyl packing material is the bonded phase best suited for removal of atrazine and its degradation products from water. On the basis of the complexity of the chromatogram, the cyclohexyl cartridges are superior to *n*-octadecyl cartridges for discrimination between low molecular weight analytes and high molecular weight organic matter in the extraction process. Other surface chemistry specificities that were evaluated include *n*-octadecyl, *n*-octyl, phenyl, cyano, amino, and aliphatic diol. For determinations that focus on the most water soluble analytes, such as deisopropylatrazine, a larger capacity cyclohexyl cartridge is suggested. For most natural water samples with dissolved organic carbon levels <5 mg/L, the use of a test sample volume of 0.25–0.5 L is recommended. An elution volume of 2.0 mL produces acceptable recoveries for all analytes sorbed onto the packing. Extraction of a 0.250-L water sample followed by elution with 2.0 mL of methanol produces an enrichment factor of 125. This condition meets the processing requirements for all surface and ground water samples analyzed to date. Similarly, extraction of 10-g soil sample followed by ellution with 2.0 mL produces an enrichment factor of 5. Although greater enrichment factors can be achieved with larger extraction volumes or larger soil weights, the larger sample size is accompanied by potential problems such as longer extraction time, lower recovery percentage, and increased concentrations of potentially interfering compounds. The plots in Figure 6 summarize the results of spikes on a representative Iowa agricultural drainage surface water and on both vadose-zone and saturated-zone ground water. Across the concentration range 1–20 ppb, mean recoveries for DEA, A, and TBA in all matrices fell within 115–90% of theoretical values, with an RSD of <25%. Compared to the other compounds, recovery of DIA in all matrices was greatly reduced. This has been reported by others (Thurman et al., 1990) and probably results from its lower distribution coefficient, a manifestation of greater water solubility. Triazines and their degradates encompass a broad range of water solubilities such that complete and quantitative recovery for each from a single pass through a procedure is not practical. As a result, optimum test sample weight is compromised. Water samples having volumes from 100 to 1000 mL and soil weights from 1 to 10 g are relatively easy to work with. A good compromise between length of extraction and sensitivity of the method is found with 250-mL water samples and 10-g soil samples.

During 1988 and 1989, well-water samples were obtained from two midwestern cornbelt locations. One site was an atrazine spill which occurred during a mixing operation in west-central Wisconsin; the other was an atrazine-contaminated potable supply well in the southern part of the state. Each sample was split, with one portion analyzed according to this method and the other analyzed independently in another laboratory using the traditional solvent extraction–gas chromatographic approach. Comparison of results for DIA, DEA, and A showed excellent agreement within expected variances associated with multilaboratory, multioperator, multimethod collaboration (Steinheimer and Ondrus, 1990a,b). The results show that the bonded-phase extraction HPLC method is capable of generating water-quality data for atrazine metabolites equivalent to that produced from classical GC approaches.

CONCLUSION

Atrazine and metabolites are determined in both agricultural soils and associated water by a common protocol. The method will support the herbicide–degradate analysis requirements of the five-state MSEA program. It lays the groundwork for other important advances for LC techniques including HPLC with particle beam mass spectrometry as detector and the determination, underivatized, of non-gas-chromatographable hydroxy analogs of DIA, DEA, DEDIA, and other triazines. Removal of polar, ionic, and hydrophilic herbicide analytes from soil by admixture only with aqueous extractants is a viable approach for emerging new weed control agents such as sulfonylureas and imidazolinones.

ABBREVIATIONS USED

A, atrazine, 2-chloro-4-(ethylamino)-6-[(1-methylethyl)-amino]-*sym*-1,3,5-triazine; HA, hydroxyatrazine, 2-hydroxy-4-(ethylamino)-6-[(1-methylethyl)amino]-*sym*-1,3,5-triazine; DEA, deethylatrazine, 2-chloro-4-amino-6-[(1-methylethyl)amino]-*sym*-1,3,5-triazine; DIA, deisopropylatrazine, 2-chloro-4-amino-6-(ethylamino)-*sym*-1,3,5-triazine; TBA, terbuthylazine, 2-chloro-4-(ethylamino)-6-[(2-methyl-2-propyl)amino]-*sym*-1,3,5-triazine.

ACKNOWLEDGMENT

I thank Drs. Robert Williams, Janis McFarland, and Homer LeBaron, all of the Ciba-Geigy Corp., for the gift of the environmental degradation compounds formed from atrazine. I appreciate the technical assistance and enthusiastic support of the early stages of this work by Professor Martin G. Ondrus, Department of Chemistry, University of Wisconsin—Stout.

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Registry No. Supplied by Author: Alachlor, 15972-60-8; atrazine, 1912-24-9; carbofuran, 1563-66-2; cyanazine, 21725-46-2; deaminodiketometribuzin, 52236-30-3; deethylatrazine, 6190-65-4; deethyldeisopropylatrazine, 3397-62-4; deethylhydroxyatrazine, 19988-24-0; deisopropylatrazine, 1007-28-9; deisopropylhydroxyatrazine, 7313-54-4; diketometribuzin, 56507-37-0; hydroxyatrazine, 2163-68-0; metolachlor, 51218-45-2; metribuzin, 21987-64-9; simazine, 122-34-9; terbuthylazine, 5915-41-3.

ATTACHMENT II

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Occurrence of Atrazine and Degradates as Contaminants of Subsurface Drainage and Shallow Groundwater

K. Jayachandran, T. R. Steinheimer,* L. Somasundaram, T. B. Moorman, R. S. Kanwar, and J. R. Coats

ABSTRACT

Atrazine is a commonly used herbicide in corn (*Zea mays* L.) growing areas of the USA. Because of its heavy usage, moderate persistence, and mobility in soil, monitoring of atrazine movement under field conditions is essential to assess its potential to contaminate groundwater. Concentrations of atrazine, deisopropylatrazine (DIA), and deethylatrazine (DEA) were measured in subsurface drainage and shallow groundwater beneath continuous, no-till corn. Water samples were collected from the subsurface drain (tile) outlets and suction lysimeters in the growing seasons of 1990 and 1991, and analyzed for atrazine and two principle degradates using solid-phase extraction and HPLC. In 1990, atrazine concentration ranged from 1.3 to 5.1 μg L^{-1} in tile-drain water and from 0.5 to 20.5 μg L^{-1} in lysimeter water. In general, concentrations of parent and degradates in solution were atrazine > DEA > DIA. Lesser levels of atrazine were measured in 1991 from Plots 2 and 4; however, greater concentrations of atrazine (6.0–8.4 μg L^{-1}) were measured from Plot 5. Throughout the two growing seasons, atrazine concentration in Plot 5 tile-drain water was greater than that of Plots 2 and 4, suggesting a preferential movement of atrazine. Concentrations of DIA and DEA ranged from 0.1 to 2.2 and 0.9 to 3.2 μg L^{-1}, respectively, indicating that the degradation products by themselves or in combination with parent atrazine can exceed the maximum contaminant level (mcl) of 3 μg L^{-1} even though atrazine by itself may be <3 μg L^{-1}. The deethylatrazine-to-atrazine ratio (DAR) is an indicator of residence time in soil during transport of atrazine to groundwater. In Plots 2 and 4, DAR values for tile-drain water ranged from 0.43 to 2.70 and 0.50 to 2.66, respectively. By comparison, a DAR of 0.38 to 0.60 was observed in Plot 5, suggesting less residence time in the soil.

Groundwater pollution by agricultural chemicals has become a growing concern in the USA because 40 to 50% of domestic drinking water is pumped from groundwater resources (Jury, 1982; Hallberg, 1986). Several studies suggest that water pollution is the most damaging and widespread environmental effect of agricultural production (Cohen et al., 1984: Hallberg, 1989; Ritter, 1990). As a result, numerous monitoring programs have been conducted to determine the presence of agricultural contaminants in surface water and groundwater. The potential of pesticides to contaminate our groundwater has been well documented (Hallberg, 1989; Rostad et al., 1989; Spalding et al., 1989).

Atrazine (2-chloro-4-ethylamino-6-isopropylamino-*s*-triazine) is a preemergent herbicide commonly used in corn (*Zea mays* L.) growing regions of Iowa, where nearly 3.2 $\times 10^6$ kg a.i. is applied annually. Atrazine is also one of the commonly detected compounds in groundwater in Iowa and the Midwest regions (Hallberg, 1989; Spalding et al., 1989; Hartzler and Jost, 1990; Stoltenberg et al., 1990; Goolsby et al.; 1991). The frequency of atrazine detection in groundwater results from its intense usage, moderate persistence, and mobility through the soil profile (Spalding et al., 1989).

As atrazine moves through the soil profile, several factors including moisture, temperature, aeration, soil chemical properties, and microbial activity influence the fate of this compound. Atrazine is degraded both chemically and biologically. Dealkylation of atrazine is the main biotic degradation pathway in the soil environment. Several species of bacteria and fungi are effective at deethylation, forming deethylatrazine (2-chloro-4-amino-6-isopropylamino-*s*-triazine; DEA), and some species of microorganisms are more proficient at deisopropylation, forming deisopropylatrazine (2-chloro-4-ethylamino-6-amino-*s*-triazine; DIA) (Kaufman and Kearney, 1970; Behki and Khan, 1986). Hydrolysis of atrazine to hydroxyatrazine (2-hydroxy-4-ethylamino-6-isopropylamino-*s*-triazine) is the major abiotic degradative pathway (Skipper et al., 1967; Obien and Green, 1969). The *N*-dealkylation of atrazine by soil microorganisms is potentially more important for water quality studies, because the resulting compounds are more water-soluble and more mobile in the soil profile than hydroxyatrazine. Hydroxyatrazine is more strongly bound to the soil than atrazine, DEA, and DIA, and therefore is less mobile in soil (Russell et al., 1968; Helling, 1971), so that the possibility of leaching into groundwater appears to be minimal.

Most of the groundwater-monitoring programs focus only on the parent compound and very little information is available on the potential of pesticide degradation products. A few studies have detected the presence of atrazine degradation products, DIA and DEA, in groundwater (Muir and Baker, 1976; Rostad et al., 1989; Adams and Thurman, 1991). Because metabolites are also toxic from an exposure point of view (Hallberg, 1989), measuring the environmental fate of pesticide degradation products is increasingly important. Both atrazine metabolites are primary amino derivatives of an azaarene ring system. These types of organic compounds are known mammalian carcinogens (Hayes and Laws, 1991). Thus, their occurrence in water resources drawn for domestic supply constitutes a potential risk to human health. The current maximum contaminant level (mcl) for atrazine is 3 μg L^{-1} in drinking water; however, this does not consider the degradation products (Belluck et al., 1991).

Soil microorganisms convert significant quantities of atrazine to DEA. Based on this metabolic process, a de-

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Abbreviations: DEA, deethylatrazine; DIA, deisopropylatrazine; mcl, maximum contaminant level; DAR, deethylatrazine-to-atrazine ratio; PVC, polyvinyl chloride; TBA, terbuthylazine; SPE, solid-phase extraction; CH, cyclohexyl; DIAR, deisopropylatrazine-to-atrazine ratio.

ethylatrazine-to-atrazine ratio (DAR) has been hypothesized as an indicator of hydrogeologic and geochemical conditions existing in shallow groundwater (Adams and Thurman, 1991). The DAR also may be an indicator of residence time in the soil during transport of atrazine. Prolonged residence time in soil during atrazine transport should result in large DAR values, whereas, mixing with atrazine-contaminated groundwater from external point-sources or originating from preferential flow processes would be expected to yield small DAR (<0.5) values.

This study was initiated to monitor atrazine and its degradation products at the Till Hydrology Site experimental plots, 13 km west of Ames, IA, in which corn was continuously grown under no-till management. Water samples were collected from tile-drains and suction lysimeters during the growing seasons of 1990 and 1991 following herbicide application to determine the concentration of atrazine and its degradation products that moved into the subsurface drainage system.

MATERIALS AND METHODS

Site Description

The research field is located at the Agronomy and Agricultural Engineering Research Center, 13 km west of Ames, IA. The experimental plots are located on a Nicollet loam soil (fine-loamy, mixed, mesic Aquic Hapludolls) with a maximum slope of 2%. This soil series consists of deep, moderate to poorly drained soils formed in loamy glacial till under prairie vegetation. The groundwater system consists of an unconfined aquifer within a highly weathered glacial till and includes a perched water table varying from a depth of <1 m to >3 m. The 4.0-ha field is divided into 10 experimental plots in which corn was grown continuously since 1984 using no-till and conventional tillage practices. Three no-till plots (Plots 2, 4, and 5) were selected for studying the movement of atrazine and its degradates into shallow groundwater. The area of the experimental plots were 3360 m^2 for Plot 2, 4050 for Plot 4, and 2310 for Plot 5.

Each experimental plot is drained by a separate tile-drain (10.2 cm diam.) spaced at 36.6 m apart. Tile drains were installed in this area in 1961 at a depth of 122 cm. Details on installation of deep sumps to intercept tile lines and measurement of tile flow rates are described elsewhere (Kanwar et al., 1988). A set of two polyvinylchloride (PVC) suction lysimeters were installed in two locations in each plot at 90- and 150-cm depths to collect water periodically for pesticide analysis. Installation of these devices included a soil slurry pack over the porous cups. A series of five piezometers (3.8 cm diam. plastic pipe with an open bottom) were also installed in Plot 4 at depths of 120, 180, 240, 300, and 360 cm to collect water from these depths for pesticide analysis. Piezometers were constructed from PVC casings and not polyethylene or polypropylene; furthermore, all wells were purged prior to sampling. Therefore, all atrazine loss from adsorption is assumed to be minimal.

The pesticide application history for the experimental field is listed in Table 1. Atrazine was broadcast applied as a preemergent herbicide at a rate of 1.68 kg ha^{-1} and corn, Pioneer[1] hybrid no. 3475, was planted on 2 May 1990. Plot 5 received atrazine broadcast at a rate of 2.24 kg ha^{-1} on 14 Nov. 1990 for a rainfall simulation study (Table 1). No atrazine was applied in 1991.

[1] Mention of a trade name, proprietary product, or specific equipment does not constitute a guarantee or warranty by the USDA and does not imply its approval to the exclusion of other products that may be suitable.

Table 1. Summary of pesticide use history in the experimental plots at the Till Hydrology Site (1986–1991).

Year	Crop	Variety	Pesticide† applied	Application rate
				kg ha^{-1}
1986	Corn	Pioneer 3475	Alachlor	2.80
			Cyanazine	2.24
			Carbofuran	1.45
1987	Corn	Pioneer 3475	Atrazine	2.24
			Metolachlor	2.80
			Chlorpyrifos	1.45
1988	Corn	Pioneer 3475	Alachlor	2.24
			Cyanazine	2.24
			Chlorpyrifos	1.45
			Glyphosate	1.68
1989	Corn	Pioneer 3475	Alachlor	2.24
			Cyanazine	2.24
			Chlorpyrifos	1.45
			Glyphosate	1.68
1990	Corn	Pioneer 3475	Atrazine	1.68
			Metolachlor	2.24
			2,4-D	1.12
			Glyphosate	1.12
			Terbufos	1.45
1991	Corn	Pioneer 3475	Alachlor	2.24
			Cyanazine	2.24
			2,4-D	1.12
			Glyphosate	1.12
			Terbufos	1.45

† Additional atrazine (2.24 kg ha^{-1}) was broadcast applied on Plot 5 in November 1990.

Sample Collection

Water sampling was started in early May 1990 after planting and herbicide application, and continued until 20 August. At the beginning of this field study, sampling sequences were planned and executed on a weekly interval basis; later, as the study progressed, the sampling sequences were modified according to the tile-flow events. Sampling was terminated after 20 August (110 d after atrazine application) because tile flow ceased. A similar situation occurred in the following season (1991), where sampling was started immediately after planting 10 May 1991 and continued until 5 June 1991.

Water samples were collected in acid-washed 500-mL glass bottles. Duplicate samples were collected from the overflow on a V-notch weir located in a manhole at the tile-drain outlet. Samples were transported to the laboratory and immediately stored in the dark at 4 °C until analysis. The volume of each sample collected from the tile-drain outlet ranged from 250 to 500 mL, with an average volume of abut 400 mL. Precipitation data (Fig. 1A and 2A) were recorded at a meteorological station at the research center. Daily tile flow rate measurements (Fig. 1B and 2B) were used to calculate the amount of atrazine drained through the tile lines. Based on the daily tile flow events and analytical data points, a linear regression equation was used to extrapolate from late May through August for both growing seasons to estimate the loss of atrazine and degradates in the tile-drain water. The stage recorder and calibrated V-notch weir were installed in Plot 5 in 1991, so tile flow data were collected only for Plots 2 and 4 in 1990.

Water samples were also collected for analysis from suction lysimeters and piezometers for analyses. About 24 h before sampling, standing water was pumped and discarded from the piezometer and a vacuum was applied to each lysimeter to collect fresh samples. Sample containers and storage procedure were as described earlier. Water samples from piezometers were collected only in the months of May and June 1990. Samples from lysi-

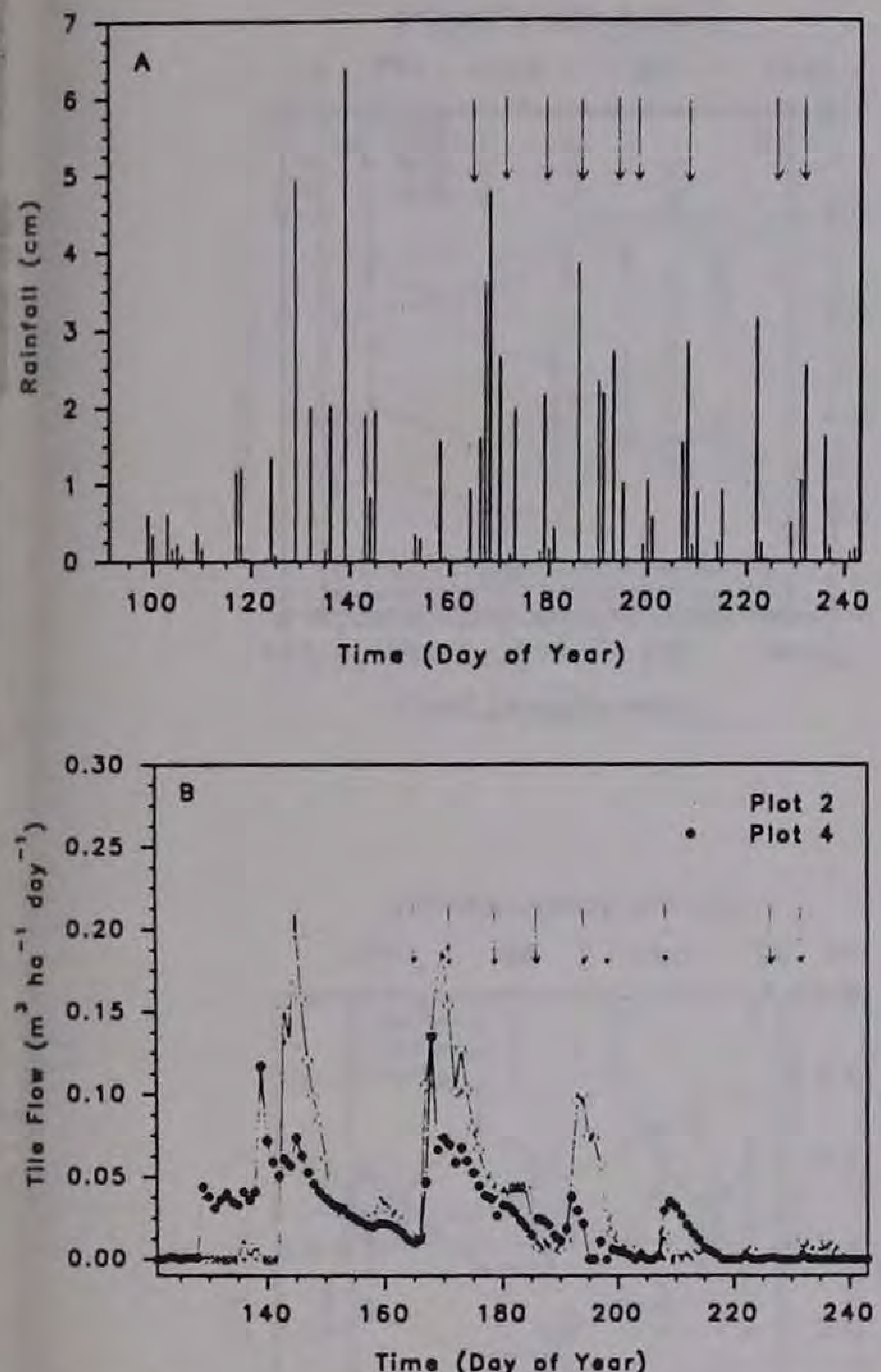

Fig. 1. (*A*) Daily precipitation events from April to August 1990 at the Till Hydrology Site, and (*B*) daily tile-flow measurements from May to August 1990. Arrows indicate sampling period.

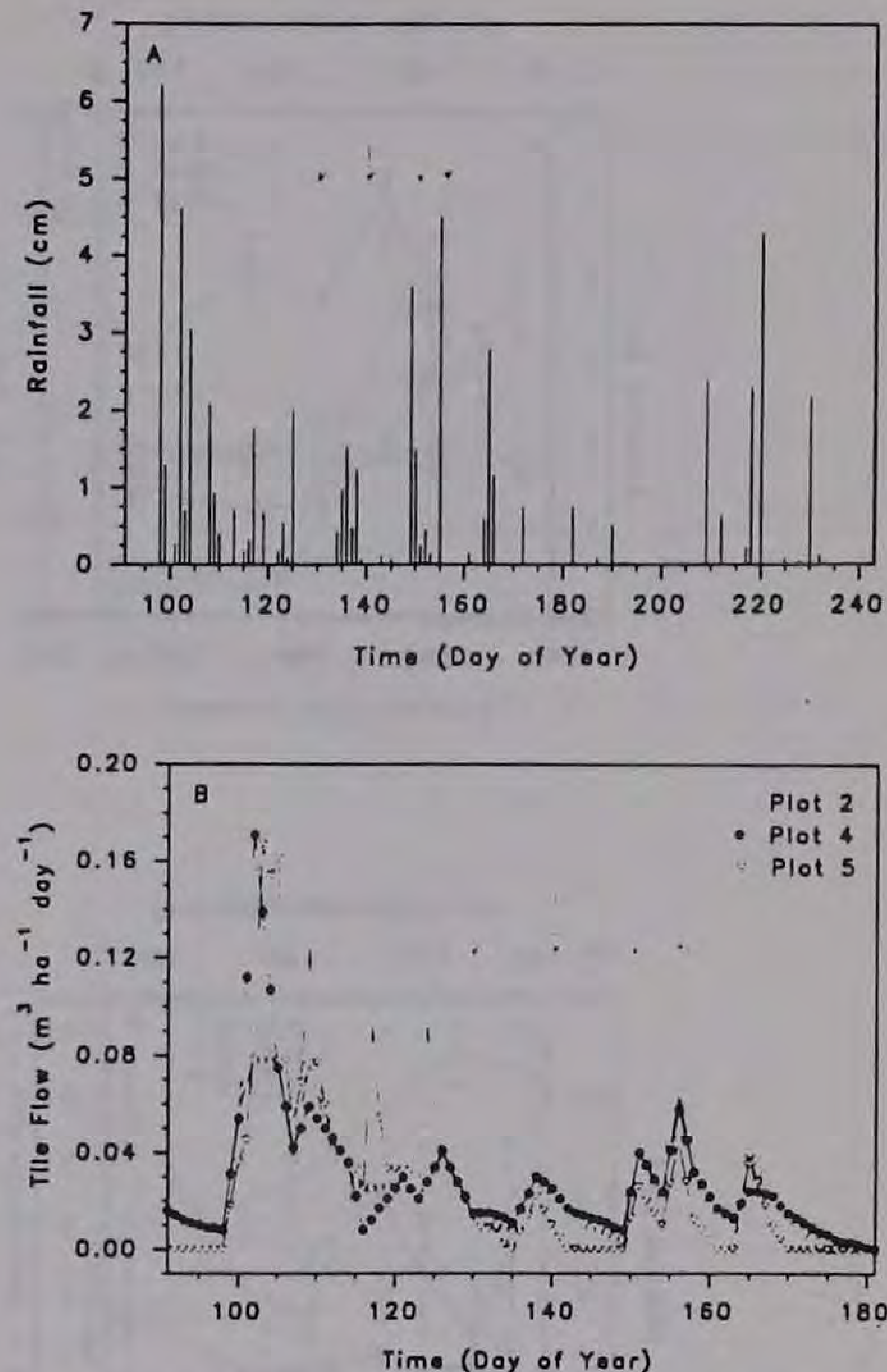

Fig. 2. (*A*) Daily precipitation events from April to August 1991 at the Till Hydrology Site and (*B*) daily tile-flow measurements from April to June 1991. Arrows indicate sampling period.

meters were collected after sufficient precipitation. The volume of samples collected from each lysimeter varied from 20 to 400 mL, with an average volume of about 300 mL. The lack of soil moisture prevented sample collection from lysimeters at some sampling periods.

Sample Analysis

Samples were analyzed by the method of Steinheimer and Ondrus (1990) as amended by Steinheimer (1993). Test sample volumes of 100 to 500 mL (typically 250 mL) were spiked with a surrogate compound, terbuthylazine (2-(tert-butylamino)-4-chloro-6-ethylamino-*s*-triazine; TBA), at 1 µg L^{-1}. Three analytes together with the surrogate were removed from water by solid-phase extraction (SPE) on cyclohexyl (CH) cartridges (Analytichem BondElut, Varian Sample Preparation Products, Harbour City, CA) and followed by elution with pesticide-grade MeOH (Burdick and Jackson, Muskegon, MI). Final extract volume was reduced to 0.5 mL by concentration under N_2 stream at 45 °C.

Instrumental determination was achieved on a Model 1090M Series II liquid chromatograph (Hewlett-Packard Company, Little Falls, DE) equipped with an autosampler, a thermostated column compartment, and a photodiode-array detector. System operations were controlled from an HP ChemStation running PASCAL Series software (Rev. 5.21). Liquid chromatography separations were accomplished using acetonitrile-water gradients on LiChrospher 100 RP-18 (Hewlett-Packard Company, Little Falls, DE) column (150 by 4 mm, 5 µm spherical packing) at 40 °C. The analytical column was preceded by a guard column of the same packing (4 by 4 mm). Identifications were made by peak comparisons with spectra stored in a user-generated library of reference spectra. Six-point external-standard quantitative calibration plots were developed for each analyte by injection of 25-µL volumes of serially diluted four-component-standard mixtures. Correlation coefficients (r^2) for the standard plot of DEA, atrazine, and TBA were 0.999 and 0.996 for DIA, all within the concentration range of 0.25 to 2.50 mg L^{-1}. Analytical purity-certified reference standards were provided by the Pesticide Repository, USEPA, Research Triangle Park, NC, and by the Riedel deHaen (Crescent Chemical Company, Hauppage, NY).

A parallel Quality Assurance and Quality Control program was implemented to assure the precision and accuracy of the results. Check samples were prepared by spiking surface water representative of agricultural land drainage. Recovery studies on grab samples taken during base-flow from the south fork of the Skunk River (near Ames, IA) showed DEA, atrazine, and TBA were consistently >90%. Recovery efficiency for DIA, about

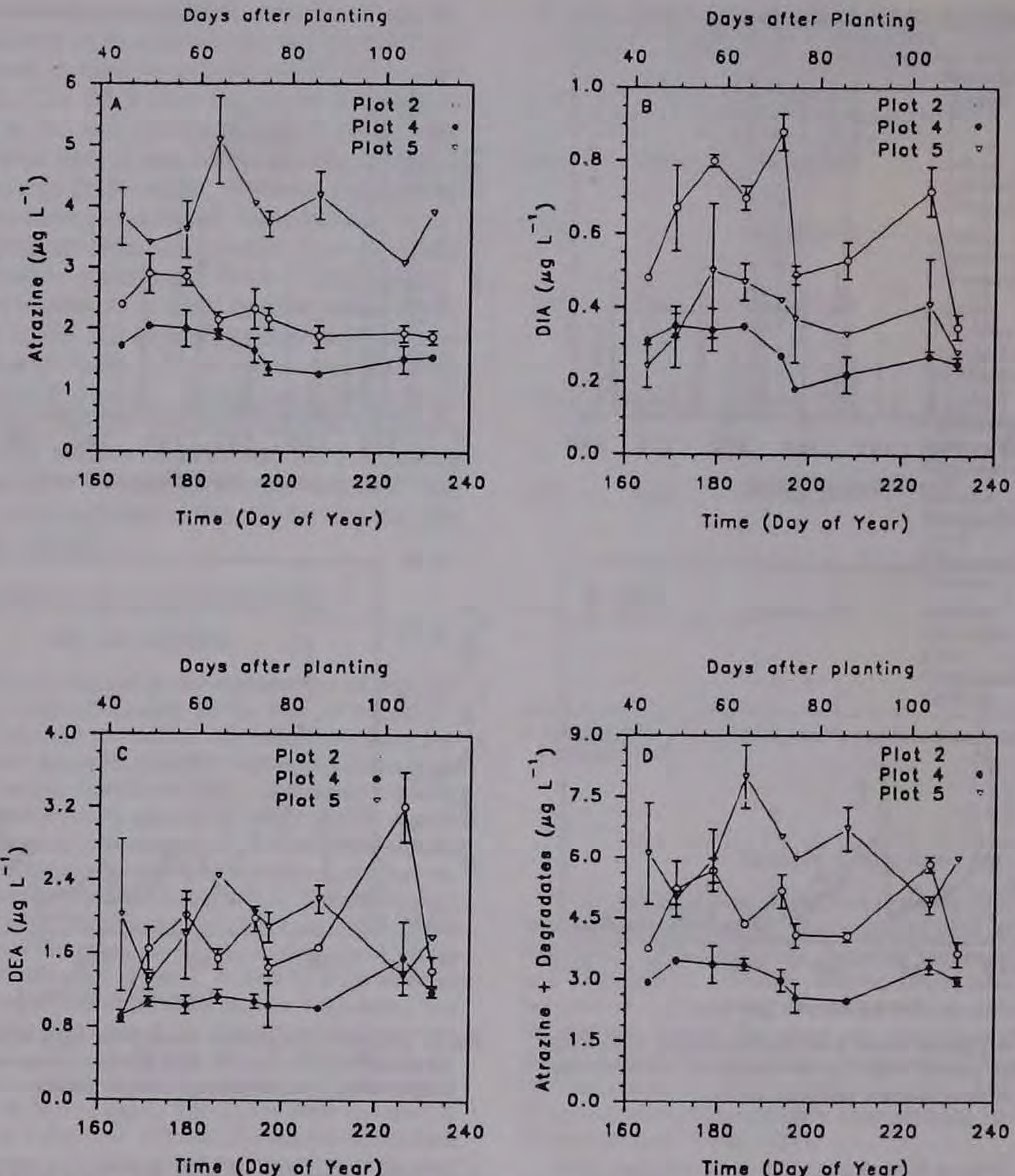

Fig. 3. Concentrations of (*A*) atrazine, (*B*) deisopropylatrazine (DIA), (*C*) deethylatrazine (DEA), and (*D*) atrazine + degradates in tile-drain water during 1990 growing season. Error bars repres 1t standard error of mean.

60%, required a matrix-spike recovery correction for the analyte. Each instrumental sequence consisted of 10 to 12 sample extracts sandwiched between two methanol blanks and two standard mixtures treated as unknowns, both at the beginning and at the end of the sequence. All injections were duplicated, with coefficients of variation calculated to be 7.5, 3.3 2.7, and 1.4% for DIA, DEA, atrazine, and TBA, respectively. Mean recovery of TBA for the entire sampling and analysis regime was 97%. Method detection limits are estimated at 0.03, 0.05, and 0.10 μg L^{-1} for DIA, DEA, and atrazine, respectively.

RESULTS AND DISCUSSION

Occurrence of Atrazine Congeners in Tile-Flow Drainage

The concentrations of atrazine, DIA, and DEA determined during the two growing seasons of 1990 and 1991, are presented in Fig. 3 and 4. Because each experimental plot was different in tile-drainage pattern (Fig. 1B and 2B) and transport of atrazine and degradates into groundwater (Table 2), results from each plot are presented separately. The overall concentrations of atrazine in tile-drain water during the period from 43 to 110 d after herbicide application ranged from 1.9 to 2.9 μg L^{-1} in Plot 2, 1.3 to 2.0 μg L^{-1} in Plot 4, and 3.1 to 5.1 μg L^{-1} in Plot 5 (Fig. 3A). These results are consistent with other reports of similar or greater concentrations of atrazine found in shallow groundwater systems (Muir and Baker, 1976; Hall and Hartwig, 1978; Spalding et al., 1979; Wehtje et al., 1984; Hallberg et al., 1985; Pionke et al., 1988; Isensee et al., 1990; Kanwar, 1991; Gaynor et al., 1992). Throughout the sampling periods in 1990, atrazine concentrations in Plot 5 were two times greater than in Plots 2 and 4. Although there is a slight lateral gradient in groundwater flow as a result of <2% relief, topography does not significantly influence the water table in any of the three plots. There-

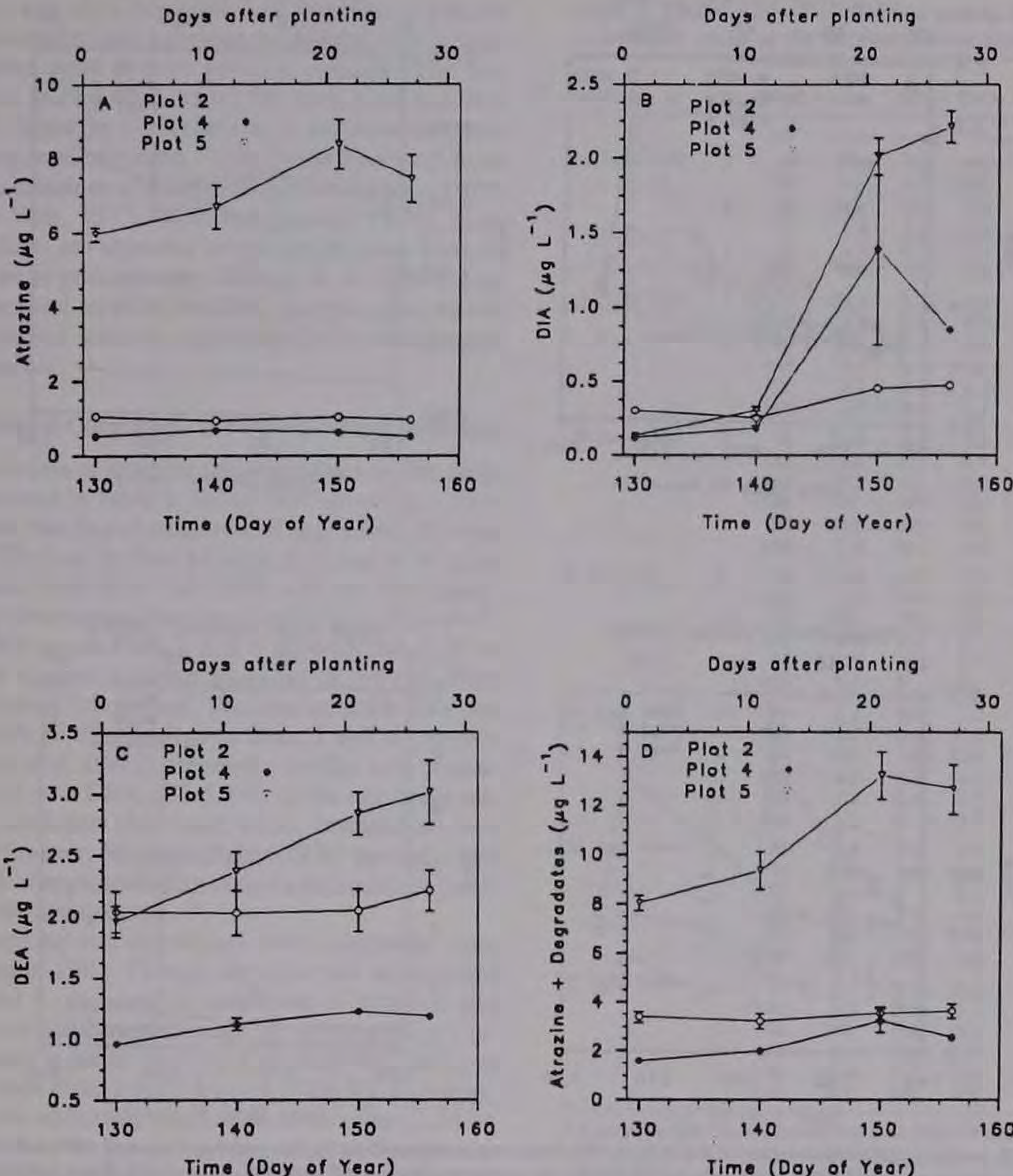

Fig. 4. Concentrations of (*A*) atrazine, (*B*) deisopropylatrazine (DIA), (*C*) deethylatrazine (DEA), and (*D*) atrazine + degradates in tile-drain water during 1991 growing season. Error bars represent standard error of mean.

fore, responses to groundwater level changes in Plot 5 are no different than Plots 2 and 4. Preferential flow through macropores could be of greater importance in this plot. Preferential flow of atrazine through macropores has been well documented (Isensee et al., 1990; Kanwar, 1991).

Table 2. Atrazine and degradates loss with subsurface drainage water during the growing seasons (May–Aug.) of 1990 and 1991.

Year	Plot no.	Atrazine	DIA	DEA	Total†
		g ha^{-1}			
1990	2	9.83	2.54	5.24	17.61
	4	5.40	0.92	2.63	8.95
	5	ND‡	ND	ND	ND
1991	2	1.11	0.44	2.39	3.94
	4	0.69	0.95	1.38	3.02
	5	5.40	0.88	1.88	8.16

† Total = DIA + DEA + atrazine.
‡ ND = not determined.

In the following season (1991), average concentrations of 1.0 and 0.6 µg L^{-1} atrazine were measured in Plots 2 and 4, respectively (Fig. 4A). These residues probably represent carryover from previous year's application. In Plot 5, greater concentrations of atrazine were measured in tile-drain water (Fig. 4A) than in drainage from Plots 2 and 4. In 1991, there was no spring atrazine application; however, Plot 5 received an additional application of atrazine at 2.24 kg ha^{-1} in November 1990. The average concentration of atrazine in Plot 5 was 6 to 8 times greater than Plot 2 and 10 to 14 times greater than Plot 4. The early season tile-flow pattern (Fig. 2B) in Plot 5 further supports the preferential flow effect on this plot. Intense rainfall events and a corresponding increase in tile-flow has been documented by Muir and Baker (1976), Kanwar (1991), and Kanwar et al. (1992); however, in our study there was no immediate effect of heavy rainfall on flow rates of drain

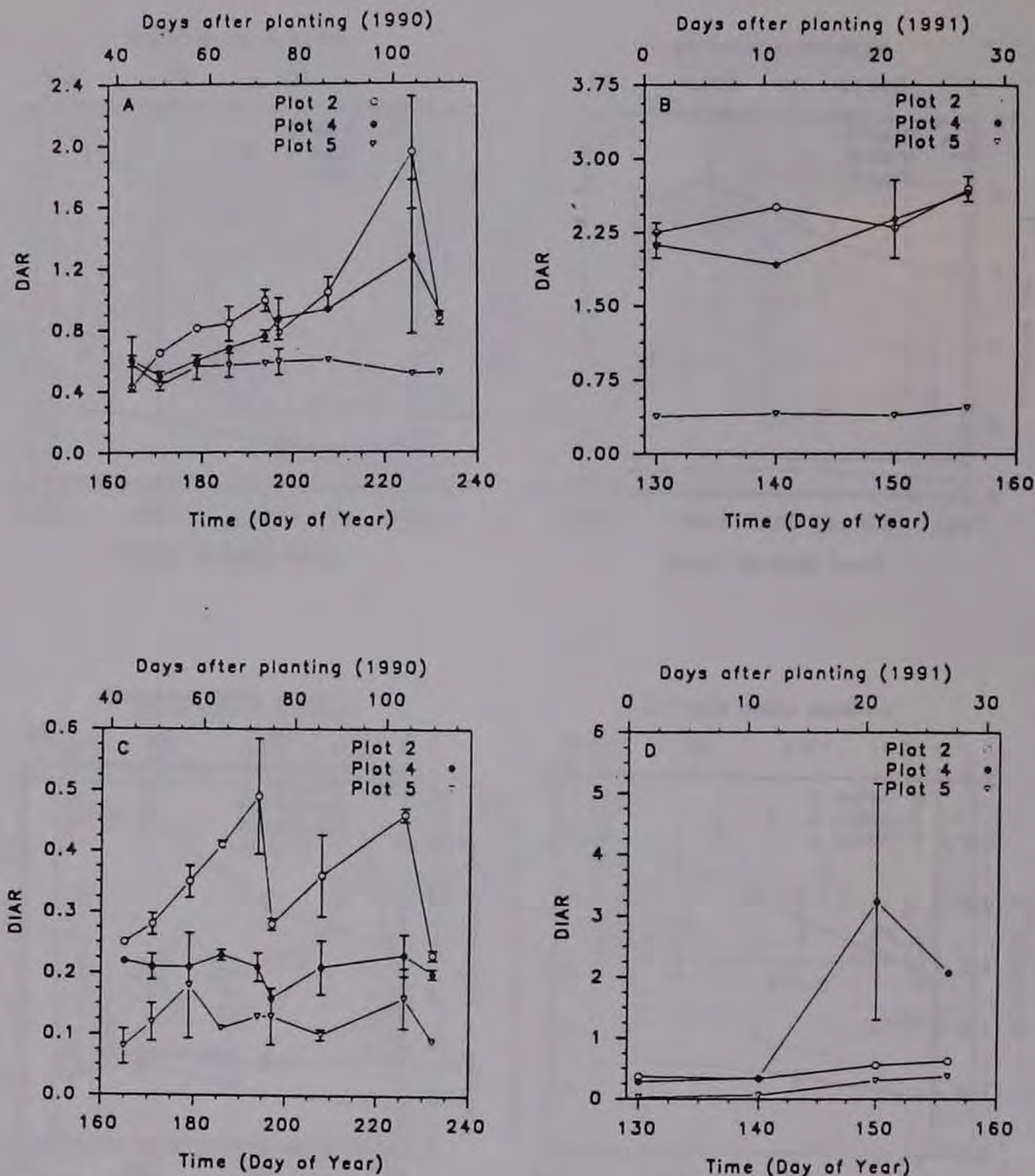

Fig. 5. (*A*) and (*B*) deethylatrazine-to-atrazine ratio (DAR) for tile-drain water collected during the growing seasons of 1990 and 1991, respectively, and (*C*) and (*D*) deisopropylatrazine-to-atrazine ratio (DIAR) for the same samples of 1990 and 1991, respectively. Error bars represent standard error of mean.

water except in the early part of the growing season of 1990 (Fig. 1 and 2). This was partly because 1988 and 1989 were extremely dry years and depth of water table was about 3 m, in the beginning of 1990. The tile-flow rates in our sampling period are relatively small compared with the early season rate. This could be due to the growing corn crop at the surface, which takes up a considerable amount of water from the profile.

Two major degradates of atrazine, DIA and DEA, were measured in all water samples collected during both seasons. Deethylatrazine concentrations in all three plots were greater than those of DIA (Fig. 3B, 3C, 4B, 4C); however, there was a greater concentration of DIA than DEA in Plot 4 on the 30 May 1991 sampling. A large standard error (0.642) associated with this data suggests that this may be an anomaly. Skipper and Volk (1972) showed that microbial removal of the ethyl side chain is 8 to 12 times more rapid than for the isopropyl side chain. Using radiotracer techniques on similar soil associations taken from the same field, Kruger et al. (1993a) showed that DEA and fully dealkylated atrazine were major degradation products. They also studied degradation and movement in undisturbed soil columns (Kruger et al., 1993b). In both studies, DEA was a major degradation product followed by DIA. Others have found a similar relationship (greater concentration of DEA than DIA) between these two degradates under both field and laboratory conditions (Sirons et al., 1973; Muir and Baker, 1976; Schiavon, 1988; Adams and Thurman, 1991; Gaynor, 1992).

Total atrazine residue (atrazine + DIA + DEA) concentrations are important, because the principal degradates are assumed to be at least as toxic as atrazine (Belluck et al., 1991), and their presence is of concern at greater levels. Total atrazine load exceeded the present mcl in samples from three plots in both growing seasons. The one exception was in Plot 4, in which the total load was less than the mcl. Since the *s*-triazine ring is resistant to cleavage with only small amounts $^{14}CO_2$ being liberated from ring-labeled *s*-triazines in soil (Kaufman and Karney, 1970; Skipper and Volk, 1972; Wolf and Martin, 1975), atrazine's degradates are expected to persist in some form in soil as well as in groundwater. Belluck et al. (1991) suggests that the total atrazine residue, atrazine plus its degrades, can exceed atrazine regulatory limits even though atrazine does not.

Losses of Atrazine Congeners through Tile-Flow Drainage

Quantitative loss of atrazine and degradates in tile-drain water is presented in Table 2. In the 1990 growing season (May–August), the loss of atrazine and degradates is twice as great for Plot 2 as for Plot 4 (Table 2). Loss of atrazine and degradates from Plot 5 for 1990 was not calculated, because only limited tile-flow data on that plot were available. Calculations on Plots 2 and 4 showed that 0.30 to 0.60% of the applied atrazine appeared in the tile-drain water as the parent compound. The total atrazine loss was 1.05 and 0.50% of that applied to Plots 2 and 4, respectively. Gaynor et al. (1992) reported a similar loss of atrazine combined with DEA (1.2–1.4%) in the tile-drain water from a Brookston clay loam under continuous-corn production. However, Muir and Baker (1976) showed a loss of only 0.15% of applied atrazine and its degradation products in the tile-drain water.

Loss of atrazine and degradates were calculated from all three plots in 1991. Though atrazine was not applied in Plots 2 and 4, measurable quantities of atrazine and degradates were discharged through tile-drainage flow (Table 2). A greater quantity (0.14%) of atrazine was lost from Plot 5 than from Plots 2 (0.07%) or 4 (0.04%). However, considering the additional application of atrazine (2.24 kg ha^{-1}) on this plot, the percentage loss may not be greater than that which occurred in the previous growing season. This suggests that the amount of rainfall governs transport of atrazine in the tile-drain water. The cumulative seasonal rainfall in 1990 (73.2 cm from May to August) was twice the cumulative rainfall in 1991.

Atrazine Congeners in Lysimeter and Piezometer Samples

During the early portion of the 1991 growing season, lysimeters yielded recoverable sample. However, later in the growing season reduced rainfall resulted in soil conditions in which no samples were captured. A maximum atrazine concentration of 20.5 µg L^{-1} was measured at a 90-cm depth in Plot 2 on the 18 June 1990 sample (Table 3). Hall and Hartwig (1978) reported a similar level of atrazine from suction lysimeters at a 120-cm depth in silty clay and clay loam soils. The concentration of atrazine in Plot 2 gradually declined to 2.4 µg L^{-1} by 20 Aug. 1990 (Table 3). At the 150-cm depth, the concentration of atrazine was less than at the 90-cm depth, but followed a similar trend as seen at the 90-cm depth. In general, Plot 2 showed greater concentrations of atrazine when compared with Plots 4 and 5, which is in contrast to the observation made on tile-flow analysis, where Plot 5 atrazine concentrations were always greater than those in Plots 2 and 4. In 1991, the Plot 5 lysimeter sample at the 90-cm depth had greater concentrations of atrazine than Plot 2, due in part to the additional application of atrazine on this plot. Deisopropylatrazine and DEA were detected in most samples, with the exception of the few at which the concentration was near the quantitation limit. Throughout the sampling periods, DEA concentrations at both depths were greater than DIA concentrations. The total atrazine residue (atrazine + DIA + DEA) concentrations were greater at a 90-cm depth from Plot 2 compared with the other two plots.

The average atrazine and degradates concentrations in the individual piezometer samples taken at different depths

Table 3. Concentrations of atrazine and its degradates in suction lysimeter water at the 90 and 150-cm depth (1990–1991).†

Date of collection	Plot no.	Depth	Atrazine	DIA	DEA	Total‡	DIAR§	DAR¶
		cm	µg L^{-1}					
14 June 1990	2	90	NS#	NS	NS	NS	NS	NS
		150	NS	NS	NS	NS	NS	NS
	4	90	NS	NS	NS	NS	NS	NS
		150	1.8	0.2	0.4	2.4	0.10	0.27
	5	90	4.0	0	1.1	5.1	–	0.33
		150	NS	NS	NS	NS	NS	NS
18 June 1990	2	90	20.5	0.3	3.0	23.8	0.02	0.17
		150	3.6	0.3	0.7	4.6	0.09	0.24
	4	90	NS	NS	NS	NS	NS	NS
		150	1.3	0.1	0.1	1.5	0.13	0.13
	5	90	9.7	0.4	3.5	13.6	0.06	0.41
		150	4.7	0.5	0.9	6.1	0.12	0.21
20 June 1990	2	90	13.9	0.6	2.5	17.0	0.06	0.20
		150	4.2	0.3	0.8	5.3	0.08	0.23
	4	90	0.7	0.2	0.3	1.2	0.30	0.46
		150	NS	NS	NS	NS	NS	NS
	5	90	NS	NS	NS	NS	NS	NS
		150	2.8	0.5	0.6	3.9	0.24	0.26
6 July 1990	2	90	8.9	1.3	3.3	13.5	0.18	0.42
		150	2.6	0.4	0.9	3.9	0.20	0.39
	4	90	NS	NS	NS	NS	NS	NS
		150	0.4	0.2	0.2	0.8	0.68	0.63
	5	90	4.2	0.2	2.4	6.8	0.06	0.67
		150	1.5	0	0	1.5	–	–
14 Aug. 1990	2	90	5.3	1.2	3.9	10.4	0.28	0.85
		150	1.7	0.5	0.9	3.1	0.35	0.57
	4	90	NS	NS	NS	NS	NS	NS
		150	0.6	0.2	0.6	1.4	0.33	1.13
	5	90	2.6	0.3	2.7	5.6	0.16	1.19
		150	1.2	0	0	1.2	–	–
20 Aug. 1990	2	90	2.4	0.3	1.0	3.7	0.17	0.46
		150	NS	NS	NS	NS	NS	NS
	4	90	0.6	0	0.5	1.1	–	1.00
		150	NS	NS	NS	NS	NS	NS
	5	90	NS	NS	NS	NS	NS	NS
		150	NS	NS	NS	NS	NS	NS
12 June 1991	2	90	3.7	0.3	3.1	7.1	0.09	0.97
		150	2.0	0.6	3.2	5.8	0.34	1.83
	4	90	NS	NS	NS	NS	NS	NS
		150	0.2	0.7	0.6	1.5	4.53	3.56
	5	90	18.0	1.7	6.0	25.7	0.12	0.38
		150	NS	NS	NS	NS	NS	NS

† A single sample was collected from each plot and depth and analyzed. Each value is a mean of replicate injections.
‡ Total = DIA + DEA + atrazine.
§ DIAR = deisopropylatrazine-to-atrazine ratio.
¶ DAR = deethylatrazine-to-atrazine ratio.
# NS = not sampled due to inadequate soil moisture.

Table 4. Concentrations of atrazine and its degradates in piezometer water collected in the months of May and June 1990 from Plot 4.†

Date of collection	Depth	Atrazine	DIA	DEA	Total‡	DIAR§	DAR¶
	cm	μg L⁻¹					
18 May 1990	120	5.6	0.5	0.7	6.8	0.11	0.14
	180	13.8	1.0	0.9	15.7	0.09	0.07
	240	0.3	0.3	0.1	0.7	1.08	0.41
	300	1.8	–	–	1.8	–	–
	360	0.1	0.2	–	0.3	2.64	–
12 June 1990	120	6.4	0.4	0.5	7.3	0.08	0.09
	180	13.1	0.8	1.1	15.0	0.07	0.10
	240	0.1	0.2	–	0.3	1.92	–
	300	0.1	–	–	0.1	–	–
	360	–	–	–	–	–	–

† A single sample from each depth was collected and analyzed. Each value is a mean of replicate injections.
‡ Total = DIA + DEA + atrazine.
§ DIAR = deisopropylatrazine-to-atrazine ratio.
¶ DAR = deethylatrazine-to-atrazine ratio.

during May and June of 1990 are presented in Table 4. The average concentration of 6 μg L^{-1} atrazine was detected at the 120-cm depth, whereas at the 180-cm depth, a concentration of 13.5 μg L^{-1} was measured. The atrazine concentration was significantly decreased below the 180-cm depth, suggesting that atrazine is moving at a much slower rate beneath that depth. The distribution of degradates at different depths in the piezometers followed a pattern similar to atrazine, although concentrations were diminished.

Geochemical Implications of Parent to Degradate Ratios

For the soil metabolism of atrazine, a parent-to-metabolite ratio has been proposed as an indicator of biogeochemical processes occurring in the soil, which influence groundwater quality. In both growing seasons the DAR values in Plot 5 did not change during the sampling periods (average DAR 0.55 in 1990 and 0.41 in 1991), suggesting a possible role for preferential flow through macropore environments, thus allowing less time for deethylation of atrazine (Fig. 5A and 5B). In Plots 2 and 4, the DAR values during 1990 were at 0.43 and 0.60 in the early part of the growing season a. d gradually in^reased to 1.95 and 1.27 during mid to late summer, indicating that the biodegradation process correlated directly with residence time. A smaller DAR at the beginning of the growing season followed by a gradual increase in the later part of the season was also reported by Adams and Thurman (1991).

Because DIA was also detected in almost all samples, and micrrbial removal of the isopropyl side-chain is well documented, a deisopropy.atrazine-to-atrazine ratio (DIAR) was also calculated and correlated with DAR values. In general, the DIAR values were smaller than DAR values. The correlation coefficients (r^2) between DAR and DIAR were 0.65 for 1990 and 0.47 for 1991 data. The majority of the DIAR values were less than 0.5 and remained relatively constant. Following formation in the soil, DIA is either rapidly degraded into other chemical congeners or is rapidly leached through the soil profile by virtue of its enhanced hydrophilicity compared to DEA. Therefore, the use of DIAR value to explain the movement of atrazine does not offer the same utility as the DAR values.

The DIAR and DAR values for lysimeter and piezometer samples are presented in Tables 3 and 4. In lysimeter samples, particularly at a 90-cm depth from the plot where a greater concentration of atrazine was detected, the DAR value was 0.17. Where lesser atrazine concentration was measured, greater concentration of DEA was observed, producing DAR values as great as 0.85. This suggests prolonged residence time for atrazine in the surface soil, resulting in greater microbial degradation.

CONCLUSIONS

Atrazine, DIA, and DEA were consistently detected in both shallow groundwater and subsurface tile-drainage beneath no-till continuous corn plots in central Iowa during 2 yr. Atrazine concentration exceeded the mcl of 3 μg L^{-1} in a significant percentage (>40%) of samples. Variability in concentration of atrazine and degradates was associated with characteristics of the individual plots (atrazine 0.5–8.4, DIA 0.1–2.2, and DEA 0.9–3.2 μg L^{-1}). The ratio of deethylatrazine-to-atrazine (DAR) suggested that shorter residence time in the soil allowed minimal microbial contact in Plot 5, where the greatest atrazine concentrations were determined in tile drainage. Atrazine was detected in both shallow groundwater and in tile drainage several months following the most recent application. Because most tile drainage is discharged to the surface, contamination with atrazine and degradates represents a risk to surface water quality. However, the occurrence of these contaminants in the shallow groundwater system does not preclude movement into deeper aquifer environments.

ACKNOWLEDGMENTS

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SOIL RESEARCH

Section 5-N Soil Characteristics

Section 5-N.1 Soil, Water, and Physical Parameters

S. Logsdon NSTL

Bassett's No-till Field: (In cooperation with C. Cambardella, T. Moorman, and T. Steinheimer at the NSTL)

Site Locations

Fourteen locations within the no-till field have been selected for study. Detailed locations and elevations have not been mapped yet, but Figure 1 provides approximate locations of sampling sites 39-44 and 45-52 in relation to soil mapping units.

Sampling Techniques and Observation Schedule

Groundwater Monitoring

Groundwater monitoring wells (piezometers) in the Bassett no-till field were installed by United States Geological Survey in fall 1992 and winter 1993 at two depths for each sampling site. Wells are cased with 5-cm inner diameter PVC pipe with screw fittings (Ti Loc Brainard Kilman). The bottom 75 cm in each well is screened and the upper 75 cm section can be removed during planting and harvesting operations. Depth to groundwater in wells has been monitored manually since spring 1993 during the growing season as dictated by weather conditions.

Depth to groundwater was referenced at the top of each well casing and measured with a battery-operated well depth indicator. The indicator tape is rinsed

Soil Mapping Units:

90 Okoboji
107 Webster
507 Canisteo
55 Nicollet
138 Clarion

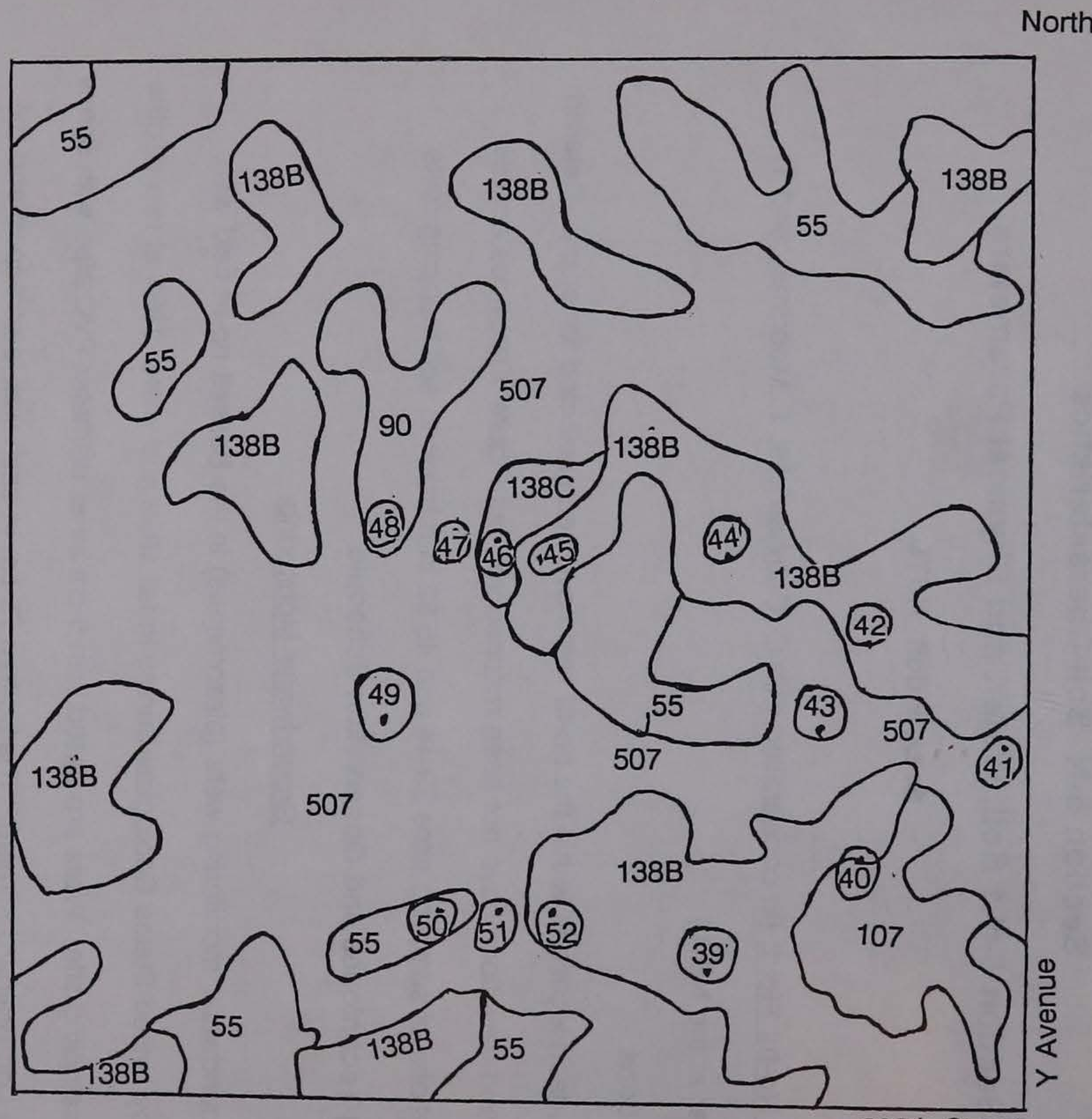

Figure 1. Approximate locations of study sites in relation to soil mapping units in SE 1/4, Section 24, T.83N., R.25W.

with distilled water between wells, and depths are recorded manually on data sheets. Calibration of the tape is not necessary because the degree of accuracy is sufficient. Measurements are supervised by a National Soil Tilth Lab (NSTL) technician, but may be made by an hourly employee. When possible, depths are measured one and sometimes two days after a significant rainfall event. Measurements occur no more frequently than twice a week. If no significant events occur, depths are monitored at least once every three weeks, and are coordinated with groundwater sampling by others. Plans are to continue monitoring the wells once a month during the winter.

Neutron Probes

During the growing season, neutron probe measurements (Gardner, 1986) are made on the same schedule as groundwater monitoring, for depths from 30 to 250 cm beneath the soil surface. Additional monitoring may proceed during dry periods when well monitoring has tapered off. Access tubes are 5 cm diameter steel EMT, installed with a Giddings auger. Bentonite was filled in around the top 20 cm of each tube to provide good soil tube contact and prevent water flow down the side of the tube.

Surface soil water samples have not been collected regularly, but will be in the future on the same schedule as neutron probe monitoring. Surface soil water samples are needed because neutron probe moisture measurements cannot be made near the soil surface.

Neutron probe measurements are made by a NSTL technician equipped with a radiation badge, and are recorded in a log book.

Tensiometers

Tensiometers are installed during the growing season at four depths at each sampling site beginning with 1993. Each consists of 2.5 cm inner diameter PVC tube with a 7.6 cm long ceramic head glued to the base, and a 2.5 cm acrylic tube glued to the top to which a septum is attached (Soil Moisture Systems, Construction of Tensiometers). A tensiometer installation corer or other soil sampler is used to make a hole in the soil just smaller than the tensiometer tube, and the tensiometer is then slid into place. Bentonite is packed around the surface 20 cm to prevent water flow down the side of the tensiometer.

Tensiometers are manually read with carry-along transducers connected to needles that are inserted through septa for the measurement (Stannard, 1990). A NSTL technician supervises the readings, which may be performed by hourly employees. All four transducers for a location are read at the same time and recorded on a Campell Scientific 21X data logger. Transducers are prepared for field measurements by taking blank readings during transport to the field. Readings are taken every 5 s for 1 min. The schedule for tensiometer readings is the same as for groundwater monitoring, except that tensiometers are not installed during the winter.

Soil Characteristics

Soil cores were taken fall 1993 at each site for detailed soil descriptions. A 38 mm diameter Giddings hydraulic probe fitted with a clear acrylic liner was used to collect an intact core down to 2 m. Liners were removed, capped, brought back to the laboratory, and stored in a cooler. Soil cores were removed from the liners and a soil profile description made for each. Soil morphologic characteristics such as horizonation, color, structure, drainage class, and other features (shells, Fe and Mn concretions, sand and gravel layers, etc.) were determined by a NSTL scientist for each core and recorded on data sheets.

Soil particle size analysis (Gee and Bauder, 1986) will be determined by the hydrometer method for each major horizon in each core collected at each site. If possible a determination will be made of total carbon, organic carbon, and carbonate carbon.

Undisturbed soil cores were collected for many of the horizons at each site, but wetness prevented the collection of "good" samples from some of the deep horizons. These cores (73 mm diameter by 76 mm long) were collected in thin-walled steel cylinders with a Giddings hydraulic probe. Deep horizon undisturbed soil cores will be collected again. Soil cores are used to determine soil hydraulic properties and bulk density. Preliminary bulk density was determined from the moisture content of the trimmed soil. Saturated hydraulic conductivity was determined by the falling-head method (Klute and Dirksen, 1986). The undisturbed cores will be desorbed to 100, 300, 600, and 900 mbars within individual desorption units, then disturbed subsamples will be desorbed to 3 and 15 bars. Other subsamples will be used at the end of 900 mbar desorption to get soil moisture content for another estimate of bulk density.

Tile Flow

Plans are being made to install tile monitoring equipment at the east end of the field for measuring rainfall event infiltration of water and surface applied pesticides.

Data Format and Processing

Water level depth for each well is entered on the computer and processed by a QUICK BASIC program which converts data to groundwater depth below soil surface. This data is entered on data sheets organized by well location (rather than by date). A NSTL technician and scientist process and review the data.

This data will be used to indicate groundwater or piezometric head levels in relation to landscape position. Though the screened zone is diffuse, horizontal and vertical gradients will be calculated to indicate flow gradients.

Neutron probe data are recorded in a log book. A NSTL technician and scientist process and review the data. Probe calibration is only partially accomplished so far; soil water samples were collected to 2.5 m at the same time as measurements were made with the neutron probe. Calibration data has only been collected for the wet end of the curve, so calibration is suspect until calibration samples at the dry end can be collected. In the interim, the intercept of the "universal" calibration curve supplied with the instrument is being used for the dry point in the calibration curve.

Tensiometer data is downloaded to the computer, processed on a QUICK BASIC program, and is reviewed by a NSTL scientist. A data summary is recorded on data sheets for each location over time.

Neutron probe data will be used in conjunction with well and tensiometer data to determine water flow patterns in this field in the watershed. During the growing season, the data will also be used to determine water uptake patterns.

Laboratory soil data (particle size analyses, bulk density, hydraulic property measurements, etc.) are recorded either on data sheets or on the computer (weights from balance connected to laptop). Data is processed by QUICK BASIC and C programs, and reviewed by a NSTL scientist.

Each of the data components collected for each location (water level in wells, neutron probe soil, tensiometers, and soil water content) will be compared to the other components as a QA/QC check. These measurements will characterize water flow patterns within the no-till field in relation to movement of nitrate and pesticides within and out of the field. The final data will be available in ASCII computer files.

Individual Research Studies

Soil core measurements in Bassett's pothole (disk) field

Undisturbed soil cores were collected with depth in the fall of 1991 near 14 well sites (refer to Section 5-M.2 of this report). A Giddings hydraulic probe was used to collect the samples. These cores were used to determine saturated hydraulic conductivity, bulk density, and soil water desorption.

Lateral flow on one hill in Bassett's no-till field

Shallower wells have been installed at sites 45, 46, and 47, during winter 1994, and wells at two depths have been added at similar landscape positions on the northwest side of the same hill (Fig. 1). These well sites are called 46b and 47b. The wells were installed with a Giddings hydraulic probe. Twelve of these wells (including 48) will be automated for measuring depth to groundwater during sampling events.

Between these two sets of wells, horizontal time-domain reflectometry (TDR) waveguides (Baker and Allmaras, 1990; Baker and Spaans, 1993) were installed in the fall of 1993 at similar landscape positions (designated 45a, 46a, and 47a). Three soil pits were dug and TDR waveguides were installed horizontally into the soil at 8 different depths between the soil surface and 1 m. The TDR are for automated monitoring of water content, in conjunction with a groundwater sampling event. Both disturbed soil samples and undisturbed soil cores were collected by hand along the sides of the installation pits.

Preferential water flow patterns with depth

In conjunction with other monitoring by D. Jaynes, ponded and tension infiltrometers (Logsdon and Jaynes, 1993) were used to characterize macropore flow at several depths in three soils during summer-fall 1992: Clarion in Bassett's pothole (disk) field; Okoboji in Bassett's disk field; and Nicollet in Black's east (chisel) field. In addition, undisturbed soil cores were collected by hand at the same depths for determination of saturated hydraulic conductivity, and soil moisture desorption.

Lateral solute movement

Bromide and dye (rhodamine WT) were applied in a strip near the top third of a hill in Bassett's pothole (disk) field during spring 1993. Three wells, 3 neutron access tubes, and 4 sets of tensiometers were installed downslope. Soil samples for bromide analysis were collected downslope on four dates. After harvest, a pit was dug to observe dye movement, and undisturbed soil cores were taken by hand at several depths for measurement of saturated hydraulic conductivity, bulk density, and soil moisture desorption. This study was conducted in cooperation with D. Jaynes.

Surface ponded and tension infiltration

During four sampling events (summer 1991 through spring 1992) in Bassett's pothole (disk) field, ponded and tension infiltration (Logsdon and Jaynes, 1993) was measured across a transect just south of the east-west well sites. These measurements characterize the macropore function of the top 5 cm of soil, and give an indication of spatial and temporal variability.

Near surface ponded and tension infiltration

Ponded and tension infiltration (Logsdon and Jaynes, 1993) was measured fall 1991 for three soils (Clarion, Nicollet, Webster) at 4 depths (0, 15, 25, and 35 cm) at two locations per soil within Bassett's "pothole" (disk) field. These measurements characterize functional preferential pathways for water.

No-till conversion study

Bassett's no-till field has been paired with Bassett's disk field by examining three map units (Clarion, Nicollet, and Canisteo), with two replicates per map unit. The purpose of the study is to measure soil properties during the conversion period to a no-till system. In 1992, ponded and tension infiltration was measured at these locations. In 1993, incremental (2 cm increments) bulk density measurements (Allmaras et al., 1988) were measured to 30 cm depth at these locations. Once or twice a year through 1997, incremental bulk density will be measured, possibly supplemented with ponded and tension infiltration measurements. The incremental samples can also be used to characterize distribution of residue, weed seed, and organic carbon.

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Section 5-N.2 Field-scale Variability of Soil Properties

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Note: Portions of this section were extracted from Cambardella et al. (1994).

Site Locations

Field-scale distributions and spatial trends for 28 different soil parameters were studied at two sites within Walnut Creek watershed. The study was conducted on the "Pothole field" and Bassett's no-till field[1]; both are intensively monitored fields located in the northwest end of Walnut Creek watershed (refer to Section 5-D for site location descriptions). The Pothole field has an area of 36 ha and is cropped to corn (Zea Mays L.) and soybeans (Glycine max L.). Tillage is done in the fall with a chisel plow and weeds are controlled with a combination of cultivation and herbicides. Anhydrous ammonia fertilizer is applied in the fall. Corn residue has been removed from the field in the fall after harvest since 1980. The field has an elevation gradient of 4.05 meters from the lowest to the highest point and contains one drained and one undrained pothole.

Basset's no-till field is located approximately 2 km directly north of the Pothole field and covers an area of 96 ha. The elevation gradient across the field is 4.24 m. Until 1991, this field had been under similar management practices as the Pothole field except that corn residue was not removed. Since 1991, the field has not been

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[1]Bassett's no-till field is also referenced in Section 5-N.1 of this report.

chiseled as the farmer-operator began the transition to no-tillage. The no-till field was cropped to soybeans in 1992 and no fertilizer was applied.

Field Sampling Techniques

<u>Pothole Field</u>

A 250 x 250 m square sampling grid (6.25 ha) was established on the southeast corner of the Pothole field in the last week of April 1992, just before corn planting (Fig. 1). The grid encompassed soils formed in summit, backslope and depression landscape positions. The grid pattern consisted of main intersection points separated by a distance of 25 m and secondary points at 2, 5 and 10 m intervals to produce a total of 241 sampling points. Each grid point was surveyed using a rod and transit to determine elevations.

Three randomly-located soil cores were collected to a depth of 15 cm from within a 1-m circle around each grid point using a 6-cm inner-diameter coring tool. The three cores from each grid point were composited and stored in plastic bags for transport back to the laboratory.

Separate intact cores were removed from the main intersection points of the grid (121 samples) for estimates of denitrification and respiration. Cores were obtained by pounding a steel coring tube (5-cm inner-diameter) containing a plastic cylinder insert into the ground to a depth of 15 cm. The plastic insert was then removed from the coring tube and stoppered at both ends for transport back to the National Soil Tilth Laboratory (NSTL).

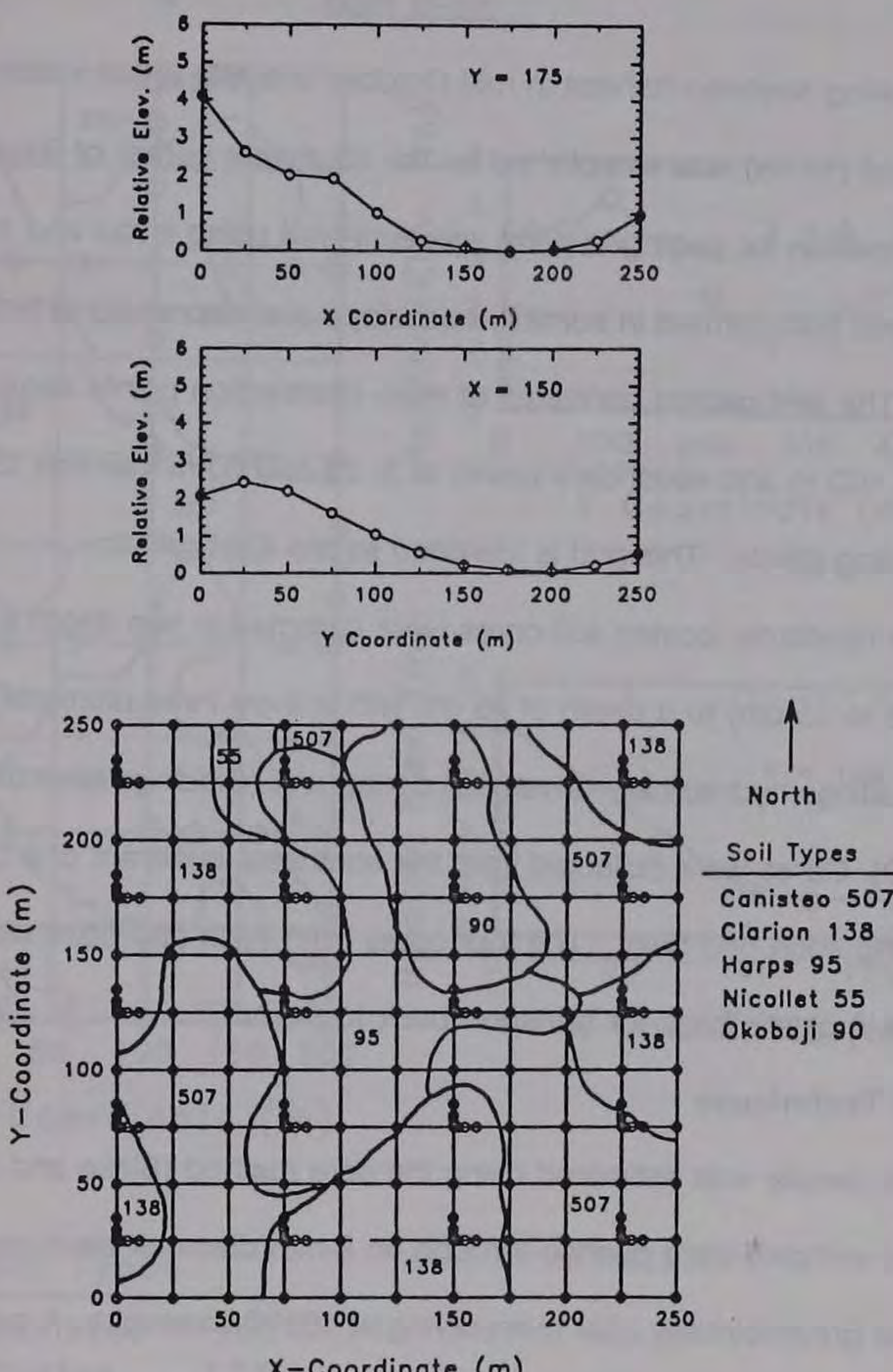


Figure 1. Relative elevations across two transects of the Pothole field and the sampling grid in relation to soil map units. A large depressional area is centered at approximate coordinates of (175,175), and a smaller depressional area at (250,0). The highest point in the grid is at (0,175). Open circles signify grid sampling points.

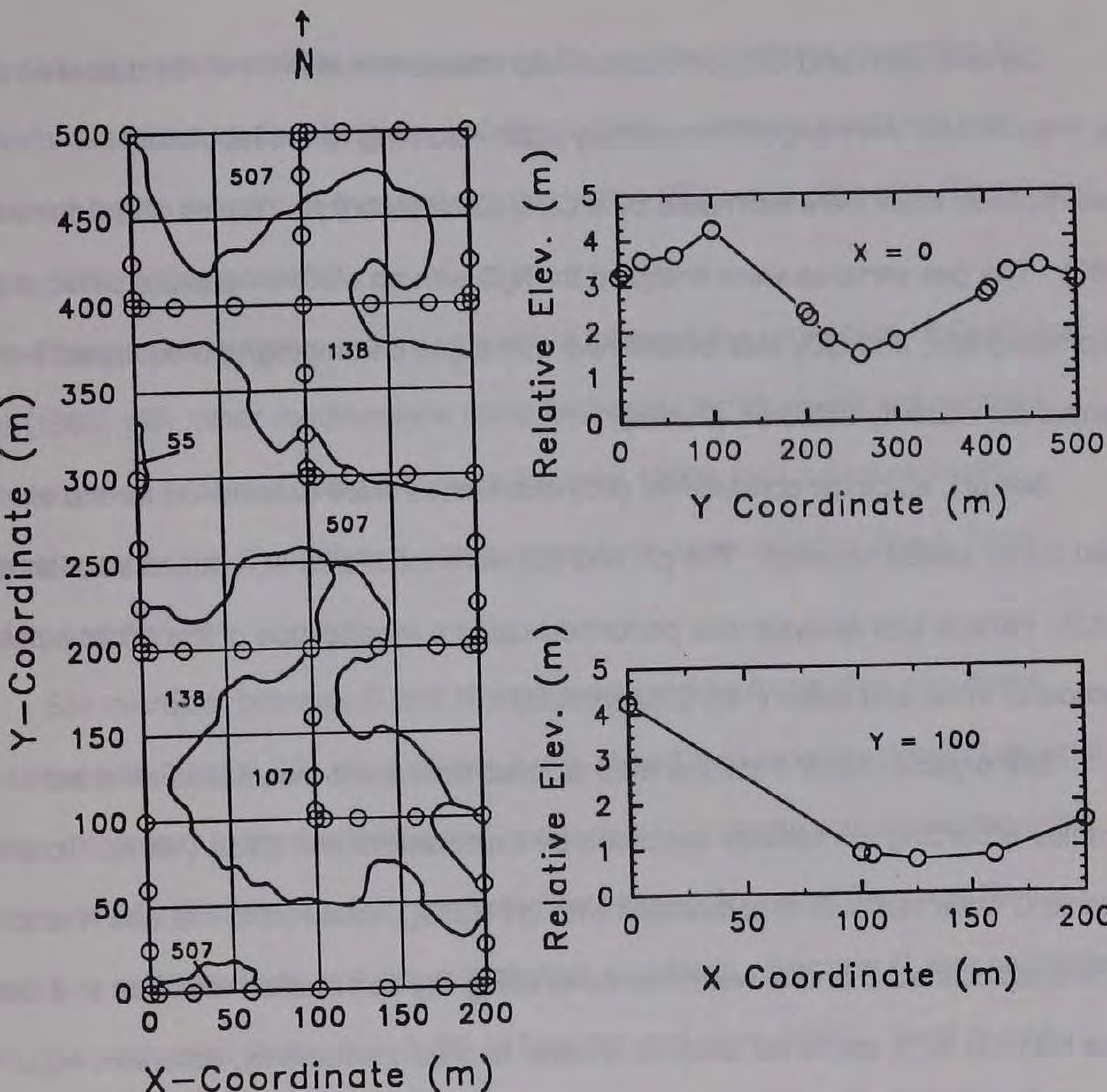
No-till Field

Following soybean harvest in mid-October of 1992, a 200 x 500 m rectangular sampling grid (10 ha) was established on the southeast corner of Basset's no-till field (Fig. 2). Elevation for each grid point was surveyed using a rod and transit. The grid encompassed soils formed in summit, backslope and depressional landscape positions. The grid pattern consisted of main intersection points separated by a distance of 100 m and secondary points at 5, 25 and 60 m intervals to produce a total of 72 sampling points. This grid is identified as the East grid.

Four randomly located soil cores were collected in two depth increments (0 to 7.5 and 7.5 to 15 cm) to a depth of 15 cm with a 8-cm inner-diameter coring tube using a Giddings hydraulically-driven soil coring unit (Giddings Machine Co., Ft. Collins, CO). Cores were collected from the southeast quadrant of a 3-m diameter circle around each grid point. The four cores from each grid point were composited and stored in plastic bags for transport back to the NSTL.

Analytical Techniques

Bulk density was estimated using the core method (Blake and Hartge, 1986). Field-moist samples were pushed through an 8-mm diameter sieve and water content determined gravimetrically after oven-drying at 105°C overnight. A subsample was dried at 40°C and stored at room temperature prior to analysis. Another subsample was air-dried, passed through a 2-mm diameter sieve and stored at room temperature prior to analysis. The remainder was stored moist at 4°C. All data were expressed on an oven-dry weight basis. (Cambardella and Moorman)



Soil Types	
Canisteo	507
Clarion	138
Nicollet	55
Webster	107

Figure 2. Relative elevation across two transects of the No-till field and the sampling grid in relation to soil map units. The highest point on the grid is at (0,100) and the lowest at (200,500). Drainage is generally from west to east. Open circles signify grid sampling points.

Denitrification and CO_2 production rate measurements of the intact cores from the Pothole field were begun immediately upon returning to the laboratory. Denitrification rates were estimated by a C_2H_2 block technique (Parkin and Robinson, 1989). The gas samples were analyzed for N_2O with an electron capture detector-gas chromatograph, and CO_2 was determined with a gas chromatograph equipped with a thermal conductivity detector. (Parkin)

Soil pH, electrical conductivity (EC) and texture were determined for the air-dried 2-mm sieved samples. The pH and EC were measured at a soil to solution ratio of 1:2. Particle size analysis was performed using a modification of the micro-pipet method of Miller and Miller (1987). (Moorman)

Soil organic matter fractions were isolated from the 2-mm sieved air-dried samples according to methods described by Cambardella and Elliott (1992). Total organic C (after removal of carbonates with 2N H_2SO_4), total N, POM C and N and mineral-associated C and N were measured using dry combustion methods in a Carlo-Erba NA1500 NCS elemental analyzer (Haake Buchler Instruments, Paterson, NJ). (Cambardella)

Field moist, 8-mm sieved soil subsamples were extracted with 2M KCl, and inorganic N [(NO_3 + NO_2) and NH_4] in the filtrate was determined using flow injection technology (Lachat Instruments, Milwaukee, WI). Mineralizable N was measured in the 2-mm sieved air-dried subsamples using methods described by Keeney and Bremner (1967). (Cambardella)

Wet aggregate stability was assessed for air-dried samples according to methods described by Cambardella and Elliott (1993). Macroaggregation was calculated as the percent of the total soil that was >250 μm in diameter (Tisdall and Oades, 1982). (Cambardella)

Ergosterol extraction and measurement followed the procedure of Grant and West (1986) with minor modifications using field-moist 8-mm sieved soil samples. Ergosterol was analyzed using a Hewlett Packard 1090A high pressure liquid chromatograph (HPLC) equipped with a photodiode array detector (Eash, 1993). (Karlen and Parkin)

Soil microbial biomass C and N were measured by fumigation and direct extraction with 0.5M K_2SO_4 on duplicate 8-mm sieved field-moist samples (Tate et al., 1988). Organic C in the fumigated and nonfumigated extracts was measured using a Dohrmann DC-180 Total Carbon analyzer (Rosemount Analytical Services, Santa Clara, CA) calibrated with potassium phthalate standards. Biomass C was calculated using the correction factor (k = 0.33) of Sparling and West (1988). Total N was measured in the fumigated and nonfumigated extracts using Lachat flow-injection analysis (Lachat Instruments, Milwaukee, WI) following wet oxidation with the addition of Devarda's alloy to reduce NO_3-N to NH_4-N (Brooks et al., 1985a). Biomass N was calculated using equations presented in Brooks et al. (1985b) with a correction factor of 0.54. (Cambardella)

Microbial biomass was also estimated by an alternative method which quantifies microbial phospholipid phosphate (Findlay et al., 1989). Phospholipids were extracted with a buffered solution of chloroform and methanol. The lipid-associated phosphate was hydrolyzed at 95°C in potassium persulfate after evaporation of the organic solvent and the resultant phosphate concentrations were measured colorimetrically using ammonium molybdate and malachite green reagents. Phospholipid analysis was done in the laboratories of Dr. Ron Turco and Dr. Alan Konopka at Purdue University.

Dehydrogenase assays were performed on field-moist soils that had been stored at 4°C. Soils were sieved (2-mm mesh) and treated with $CaCO_3$ (Tabatabai, 1982). Triplicate 6-g subsamples were treated with a solution containing 100 mg/ml of yeast extract and 300 mg/ml of 2,3,5-triphenyltetrazolium chloride (TTC) and incubated 24 h at 37°C. Triphenyl formazan (TPF) was extracted with methanol and measured spectrophotometrically. The average recovery of TPF added to soil and immediately extracted was 80%. (Moorman)

Atrazine sorption was determined on duplicate 4-g samples of 2-mm sieved air-dry soil. Soil was equilibrated with 15 ml of solution containing 1 mg/L atrazine dissolved in 0.01M $CaCl_2$ for 72 hours, then centrifuged. Atrazine concentration in the equilibrium solution was analyzed using HPLC (J. M. Novak, 1993, personal communication). (Moorman)

Extractable P (Bray P1) (Knudsen and Beegle, 1988) and 1 M exchangeable K, Ca and Mg (Brown and Warncke, 1988) were measured for each dried, 2-mm sieved sample. Phosphorous concentrations were measured colorimetrically using ascorbic acid-ammonium molybdate reagents with a Lachat flow-injection analyzer (Lachat

Instruments, Milwaukee, WI). Cations were measured using atomic absorption spectrophotometry. (Karlen)

Crop residue was estimated by removal of all surface residue from a 0.60 m^2 circular area at each grid point at the No-till field. Residue was removed from the same quadrant around the grid point as the soil cores. Residue amount was reported as grams of oven-dried residue per m^2 of surface area. (Cambardella and Moorman)

Observation Schedule

The sampling grid in the Pothole field was established in the last week of April 1992, just before planting. Soil cores were collected from this field within two weeks after the grid was established.

The east side of Basset's no-till was planted to soybeans in 1992 and the west side to corn. The East sampling grid was established at Basset's no-till field following soybean harvest in mid-October 1992. Soil cores were collected from this field after the grid was established. Soybean yield was also estimated for harvest transects within the sampling grid. Another grid, identical to the East sampling grid in size and grid pattern, was established at the west end of Basset's no-till field following corn harvest in November of 1992 (the West sampling grid). However, an early winter snowstorm prevented us from sampling this grid as planned in November of 1992. In the spring of 1993, we were once again unable to sample the West grid because of extremely wet and rainy weather but we were able to obtain estimates of crop residue mass and percent cover for each grid point on the West grid. The West grid was sampled at the 18 main intersection points to a depth of 15 cm in 2 depth increments

(0-7.5 cm and 7.5-15 cm) after soybean harvest in November of 1992. The East grid was also sampled in a similar fashion after corn harvest in November of 1992. Both the East and West grid at the 18 main intersection points will be sampled in 1994 and 1995 after harvest. In the Fall of 1996 after harvest, the entire East and West grid pattern (72 points) will be sampled.

Quality Assurance and Quality Control

Data is entered into spreadsheets, reduced and screened by senior level laboratory technicians for unusual values, outliers and for quality control. After initial screening, the data is reviewed by research scientists and appropriate statistical analyses are performed.

Data Format and Processing

Data are kept by the individual scientists on their personal computer (PC) harddrive and on diskette. Cambardella keeps duplicate copies of all the data from all the researchers on PC harddrive and on diskette. Statistical analyses were performed by Cambardella and Moorman.

Statistical Methods

Statistical analyses of the data was done in three stages: (1) frequency distributions were examined and background normality tests were conducted in Statistical Analysis systems (SAS); (2) distributions were described using traditional summary statistics (mean, standard deviation and CV) and with the median and interquartile range in SAS; and (3) semivariograms were defined and differences in nugget and total semivariance and range examined for the variables using GS+

software (GS+, Geostatistics for the Agronomic and Biological Science, Version 1.1, Gamma Design Software) software. Output files from SAS and geostatistical analysis are stored on Cambardella's PC.

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5-N.3 Herbicide Sorption and Biodegradation Studies

T. B. Moorman NSTL

Overview

Sorption and degradation of herbicides are key processes that affect their distribution in soil and water. This research was designed to provide estimates of these processes for the herbicides atrazine, alachlor and 2,4-D in surface and subsurface soils and to relate these processes to certain chemical and microbiological properties of the soils. Adsorption and degradation are measured in the laboratory to obtain relative comparisons of these processes without the confounding effects of climate and soil variability. This information will be used for model inputs and for assessment of the key parameters controlling herbicide fate.

Site Locations

Research was conducted in Walnut Creek watershed at Bassett's conventional tillage field "pothole field" (Tract No. 3010) and the alluvial area where Walnut Creek joins the Skunk River (Tract No. 2449 and adjacent areas, hereafter referred to as the Skunk River alluvium site, SW 1/4, SW 1/4, Section 5, T82N, R23W, Story County). The Pothole Field is described in section 5-N.2 of this report (Fig. 1). The Skunk River site consists of farmland that is adjacent to Walnut Creek where it flows east from I-35 towards the Skunk River. Soils in this area are primarily classified as Coland-Spillville-Zook association. These soils overlie alluvial deposits of sand and silt and shallow groundwater. Agricultural practices on these fields are similar to those used throughout the watershed.

Field Sampling Techniques

The spatial variability of atrazine adsorption and 2,4-D degradation was measured using a geostatistical sampling approach at the Pothole Field (Cambardella et al., 1994). Soil samples from 0-15 cm depths were collected from 241 locations within a 6.25 ha area, which included the large pothole. To assess degradation and sorption in the subsurface, continuous core samples were also collected by National Soil Tilth Laboratory (NSTL) staff in cooperation with U.S. EPA (United States Environmental Protection Agency), S. Kerr Environmental Research Laboratory, to a depth of 3 to 5 m using a hollow-stem auger (Leach et al., 1988). Continuous cores were taken from the hill-top, side-slope and depressional areas at the Pothole field and from three locations at the Skunk River alluvium site.

Experimental Procedures

Table 1 summarizes herbicide degradation and sorption processes research in Walnut Creek watershed. Analytical procedures were performed at the National Soil Tilth Laboratory (NSTL) (Moorman).

Table 1. Herbicide degradation and sorption studies in Walnut Creek watershed.

Site	Alachlor	Atrazine	2,4-D
Pothole Field	Degradation, Sorption	Degradation, Sorption	Degradation
Skunk River		Degradation, Sorption	Degradation

Herbicide Sorption

1. Soils were prepared for studies by air-drying and sieving (2 mm).

2. Adsorption to soil was measured using batch equilibration methods. Duplicate 4-g soil samples were weighed into 25-mL glass centrifuge tubes.

3. Herbicide concentrations were prepared in aqueous 0.01 M CaCl and equilibrated with 4 g of soil for 72 h at room temperature. Preliminary studies showed that 72 h equilibration was necessary to obtain short-term equilibrium and that no degradation occurred during this process. For the 241 surface soils from the pothole field, equilibrations were performed using 1.5 mg/L atrazine as the initial concentration and duplicate determinations are made on each soil sample. Adsorption of atrazine and alachlor to subsurface soils was measured using samples from the continuous cores. The initial herbicide concentrations varied from 0.05 to 20 mg/L with approximately 4,000 dpm/mL of equilibration solution included.

4. Samples were centrifuged and the solution phase was analyzed by high performance liquid chromatography (HPLC) using a methanol-water gradient and a C_{18} Nova-Pak® (Waters) column.

5. If ^{14}C-herbicide was used in the batch equilibrations, direct measurement of the solution phase concentration (Cw) was made by sampling the solution phase after equilibration and liquid scintillation spectroscopy (LSS).

Herbicide Degradation

Degradation studies utilize ^{14}C-labeled herbicides to measure transformation, mineralization and bound residues of atrazine, alachlor and 2,4-D using the methods of Moorman and Harper (1989, Attachment I). Surface (0-25 cm), lower root zone (50-100 cm), shallow vadose zone (150-250 cm), and saturated zone (>250 cm depth) are being used in atrazine, alachlor, or 2,4-D metabolism studies (see Table 1). Studies with the Skunk River sediments are restricted to 2,4-D at this time. Mineralization will be the primary method of analysis for 2,4-D, although selected samples will be analyzed by chemical extraction and HPLC. Duplicate samples of each soil will be analyzed.

1. All soils that were brought from the field were stored moist under refrigeration.

2. Soils were sieved (8 mm) and 50-g samples weighed into biometer flasks.

3. Soils were treated with ^{14}C-herbicide at concentrations of 0.1 and 1.0 mg herbicide/kg soil using the methods of Moorman and Harper (1989, Attachment I). Soils are incubated at -50 kPa water potential under uniform temperature conditions for varying times. Periodically, subsamples are frozen until herbicide analysis.

4. $^{14}CO_2$ is trapped in 0.1 M NaOH, removed from the biometer flasks, and analyzed by LSS.

5. Analysis of atrazine and alachlor will be conducted on all samples by solvent extraction twice with 80% aqueous methanol, evaporation of the methanol from the combined extracts, and partitioning with dichloromethane (CH_2Cl_2).

6. Aliquots of the combined methanol-water extracts, and aqueous phase after partitioning will be taken and analyzed by LSS for radioactivity

7. Aliquots of the concentrated CH_2Cl_2 extracts will be injected into the HPLC equipped with UV and radioactive materials detectors.

8. Nonextractable radioactive residues will be measured by combustion and trapping using a Harvey oxidizer.

Microbial Populations and Activity

Populations and activity of soil microorganisms in the 241 samples for the atrazine spatial variability study were characterized as described elsewhere in this report (Cambardella et al., 1994). In addition, subsurface samples were characterized by measurement of total heterotrophic bacteria and fungi. Bacterial populations are enumerated on 1% peptone-tryptone-yeast extract-glucose-succinate (PTYGS) medium and fungi on Martin's Rose Bengal medium using standard dilution-plating techniques (Wollum, 1982). Specific degrader populations were measured using a modification of the most-probable-number (MPN) methods of Lehmicke et al. (1979). This method relies upon the use of ^{14}C-herbicide as substrate. Herbicide-degrading microorganisms are detected by the formation of $^{14}CO_2$ from MPN tubes. The MPN (population) is calculated from MPN tables for a 5-tube series (Alexander, 1982).

Observation Schedule

Pothole field surface samples were collected in April 1992. Continuous core samples from the Pothole field were taken February 3, 1993 and from the Skunk River alluvium field June 19-21, 1993.

Data Format and Processing

Herbicide Adsorption

For the spatial variability study, atrazine adsorption was expressed as the partition coefficien. (K_d), which is calculated as:

$$K_d = C_s / C_w$$

where C_s is the soil concentration (mg/kg) and C_w is the solution concentration (mg/L) of herbicide. Complied data sets (ASCII, Lotus, Excel, or Quattro Pro) were analyzed for spatial relationships using GS+, Geostatistics for the Biological Sciences, Gamma Design Software (Cambardella et al., 1994). Regression analyses to determine the relationship between atrazine sorption and soil properties were made using Sigma Stat, Jandel Scientific and PC-SAS software.

In the studies using the continuous core samples, adsorption is calculated using the Freundlich isotherm:

$$C_s = K_f \cdot C_w^{(1/n)}$$

where K_f (the Freundich constant) is an index of sorption strength and $1/n$ is a measure of linearity over the concentration range. Estimates of K_f and $1/n$ and their respective standard errors were determined by regression using the log-transformed form of the Freundlich equation.

Herbicide Degradation

The mineralization, total extractable residue, and remaining parent herbicide will be expressed as percent of applied and averaged over the replicate samples at each time point. Degradation rates will be calculated using appropriate models (Moorman and Harper, 1989, Attachment I; Mueller et al. 1992, Attachment II). Degradation and mineralization rate constants and error terms will be calculated independently for the three landscape positions and tests for differences in the rate constants will be made. These data and the correspoi ding sorption data will be made available as part of the Assimilative Capacity Project, which is sponsored by the U.S. EPA Midwest Agricultural Surface/Subsurface Transport Effects Research (MASTER) Program.

Quality Assurance and Quality Control

Experimental Design

All experiments are designed to allow statistical analysis of the data. Error analysis can be preformed on the data to allow field variability to be separated from analytical variability. Field sampling sites are referenced with on-site measurements using survey methods and georeferenced using a Global Positioning System (GPS). Sorption measurements are made on duplicate subsamples from each sample from the field. Herbicide concentrations are made on duplicate subsamples from each soil sample during the course of degradation experiments. Abiotic controls are prepared by irradiation (50 kGr) of soil. Data are screened by technicians and scientists; when subsamples have coefficients of variation >25% they are marked for review.

Sample Handling and Storage

Soils used for biological measures (microbial populations, herbicide biodegradation) are stored moist at 4°C in sterilized bags or jars for no more than 100 days before use. Dates of sample collection, storage and use are recorded. All samples are clearly marked and dated prior to storage.

Analytical Methods

All analytical equipment is periodically serviced and calibrated according to manufacturers' recommendations. Records of equipment maintenance and performance are kept in log-books. Analytical methods (extraction and analysis) are explained in NSTL Standard Operating Procedures which include information necessary to reproduce computerized control methods for the HPLC. Authentic herbicides and metabolites are used to prepare standards for calibration of the HPLC, with 3 to 4 point calibrations generated daily. Plots of response factors against concentration are typically linear with $r^2 > 0.95$. Deviations from linearity or decreased fit indicate the need for review. Extraction efficiencies are determined for each analyte by spike and recovery tests. Extraction efficiencies typically range between 75 and 100%. Spiked soil samples are also included in routine extraction and analysis for an additional check. Mass balance estimates are obtained by calculation of extracted ^{14}C and measurement of mineralized and bound residues. The Harvey oxidizer is calibrated with standards consisting of soil spiked with known quantities of ^{14}C. Control chart analyses are performed on HPLC (UV and RAM detectors) and LSS.

Laboratory Notebooks and Data Management

Laboratory notebooks for individual projects are maintained by scientists, technicians, and graduate students. Graduate students and technicians have been trained in the basic elements of QA/QC. Electronic records are maintained and cross referenced to the laboratory books. Additional diskettes and hardcopies of data files are also maintained.

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Section 5-N.4 Soil Sampling for Pesticides

K. Keck NSTL

Site Locations

Soil cores were collected during 1992 and 1993 growing seasons from eight selected fields in the Walnut Creek Watershed, in the most intensively monitored areas as shown in Figure 1.

Sampling Techniques

The following equipment and supplies were used for soil sampling with a Giddings soil probe attached to a Crop Height Adjustable Tractor (CHAT) (Attachment I). The soil probe is designed to collect 122 cm deep, 5 cm diameter cores.

Giddings stainless steel sampling tubes, 5 cm i.d.
stainless steel tips, 5 cm i.d.
steel pins for attaching sampling tube adapter to tube
acetate liners (one for each core), 5 cm i.d.
cotton
methanol
plastic caps (one red cap and one black cap for each core)
permanent marker
scissors
distilled water
pipe wrench (for removing tips)
spray lubricant
bunji cords (for fastening tubes, liners to tractor for transport in field)
field book
pen
engine and tractor oils for tractor maintenance
Giddings soil probe

A Global Positioning System (GPS) was used in 1992 and 1993 to locate the positions of where soil cores were collected in the field. Latitude and longitude coordinates were entered into a GIS database for each soil core location along with

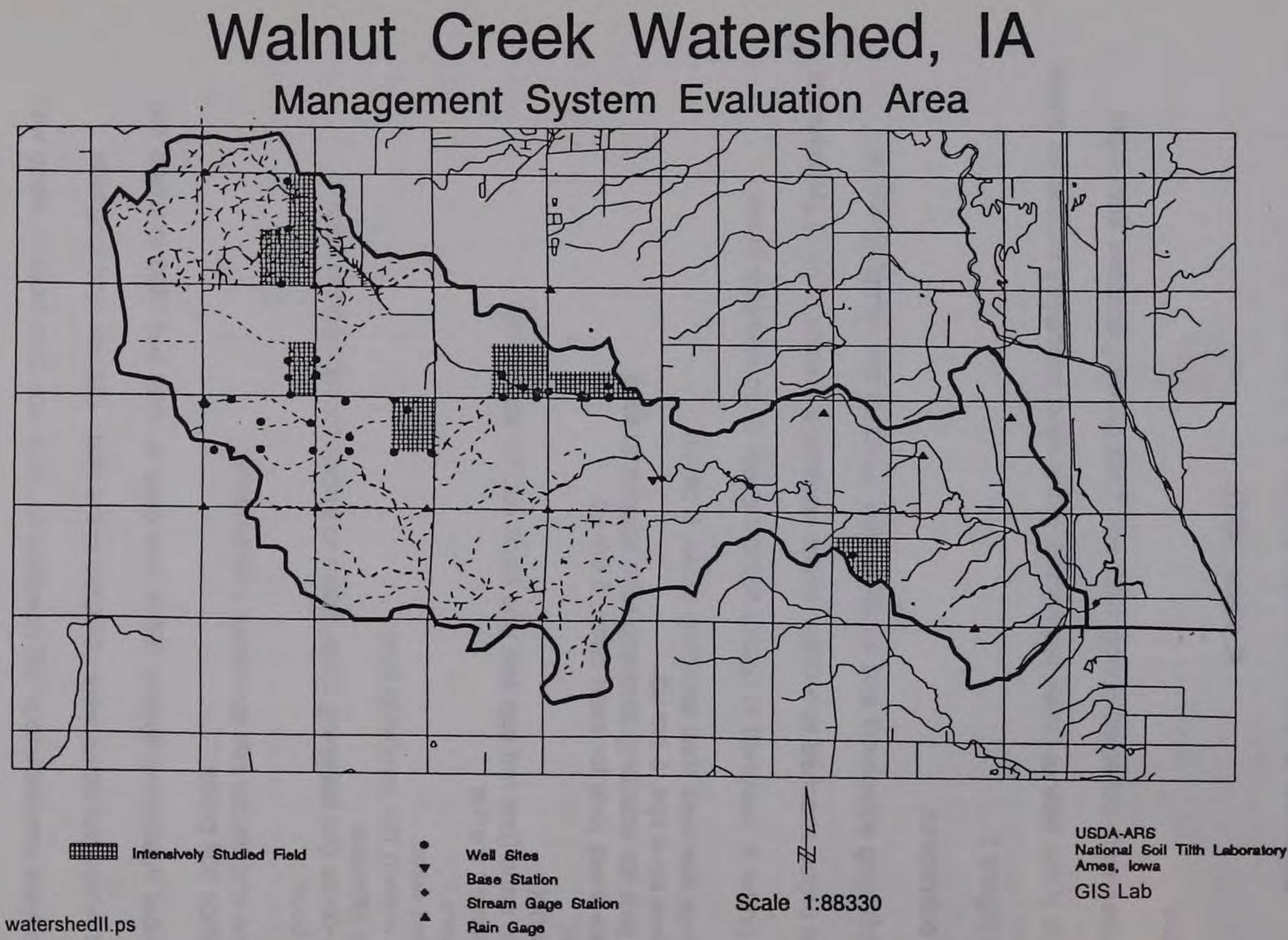

Figure 1. Sample locations in the most intensively monitored areas in Walnut Creek Watershed.

each soil cores' analytical results. Thus, there will always be a locational reference for soil core data. When a Global Positioning System is required for locating soil sampling positions the following equipment is used:

pathfinder, with antenna
bar codes
satellite availability chart

Soil samples were collected using a Giddings Soil Probe attached to the CHAT. The CHAT should be operated and maintained prior to and during soil sampling according to the following guidelines:

1. Check the engine oil level before starting the unit.
2. Check the hydraulic oil level before starting the unit. Located on the front of the oil reservoir directly behind the operator's platform is a site glass used to observe the oil level. When adding oil do not overfill the reservoir because when the oil warms and expands with operation, the reservoir will overflow.
3. Before starting the engi e, be sure that the parking brake switch is engaged.
4. After starting the engine, check to see that the alternator is functioning by noting if there is a charge indicated on the ammeter (located on the operator's console).
5. If the front and rear wheels do not seem to track correctly, place the soil

probe in the center position and rotate the steering wheel to the extreme left and then extreme right. This will sequence the steering cylinders.

After routine maintenance of the Giddings soil probe and equipment, a kelly bar (6-foot bars used with Giddings soil probe) is inserted into the sampling head and a coupler is attached between the bar and steel tube. An acetate liner is inserted into a clean steel tube and a clean steel tip is attached. If the soil is wet, then a tip fitted with a raised lip is used and prevents the soil from sticking to the sides of the acetate liner. A coupler is attached to the steel tube with a pin.

Vertical soil cores were obtained by pushing (without twisting) the Giddings soil probe and liner into the soil to a depth of 120 cm (approximately 4 ft). The probe and soil core were extracted from the soil. Soils were subsampled for soil moisture determination. After a core was taken, the tip was removed from the tube and the acetate liner was pushed out of the tube. A black cap was placed on the bottom of the acetate liner and a red cap on the top. If the core did not completely fill the liner, the excess space from the top was filled with cotton.

Between the collection of soil cores, the probe was cleaned by first running the brush, powered by the tractor's power take-off, through and outside the probe to clean the inner and outer surfaces of the probe. The probe was then rinsed with distilled water, followed by a methanol rinse. The same cleaning procedures were used for the tip. After sampling was completed, the probes and tips were cleaned and sprayed with lubricant to prevent rusting. Core information was entered into NSTL's Soil Analysis Laboratory logbook and frozen until analysis.

<u>Soil Core Processing</u>

1. A power miter saw was used to cut each core (frozen or thawed) into segments starting from the red cap (top) to the black cap (bottom). The segments were: 0 to 7.5 cm; 7.5 to 15 cm; 15 to 30 cm; 30 to 45 cm; 45 to 60 cm; 60 to 75 cm; 75 to 90 cm; 90 to 105 cm; 105 to 120 cm.

2. Handling of the core segments was as follows:

   A. The soil was pushed out of the plastic sleeve, and the core was kept intact, if possible.

   B. For segments 1 and 2, go to step D. For the other segments 0.5 cm was cut from each end with a clean spatula. The spatula was wiped clean with a Kimwipe after each use.

   C. The core segment was cut in half lengthwise. The flat portion of each half was placed face-down and the surface was scraped off.

   D. The remaining soil was wrapped in aluminum foil and labeled with the core number, date, depth and case number. This information was entered in the core logbook.

   E. Each aluminum foil packet was put in labeled small plastic bag, a rubber band was placed around all the segments of a single core or all segments for a core were put in a large plastic bag.

F. The large plastic bags containing the cores were put in paper bags labeled with the case and log numbers.

G. All samples were stored in the freezer until analysis.

Observation Schedule

Core samples were collected as follows, weather permitting:

1. Pre-treatment Background Samples: 0-30 days before herbicide (atrazine, alachlor, metolachlor, metribuzin) application with full 120-cm core.

2. Post-treatment Surface Samples: As soon (within 24 hr) after treatment as possible. Sample 0-7.5 cm depth. If it rained between application and sampling, then a 120 cm probe sample was collected in the treated zone.

3. Post-treatment Core Samples: Full 120-cm core samples were taken 2, 4, 6, and 12 weeks (approximately) after application, and again after harvest. All cores came from the treated zone (within 18 cm of row) assuming a banded spray pattern.

Quality Assurance and Quality Control

Detailed field notebooks were kept for each sampling event. The field number, sample location, core depth, weather conditions, and NSTL technician names were recorded in the notebooks. In addition, pertinent GPS data was recorded, including position fix information, number of satellites, and measurement of antennae offset from sampling location.

Data Format and Processing

Each soil segment was analyzed for atrazine, metolachlor, metribuzin, alachlor, and nitrate at the NSTL Soil Analysis Laboratory using methods described in Section 5-S of this report. Analytical results are reported by the laboratory in ASCII format, assembled in order of sampling date per field, and then given to Bob Jaquis (NSTL database manager) for entry into the watershed database.

Global Positioning System data from field sampling events was processed at the NSTL and differentially corrected with the NSTL base station (Trimble Navigation, Ltd., 1992). Standard deviations were used as screens for each latitude and longitude measurement taken in the field. These corrected and screened GPS values were assigned to soil cores and added to a computer file separate from soil core chemical data.

References

Trimble Navigation, Ltd., Trimble PFINDER™ Software User's Guide, September 1992.

Reprinted from *Agronomy Journal*
Vol. 85, No. 1

ATTACHMENT I

Adjustable Soil Coring Machine for Sampling in Tall Row Crops

J.L. Hatfield* and S.L. Schaaf

ABSTRACT

Soil sampling is difficult when the crop canopy is tall and row width is variable between experiments. A specialized hydraulically-driven soil sampling tractor was designed and constructed with variable wheel width and clearance height. The tractor has an adjustable wheel width from 1.6 (5.2) to 2.4 m (7.9 ft.) and clearance height from 2.2 (7.2) to 2.7 m (8.9 ft.). A Giddings hydraulic soil coring probe is front mounted on the tractor. The operator can control wheel width, height, position of the operator platform and probe, travel direction, and speed from the console. Soil cores are carried on the tractor between sampling locations. The tractor mounted system has performed well during sampling trips throughout the growing season in various row widths.

HYDRAULIC SOIL SAMPLING PROBES are routinely mounted on either tractors or trucks. Schickedanz et al. (1973) described a tractor-mounted soil sampler which could be used only when the crop was small, without causing crop damage. A similar problem exists with pickup-mounted units. Pickup-mounted units also are limited to specific row widths and it may not be possible to use them in no-till or ridge-tillage fields.

Bausch et al. (1977) described a high-clearance mounted soil sampler. The soil coring unit was mounted on a modified high-clearance spray tractor frame and utilized the spray tank as ballast. This modification allowed for soil sampling within a lateral range of 1.52 m (5 ft.) and potential crop height of 2 m (6.6 ft.). The tractor utilized for this sampling set up had a row width of 1 m (3.3 ft.).

Swallow et al. (1987) developed a self-contained unit which could be pulled into the field to permit collection of large soil cores ranging from 0.4 (1.3) to 0.76 m (2.5 ft.) in diameter and to a depth of 1.5 m (4.9 ft.). This type of unit did not permit sampling without crop damage during the growing season.

In environmental studies there is a need to sample soil over a range of row widths and crop heights throughout the growing season. Our objective was to develop a hydraulic coring machine built on a hydraulically driven tractor with adjustable heights, wheel widths, and sampler position.

Design and Construction

The tractor portion of this machine is a custom designed hydraulically driven tractor (Fig. 1). The basic features of this tractor consist of a range of wheel widths from 1.6 (5.2) to 2.4 m (7.9 ft.) and a potential clearance height from 2.2 (7.2) to 2.7 m (8.9 ft.). To accommodate this range of widths and heights, the tractor frame is adjusted by a series of hydraulic cylinders.

Power is supplied for the hydraulic pumps with a 26.1 kW (35.5 hp) Wisconsin[1] engine (Teledyne Wisconsin Motors, Milwaukee, WI) mounted at the rear of the tractor. Hydraulic pumps provide power for the cylinders, motors, and the soil coring unit. A Giddings hydraulic soil coring unit with rotary coring head

J.L. Hatfield, National Soil Tilth Laboratory, 2150 Pammel Drive, Ames, IA 50011, and S.L. Schaaf, Schaaf Consulting Ltd., Sidney, IA 51652. Contribution from USDA-ARS and Schaaf Consulting Ltd. Received 20 Dec. 1991. *Corresponding Author.

Published in Agron. J. 85:175–178 (1993).

[1] No endorsement implied herein by the USDA-ARS, and specific trade names are used to assist the reader.

yses, soil hydraulic properties, and neutron access tube installation. Soil cores have been collected in the zero contamination acetate liners at the rate of 15 per hour in small plots and five per hour in large watersheds. This sampling process is slowed by clean-up procedures necessary to avoid cross contamination of samples. Soil samples have been taken to a depth of 2.6 m (8.5 ft.) without anchoring the tractor. This performance is possible because the probe is mounted on the operator platform, partially transferring the force of the probe to the total weight of the tractor. This transfer of force is possible because the pivot point for the operator's platform is located under the center of the tractor. When the probe is pushed into the soil, force is partially directed toward the center of the tractor.

Two individuals can operate the tractor efficiently with one driver and one individual operating the probe. However, a single operator can perform the sampling operation. The sampling tractor permits sampling in fields with permanent ridges and no-till without damage to the row area. Soil sampling has been conducted in corn 2.5 m (8.2 ft.) tall and 0.76 m (2.5 ft.) row width without crop damage. This unit will be used in several experiments where samples are collecte throughout the growing season.

A trailer used to haul the tractor was specially mad with a cargo box for sampling probes and extra equip ment. The trailer is a dual axle fifth wheel unit wit custom built wheel chocks for easy positioning of th tractor in the trailer and tie downs to permit easy trans port. The tractor was designed and manufactured b Schaaf Consulting Ltd. The cost for the tractor wit sampling probe was $38 000.

ACKNOWLEDGMENTS

We appreciate the efforts of Rich Hartwig for his assistanc in making the original concept a reality.

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AGRONOMIC RESEARCH

Section 5-O Agronomic Characteristics

Section 5-O.1 Crop Yield Evaluations

D.L. Karlen, T.S. Colvin and R. Hartwig NSTL

Site Locations

Field-scale evaluations of crop yield variability were initiated at three locations within the Walnut Creek watershed in 1992 and repeated in 1993. Sampling locations included Bassett's conventional tillage field "pothole field", Bassett's no-till field, and Black's conventional tillage (east) field. Location descriptions are provided in Section 5-D of this report. The "pothole field" has an area of 36 ha and is rotationally cropped to corn (Zea mays L.) and soybean [Glycine max L. (merr.)]. Tillage is done in the fall with a chisel plow and weeds are controlled with a combination of cultivation and herbicides. Anhydrous ammonia fertilizer is applied in the fall. Bassett's no-till field covers an area of 96 ha. Corn and soybean are grown each year in a 2-yr crop rotation. Transition to no-till management began in 1991. Black's conventional tillage (east) is a 60-ha field that is managed using chisel-disk tillage practices and a 2-yr corn-soybean rotation, but most fertilizer nutrients are supplied by applying hog manure. A small 0.6-ha segment of this field is being used for crop yield monitoring.

Sampling Techniques

Cooperators are asked to plant a common corn hybrid (ex. Pioneer Brand 3417 in 1992; Pioneer Brand 3615 in 1993 and 1994) or soybean variety in each field so that effects of long-term management practices and soil map unit variability can be determined, without encountering genetic differences such as crop maturity. The hybrid and variety planted in 1993 have been planted in 1994 and will be used in future years so that multi-year evaluations can be made to assess effects of seasonal weather patterns.

Before harvest, a series of transects for yield monitoring are identified across each sampling area. These transects are similar to the soil sampling grids described in Section 5-N.2 of this report. The current protocol for sampling at fields within the watershed involves collecting samples by starting and stopping harvest operations at selected positions along each transect. For each sample, grain weight and moisture are measured using equipment designed by Rich Hartwig and Tom Colvin (NSTL) (Attachment I) and recorded manually on data sheets. The equipment used for this operation is available on both a Gleaner K and John Deere Model 6600 combine.

The grain weighing system consists of a tank suspended on two Weightronix model 12980-0116 weigh bars that are mounted directly beneath the clean grain auger and attached to a Weightronix model 402 (250 x 0.05 lb) digital read-out in the combine cab. A hydraulic circuit is added to the combine steering circuit to open and close the door on the weighing tank. A Dickey-John model CFMM-A continuous-flow moisture meter, normally used in commercial grain handling systems, is used for measuring grain moisture because its design allowed simple mounting (Attachment I). The sensor (part number 702823-1301) is filled as grain flows into the weigh tank. The moisture content is displayed on a panel (part number 702824-0803) in the cab, but values are recorded only when the grain weight is measured. The design ensures that the sensor determines moisture on grain that has not come from the plot edge

(Attachment I). The electrical system uses a generic cigarette-lighter-type inverter to provide 115 V from the combine electrical system. A home-built voltage regulator maintains the voltage, and although it can be adjusted to compensate for differences in engine speed or load, this feature has generally not been needed.

The frequency of data collection depends upon the intensity of monitoring desired, but generally two or more rows, depending upon crop row spacing and combine head width, are harvested along each transect for a distance of approximately 15 m. Harvest length can be increased or decreased, but with current equipment, harvest distances should not be less than 5 m. The exact position of each transect is established by standard surveying techniques and/or using geo-referencing with a global positioning system (GPS) (Section 5-U of this report provides information on GPS). The distance traveled along each transect between stops is measured by a sensor mounted on the drive wheels for the combine. While stopped, the GPS position, grain weight, and grain moisture content are recorded manually on data collection sheets. If desired, a grain sample is collected manually for subsequent chemical analysis.

Samples for total nitrogen (N) (grain protein) analysis are dried at 70°C for at least 48 hr and then ground in a flour mill and stored in sealed plastic bags until they are analyzed. Samples are analyzed using the dry combustion method with a Carlo-Erba dry combustion analyzer (model NS1500) or using the Dumas method (Bremner and Mulvaney, 1982). These methodologies give a direct reading of total N.

Grain protein is calculated for corn or soybean by multiplying the total N concentrations by a factor of 6.25.

Observation Schedule

Crop yield data are collected during harvest season for each crop. Soybean are typically harvested in late September and early October and corn is usually harvested in October and early November in Walnut Creek watershed. Crop yield measurements will be made in all three fields during 1994 and most likely in future years so that long-term yield variability at the various sampling sites can be determined.

Quality Assurance and Quality Control

To facilitate multi-year comparisons of crop yields at all sites, corn hybrids and soybean varieties are kept the same. Crop yields are always evaluated at the same location in each field and locations are confirmed using surveying and/or GPS techniques. During harvest the row-spacing (0.76 or 0.91 m), number of soybean rows harvested, and width of the combine head, if the soybean crop was drilled, are recorded in a logbook.

The grain weighing system is tested periodically in the field, under normal operating conditions, with a known weight. The sensors in this system have always provided the correct weight within the accuracy (±0.05 lb) of the system. The moisture meter is checked periodically in the field and has always given reproducible results in comparisons between experimental treatments. A calibration test of the moisture meter for corn versus an oven-dry sampling method gave an R^2 value of 0.99 (Attachment I).

Data Format and Processing

Manually-recorded crop yield data and moisture data are entered into Quattro Pro spreadsheet files. Data in these files are screened by a technician and then reviewed by one or more researchers for agreement with data obtained from data collection sheets. Data in spreadsheet files are analyzed statistically or used for developing maps with Auto-Cad, Quattro Pro, Statistical Analysis Systems (SAS), or other software.

Using the location of each harvest area that was established using GPS or surveying techniques, technicians use the data in electronic files to generate field maps for each of the sites. Crop yield maps are overlaid on soil maps as shown in the Pothole field (Fig. 1). After the yield maps are generated and overlaid on soil maps, the specific soil map unit for each harvest area is identified and this parameter (soil map unit) is included with verified data in the electronic files. Data are analyzed using Proc GLM (general linear model), Proc Means, and Proc T-test from the Statistical Analysis Systems (SAS) package. Statistical results are used to compute crop yield as a function of soil map unit (Karlen et al., 1990; Sadler et al., 1993). Crop yield data are also made available on the National Soil Tilth Laboratory (NSTL) "P" drive for use by other research cooperators.

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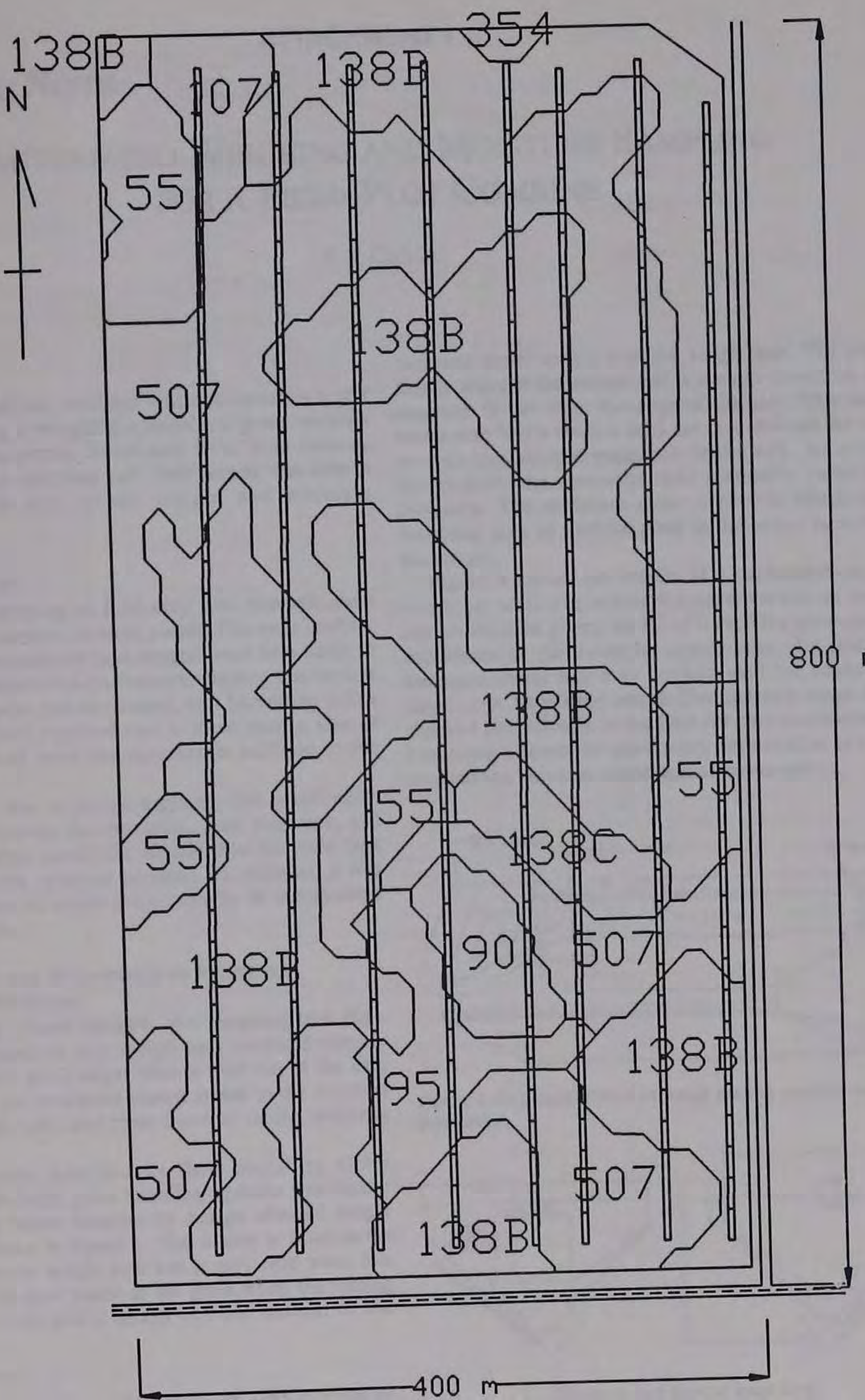

Figure 1. Transect and "plot" harvest areas for soybeans at the "pothole" field in 1993. Numbers are soil map units.

ATTACHMENT I

TECHNICAL NOTE

AUTOMATED WEIGHING AND MOISTURE SAMPLING FOR A FIELD-PLOT COMBINE

T. S. Colvin

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Published by the American Society of Agricultural Engineers, St. Joseph, MI 49085-9659 USA

ABSTRACT

A small commercial combine was converted to a plot combine by adding a weighing system and grain moisture determination equipment. Read-outs from both systems were located in the combine cab. One person was able to run the combine and record weight and moisture measurements.

INTRODUCTION

Since the beginning of field-crop plot research, there has been a need to measure yields. The tools used for these determinations have ranged from bare hands to sophisticated, automated harvesters. Before the system described in this note was developed, plot harvesting with a Gleaner K combine* required two to three people. One or two people worked with the samples in addition to the operator.

The objective was to design a system that would allow one person to operate the combine, read moisture, and sample weight, then dump the sample into the main tank without leaving the operator position. In addition, it was important to retain as much grain capacity in the combine hopper as possible.

DESCRIPTION OF THE WEIGHING AND MOISTURE MEASUREMENT SYSTEMS

The weighing system consists of a weighing tank (figs. 1 and 2) suspended on two weigh bars mounted directly beneath the clean grain auger with a read-out in the cab. Figure 3 shows the hvdraulic circuit added to the combine steering circuit to ope.ı and close the door on the weighing tank.

A Dickey-john continuous-flow moisture meter normally used in large grain handling systems was chosen as the moisture meter because its design allowed simple mounting as shown in figure 1. The sensor is filled as the grain flows into the weigh tank but is only read when it is full so there is no mov·ment of the grain when the reading is taken. The first grain drops out the bottom of the moisture meter sensor into the weigh tank. The grain that finally stays in the sensor and is used to determine the plot moisture is not from the edge of the plot. This particular meter also had a remote read-out that allowed the operator to read the sample moisture in the cab. As originally developed, the operator then manually recorded the moisture. The moisture meter sensor is attached to the weighing tank so that the grain in the sensor is included in the weight.

Figure 4 shows the results of a calibration test of the combine moisture meter for corn versus an oven-dry sample method giving an R^2 of 0.99. This gave reasonable confidence in the meter for comparative plot studies. The moisture meter has also worked well for soybeans. No other crops have been tested. The moisture meter has been checked periodically in the field for corn and soybeans and has been shown to give very repeatable results for comparison between experimental treatments.

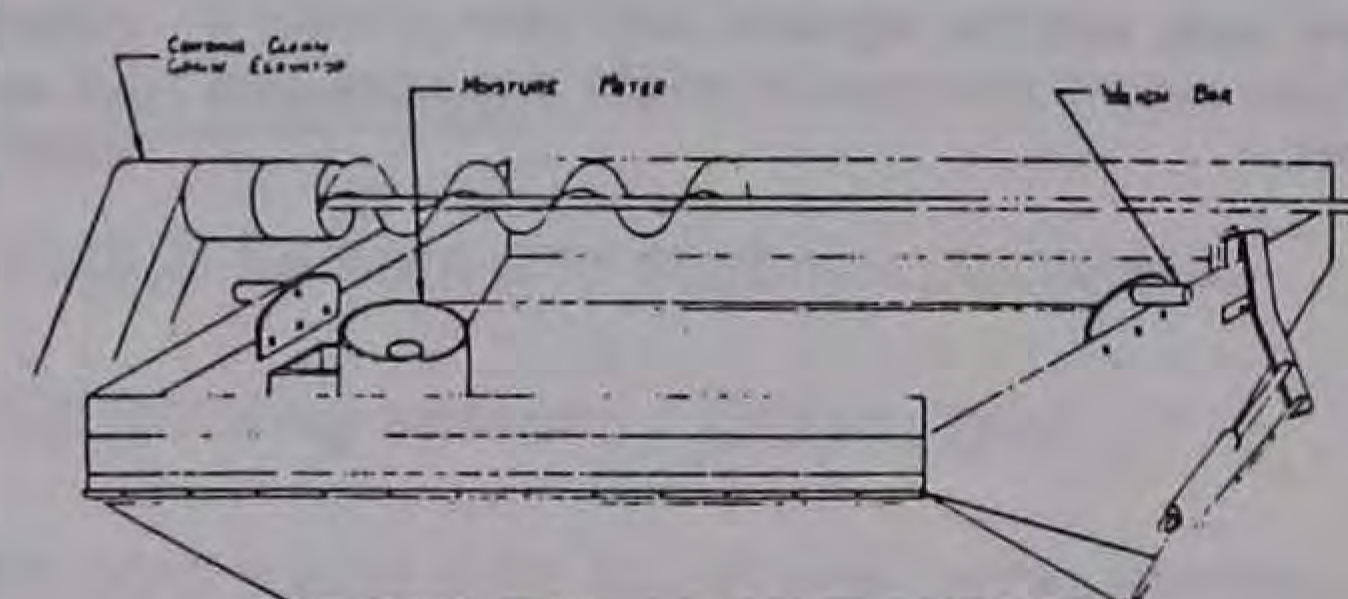

Figure 1–Orthogonal view of weigh tank in position under clean grain auger.

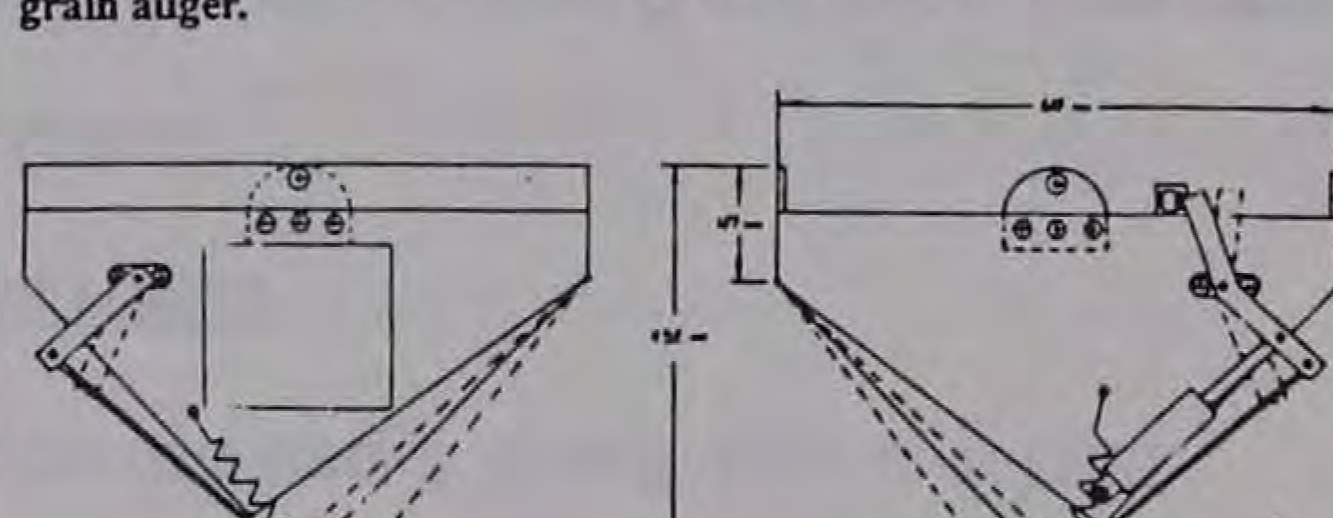

Figure 2–End views of weigh tank.

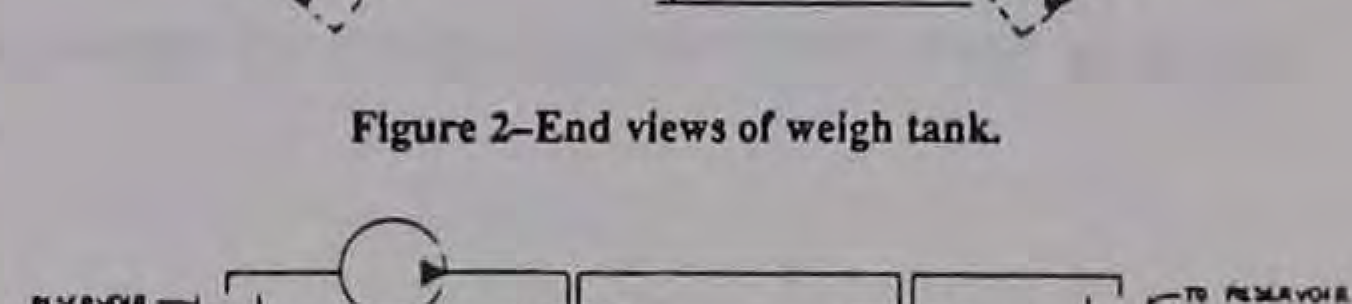

Figure 3–Hydraulic circuit used for weigh tank dump cylinders.

Article was submitted for publication in June 1989; reviewed and approved for publication by the Power and Machinery Div. of ASAE in February 1990. Presented as ASAE Paper No. 83-1593.

Joint contribution from USDA-ARS and Journal Paper No. J-13435 of the Iowa Agriculture and Home Economics Experiment Station, Ames, Iowa. Project No. 2737.

The author is T. S. Colvin, Agricultural Engineer, USDA-Agricultural Research Service, Ames, IA.

*Trade names are included for the benefit of the reader and do not imply endorsement or preferential treatment of the products by Iowa State University or the USDA.

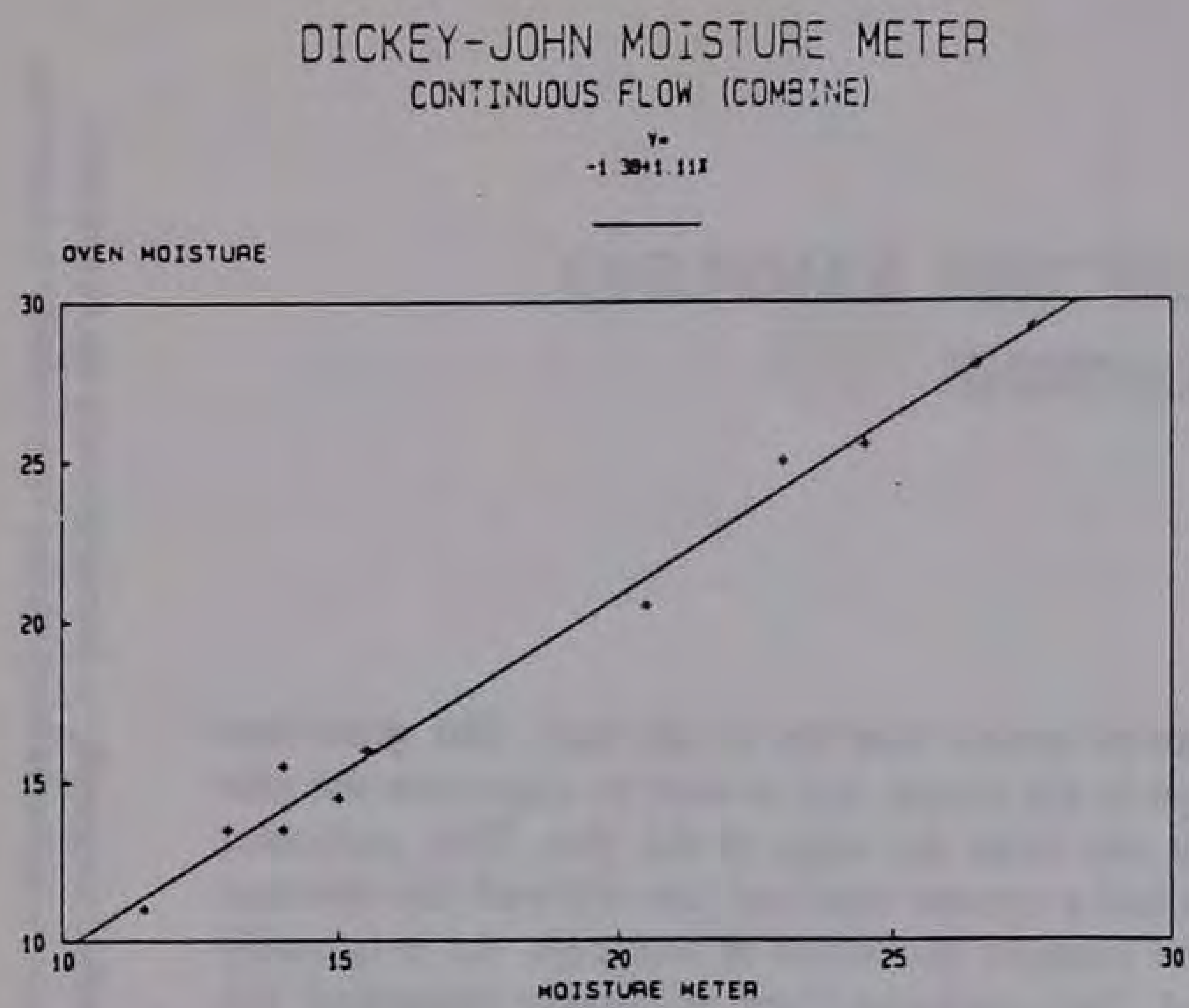

Figure 4–Comparison of moisture meter to oven for corn.

Table 1 lists model number and the manufacturers of the major components used on the combine. The electrical system used a generic cigarette-lighter-type inverter to provide 115 V from the combine electrical system with a home built voltage regulator to maintain the voltage through manual adjustment when required by changes in load or engine speed. This was originally done because of concern about the effects of a change in combine electrical system voltage on the moisture reading. Experience has shown that this is not much of a problem. Adjustments have been made with the regulator only once or twice a year. Later model electronics might not need that adjustment.

TABLE 1. Major components of automated weighing and moisture sampling system

Moisture meter (Dickey-join CFMM-A)		
	Sensor	702823-1301
	Panel	702824-0803
Weighing system (Weightronix)		
	Weigh bars	12980-0116
	Readout	(250 x 0.05 lb), model 402

Discussion

The addition of the weighing and moisture-measuring systems required no major combine modifications. It allowed the combine operator to record the sample weight and moisture and handle the grain without assistance. One of the design goals for the system was to leave as much original capacity in the combine grain tank as possible. This was done by using a relatively shallow weigh tank that extends most of the distance across the main tank. The clean grain auger is used to transport grain across the length of the weigh tank but doesn't interfere with measurements. The weighing system has been tested in the field periodically with a known weight. It has always given the correct weight considering the accuracy of the read-out. The entire system has worked well enough that another combine at this location has been equipped with an equivalent system for weighing and moisture measurement. The only problem has been uneven ground. Front to back slope has been no problem. Side slopes of 10% have required us to always have the same side low to maintain accuracy. This has not been a major problem but has required the operator to be alert.

Acknowledgment. The author thanks R.O. Hartwig for his assistance with the design of this system and for his leadership in the construction and test of this instrument.

Section 5-O.2 Crop Characteristics

K. Keck NSTL

Site Locations

Measurements of corn and soybean plants were taken in four of the most intensively monitored fields in Walnut Creek Watershed during 1991 and 1992 growing seasons. These fields include the "Pothole field" located in section 25, T83N, R25W, Boone County; Black-east (swine manure field) located in section 28, T83N, R24W, Story County; and Black-west (ridge till) and Black no-till located in section 29, T83N, R24W, Story County. Section locations are provided in Figure 1. Location descriptions are provided in Section 5-D of this report. The fields are privately owned and are farmed for profit.

Sampling Techniques and Observation Schedule

Plant Growth and Phenology

Growth stage and phenology information for corn and soybean plants was collected weekly throughout 1991 and 1992 growing seasons. Growth type, diagnostic character, and growth stage for corn plants was monitored using methods provided by Ritchie et al. (1992). Methods used for monitoring this same information for soybeans are provided by Fehr et al. (1971).

Plant Height

Corn and soybean heights were recorded weekly during 1991 and 1992 growing seasons. Six randomly selected plants for measurement and their average

Walnut Creek Watershed, IA

Management System Evaluation Area

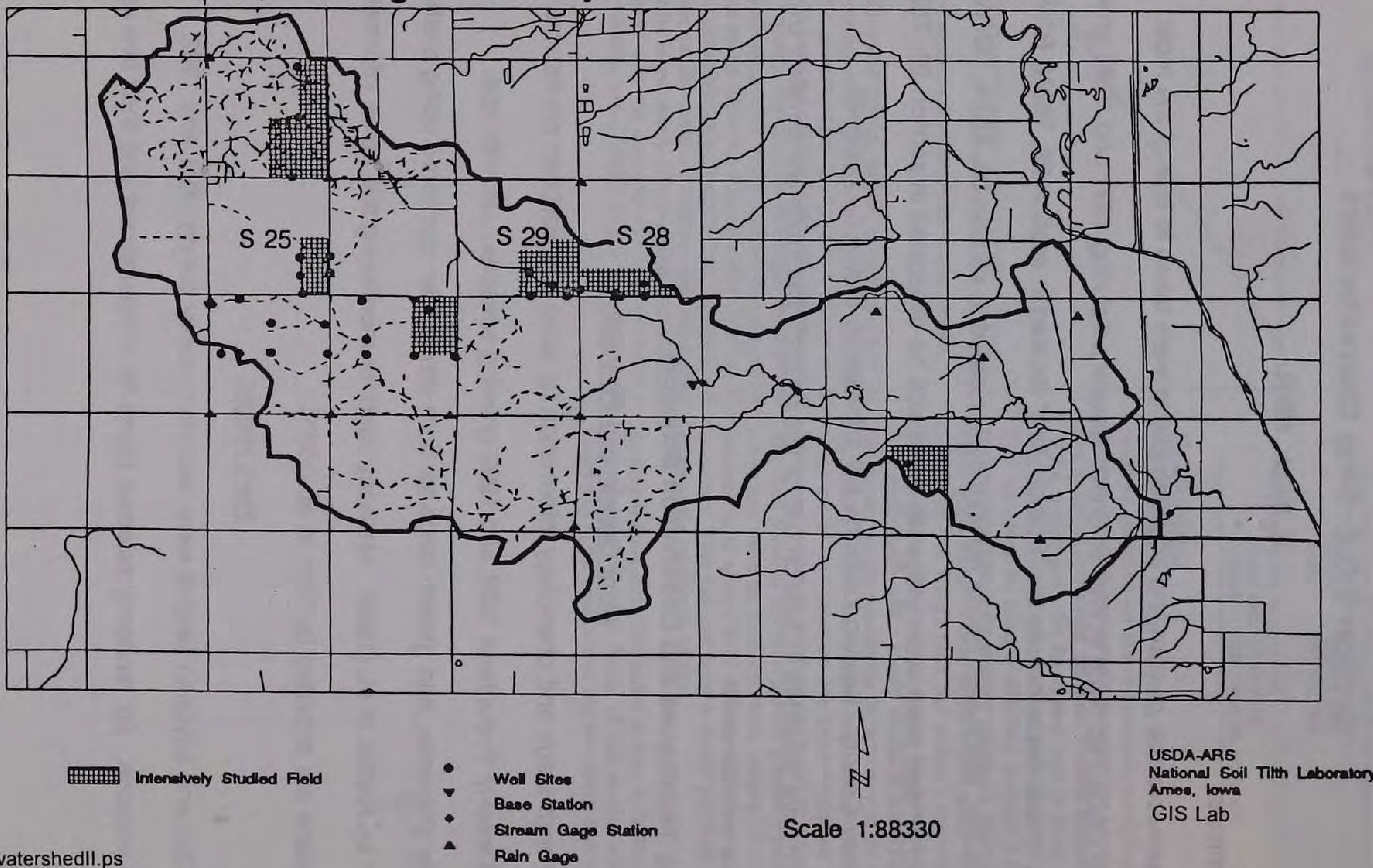

Figure 1. Fields used for corn and soybean plant measurements are located in the intensively monitored fields in sections 25, 28 and 29.

heights were recorded. Plants were of the same variety and had the same planting date.

Plant Dry Weight

Corn samples for dry weight measurements were collected four times during 1991 and 1992 growing seasons. Growth stages at which the samples were collected are the early whorl stage with 4-6 leaves, mid whorl stage with 8-10 leaves, tassel stage with 16 leaves fully emerged, and after physiological maturity.

Soybean samples for dry weight measurements were collected from plants at growth stages V3 when three nodes appeared on the main stem beginning with the unifoliate node, R2 when a flower appeared at the node immediately below the uppermost node with a completely unrolled leaf, and R8 when 95% of pods were brown and at harvest maturity.

At each dry weight sampling time, three adjacent plants were collected in the field at three random locations. Plants were cut at the soil surface and separated into stems, leaves, and fruit. Plant parts from each location were placed in plastic bags and weighed at the National Soil Tilth Lab (NSTL). Samples were dried for 24-48 hours at 65°C in open paper bags, then reweighed. Percent moisture was calculated as: (dry weight/wet weight x 100) - 100.

Plant Sampling for Kjeldahl Nitrogen

Plants collected for dry weight measurements were also used for kjeldahl nitrogen analysis. Dried corn and soybean plant samples were each ground in a Thomas Wiley mill, stored in plastic 125 ml vials, and submitted to the NSTL Soil

Analysis Laboratory for kjeldahl nitrogen analysis. Analytical procedures are provided in Section 5-S of this report.

Crop Yields

Crop yield, on a field by field basis in Walnut Creek Watershed, was obtained from cooperating farmers. A NSTL technician, contacted cooperating farmer and requested crop yields for their fields in the watershed. This information reported in bushels per acre was recorded in a file (paper) prepared for each field.

Other Preharvest Plant Measurements

The following measurements were made in the four most intensively monitored fields in Walnut Creek Watershed during 1991 and 1992 growing seasons. Measurements were taken in 4-ha areas in cornfields near continuous field monitoring equipment.

Ear counts

Ears were counted on three 5.3 m rows in each 4-ha area of cornfield prior to crop harvest.

Ear weights

Ears were harvested off all corn plants in the 5.3 m rows used for ear counts. Husks were removed from ears and each ear was weighed. Ears were dried at 65°C for five days, reweighed, shelled and finally reweighed for yield determination.

Stalk nitrate test

Cornstalk samples were collected one to two weeks after black layers formed on most corn kernels. Cornstalks were cut 15 and 36 cm above the ground and dried leaves were removed from the resulting 21 cm segments. Stalk segments were collected from 15 randomly selected plants in 4 ha areas as recommended by Blackmer and Vaughan (1991) for an accurate assessment of stalk nitrate concentrations. Stalks were dried at 65°C for 24-48 hrs, ground and submitted to the NSTL Soil Analysis Laboratory for plant nitrate analysis. Analytical procedures are provided in Section 5-S of this report.

Quality Assurance and Quality Control

Detailed field notebooks were kept with field sample numbers, sampling dates, NSTL sampling technician names, maps showing sampling locations, and sampling techniques.

Data Format and Processing

Data has been entered into Lotus spreadsheets and converted to ASCII files.

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Section 5-P Farming Surveys

K. Keck NSTL

Site Locations

All farmers owning land within the boundaries of Walnut Creek Watershed were surveyed for field acreage, crop information and pesticide and fertilizer use. Farm owner and operator names were obtained from Agricultural Stabilization and Conservation Service (ASCS) offices in Story and Boone Counties, Iowa. A list of tract and farm numbers was compiled for each farm in the watershed from ASCS maps.

Sampling Techniques

In the fall of 1991, a letter describing the research being conducted in Walnut Creek Watershed was sent to 70 farm operators in the watershed. Farmers were later contacted by phone to set up a personal interview between each of them and a technician or extension person from the National Soil Tilth Laboratory (NSTL). Surveys were scheduled at the farmers' convenience and conducted in their homes or offices. A Walnut Creek watershed field crop history survey sheet was completed for each field being farmed in the watershed. Tillage practices, pesticide and fertilizer application types and rates, and soil test results along with other farming information were requested on each survey sheet. A sample survey is provided as Attachment I. The same survey procedures were used for obtaining crop information from the same farmers in 1992.

During the summer of 1993 the survey was mailed to the same farmers. Some farmers completed the surveys and returned them immediately to NSTL, but most farmers were contacted by phone or visited by NSTL staff to obtain the information necessary to complete the survey sheet.

Observation Schedule

Surveys of farming practices in the watershed have been conducted yearly since 1991 and will continue for the duration of the water quality study.

Quality Control and Quality Assurance

Herbicide rates provided on the surveys by the farmers were compared to rates recommended by herbicide manufacturers. Farmers were contacted by phone for verification of unusual or excessive fertilizer and herbicide rates. Crop acreage were verified using ASCS maps. Crop types were verified against ASCS aerial photographs.

Data Format and Processing

Herbicide and fertilizer application rates for each field along with crop type and acreage have been written on maps of each section in the watershed for 1991-93 field seasons. Maps were generated by Geographic Information System (GIS) software Arc/Info (ESRI). A field boundary file was established in Arc/Info by digitizing aerial photographs of the watershed taken each field season. Created within the GIS is an application that stores field data manually entered from watershed maps and converts herbicide application rates per acre to pounds of active ingredient per acre. Fertilizer data is entered into the GIS as pounds of nitrogen (N), phosphorus (P), and potassium (K) per acre. Herbicide active ingredients, N, P, and K in pounds per acre within Arc/Info can be totalled over each watershed section and drainage sub-basin. Maps can be produced from the GIS to show the distribution of crops within each section of the watershed for each field season.

Information obtained from 1991-1993 surveys such as herbicide and fertilizer application rates and the number of acres being farmed are currently being entered into the GIS; 1991-92 survey information should be completed by the end of the first quarter 1994.

ATTACHMENT I. Farm survey form.

WALNUT CREEK WATERSHED FIELD CROP HISTORY---1993 CROP YEAR

Field Number ____________ Total Acres ____________

Soil test results (photocopy if possible)

Year sampled ____________ Laboratory used ____________

Organic matter: ________ pH ________ P ________ K ________

Ca ________ Mg ________ Zn ________

Cropping history

Crop acres ________ Set-aside acres ________

TILLAGE (Please note all tillage passes. If an implement was used more than once, record all dates on line provided.)

Fall 1992 field passes:	Date(s):	Spring 1993 field passes:	Date(s):	Spring/summer 1993 field passes	Date(s):
Chop stalks	______	Chop stalks	______	Rotary hoe	______
Moldboard plow	______	Moldboard plow	______	Rotary hoe	______
Chisel plow	______	Chisel plow	______	Row cult.	______
Disk (offset)	______	Disk (offset)	______	Row cult.	______
Disk (tandem)	______	Disk (tandem)	______	Sidedress N (record sidedress N here if soil was disturbed, i.e. N was injected)	______
Apply anhydrous	______	Apply anhydrous	______		
Other	______	Field cultivator	______		
		Harrow	______	Other	______
		Other	______		

CROP PLANTING

Crop ____________ Hybrid or cultivar ____________

(set-aside crop) ____________

Type of planter/drill ____________ Row width (inches) ________

Seeding rate/A ____________ Date of planting ____________

PESTICIDE USE

Product name and formulation (eg. Extrazine DF [or 4L])	Rate/A (lb, pt, qt, oz)	Time (date)	Method of application (band or broadcast) (PPI, PRE, or POST)	Band width (inches)

Herbicides:

custom or self applied? ____________

Insecticides:

Others: (e.g. fungicides)

FERTILIZER and LIME

Product (eg. dry, liquid, or anhydrous)	Analysis/grade (eg. 0-0-60 for N-P-K)	Rate lb/A actual fert. material	Method of application (with planter, broadcast, injected, or dribbled) (incorporated or not?)	Time (fall or spring and date)

custom or self applied? ____________

MANURE or SLUDGE

Animal source	Analysis (eg. 5-5-10 for N-P-K)	Rate lb or ton/A	Method of application (see above)	Time (fall or spring and date)

Other products used:
eg. nitrification inhibitor or soil additives

Section 5-Q Insect Surveys

Section 5-Q.1 Corn Rootworm Surveys

J. Tollefson ISU

Background Information and Site Locations

In preliminary 1992-93 budget proposals, the United States Department of Agriculture-Agricultural Research Service (USDA-ARS) had proposed managing corn rootworms on an area-wide basis. Walnut Creek Watershed was recommended as an area to be used to test this concept because of the intensive environmental monitoring being conducted in this watershed. In preparation for the project, ARS, Extension Service (ES), and Iowa State Agricultural Experiment Station scientists joined efforts to determine the level of incidence of corn pests and current methods used by individual farmers in the area to manage pests.

Adult western corn rootworm, *Diabrotica virgifera virgifera* LeConte, and northern corn rootworm, *D. barberi* Smith & Lawrence, populations were monitored in 13 cornfields in Walnut Creek Watershed during 1992. Table 1 lists the location, acreage, and crop rotations in each of these fields. Nine of the fields had been planted to corn the previous season and provided an estimate of the typical density of corn rootworms when corn is planted after corn. Three of the fields had been planted to soybeans the previous season, and provided an estimate of the likelihood of having infestations of northern corn rootworms with extended diapause (two-year lifecycle). The last field had been planted to both alfalfa and corn the previous season. The portion that had

Table 1. Location of Fields Sampled for Corn Rootworms within the Walnut Creek Area

Number	Location	Size (acres)	Rotation
1	SW ¼, Sec. 1 (Palestine)	20	corn on corn
4	West field of NE ¼ & SE ¼, Sec. 4 (Palestine)	100	corn on corn
13	NW ¼, Sec. 13 (Garden)	150	corn on corn
21	East field, NE ¼, Sec. 21 (Palestine)	80	corn on corn
25	East ½, SE ¼, Sec. 25 (Colfax)	80	corn on soybean
26	North field, SE ¼, Sec. 26 (Washington)	60	corn on soybean
28S	South field, Sec. 28 (Washington)	150	corn on corn
28N	North field, Sec. 28 (Washington)	140	corn on corn
29	North field, SE ¼, Sec. 29 (Washington)	120	corn on corn
30	South ½, NE ¼, Sec. 30 (Washington)	80	corn on corn and alfalfa
31	Northeast field, Sec. 31 (Washington)	120	corn on soybean
33	Northeast field, Sec. 33 (Washington)	70	corn on corn
35	Northeast field, NE ¼, Sec. 35 (Washington)	20	corn on corn

been planted to corn previously would be expected to have corn rootworms, and the portion planted in alfalfa would not have an infestation.

Sampling Techniques

Absolute population density estimates of the resident pest populations were obtained by trapping the beetles as they emerged from the soil (Hein et al., 1985). Twelve emergence traps were spaced uniformly across each field and the beetles removed from the traps and counted at approximately weekly intervals until the end of August.

The density of beetles per unit of habitat that would lay eggs to produce the following season's population (emergence plus immigration minus mortality and emigration) was determined by visually counting the beetles on corn plants. The number of beetles were counted on two randomly selected plants at each of 27 sites spaced evenly across fields (Steffey et al., 1982).

Trece™ Inc. Pherocon® AM sticky traps and vial-type, baited traps were placed side-by-side in pairs at each of 12 sites in each field. Sticky traps consist of a 28 x 23 cm yellow card with the center 23 x 18 cm area coated with adhesive that is folded around the corn plant at ear height (Hein and Tollefson, 1985). Baited traps consist of a yellow, plastic cylindrical base, capped with an inverted clear plastic cone. The cone apex contains a cork with a hole that is filled with bait. An attractant-filled fiber is twisted around the cork (Hessler and Sutter, 1993). Sticky and baited trap results are used, after being calibrated, as a tool for insect management decisions (Hein and Tollefson, 1985; Hesler and Sutter, 1993). The efficiencies of sticky and baited traps were compared. Both traps can be calibrated by comparing their counts to beetle count and subsequent larval damage.

Insect traps were placed in fields by NSTL scouts. Beetle numbers were counted on plants and traps by Iowa State Agricultural Experimental Station researchers.

Observation Schedule

Adult corn rootworm populations were monitored from the time they began to emerge until populations had declined. Emergence traps were placed in fields in July 1992. Beetle numbers were counted weekly before replacing traps until late August 1992. Beetle counts on corn plants and sticky and baited traps were conducted weekly starting in August 1992 and continued until bugs were not found on traps for two consecutive weeks which was early September 1992. Sticky and baited traps were replaced after beetles were counted.

Quality Assurance and Quality Control

Sticky traps are a relative sampling method that can reliably be used to compare populations from location to location and from time to time. Relative sampling methods cannot be used to determine population densities or to make management decisions unless they are "calibrated" by comparison with absolute estimates or by experimentally relating trap data to the event to be predicted, respectively. This was done in 1985 with the Trece™ Inc. Pherocon® AM trap (Hein and Tollefson 1985). The investigators established a threshold of six corn rootworm beetles per trap per day. Beetle catches at or above this level were considered high enough to warrant crop rotation or a planting-time rootworm insecticide if corn was planted the following year.

Agricultural Research Service entomologists proposed using baited traps to assist in making area-wide corn rootworm management decisions (Hesler and Sutter, 1993). To begin to calibrate this trap for use as a tool to make management decisions, a large number (12) of traps were placed at each study field. Baited traps could then be calibrated by comparing their beetle counts to plant counts and subsequent larval damage.

Data Format and Processing

Trap and plant beetle counts obtained during 1992 were screened by Iowa State Agricultural Research Station researchers. The average number of beetles per trap (per day) for all fields was calculated and entered into a Lotus 1-2-3® spreadsheet. Freelance Graphics® has been used to plot the number of beetles per plant and the trap catches for the 1992 season.

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Section 5-Q.2 European Corn Borer Surveys

W. Showers and M. Ferguson ISU

Background Information and Site Locations

The aggregation of adult European corn borer, *Ostrinia nubilalis* (Hubner), in dense grass within and around cornfields was first reported by Caffrey and Worthley (1927). However, Showers et al. (1974a) were the first to explore the appeal of this habitat for European corn borer (ECB) mating activities. Foxtail and other tall, dense vegetation (action sites) provide a good microclimate for the adults. Free water in the form of dew or raindrops contribute to the aggregation of the ECB in this dense vegetation (DeRozari et al., 1977) and is required for the initiation of sexual activity. After ECB females drink water, they release sex pheromone, mate, and move into cornfields to oviposit (Showers et al., 1976). Derrick and Showers (1990) found a relationship between the numbers of second-flight adult ECB in these action sites and egg masses in cornfields during anthesis stage of corn maturity.

1992 Studies

The primary objective of the 1992 study in Walnut Creek watershed was to compare trap captures from two types of pheromone-baited traps, the Hartstack (Texas Cone Trap) (Hartstack et al., 1979) and a commercial clone, the Sentry *Heliothis* trap (Sentry, Buckeye, Arizona). The Sentry is more readily available and may appeal to growers, who would like to monitor their fields. The aim of this study was to test the efficacy of the Sentry against the Hartstack.

The secondary objective of this study was to determine if sex pheromone-baited traps in habitats of grass (adequate action site), no grass (inadequate action site), and creek, in the Walnut Creek watershed can lead to determining ECB damage in cornfields. One question to be addressed was whether ECB numbers and activity at the creek sites were equivalent to the numbers and activities of the ECB at the grass sites, because of the fresh water available to the adult ECB at these creek sites (Derrick and Showers, 1990).

European corn borer populations were monitored at five study sites in Walnut Creek watershed during 1992. Three habitats were investigated in each study site in the watershed and included: corn with inadequate action sites, corn with adequate action sites, and corn adjacent to Walnut Creek. Table 1 lists locations and descriptions of the study sites.

<u>1993 Studies</u>

The primary objective of the 1993 study in Walnut Creek watershed was to continue the efficacy testing that began in 1992 of two pheromone-baited trap types. The secondary objective was to test the Z:E-11-tetradecenyl acetate (tda) charged lure (septum) produced commercially by Pherocon to the Z:E-11-tda charged lure (septum) produced in the Iowa State University (ISU) Entomology department. Both lures supposedly consist of 40 ug of 97% Z and 3% E and should be active for four weeks under Iowa field conditions. The experimental design was a split plot. Trap-type was the whole plot and lure-type the split. The experiment was replicated five times. Traps were placed along the roadside in action sites. Locations are provided in Table 2.

Table 1. Locations and descriptions of European corn borer study in sites in Walnut Creek watershed 1992.

Replicate	Habitat	Location	Field Size (Ha)	Trap Spacing (m)
I	Inadequate Action Site	SE 1/4, Sec. 6, T82N, R23W	54, cornfield	100
	Adequate Action Site	SE 1/4, Sec. 6, T82N, R23W	2, isolation cornfield	100
	Creek	SE 1/4, Sec. 6, T82N, R23W	54, cornfield	140
II	Inadequate Action Site	S 1/2, Sec. 1 & 2, T82N, R24W	32, cornfield	100
	Adequate Action Site	S 1/2, Sec.2, T82N, R24W	14, cornfield	100
	Creek	SW 1/4, Sec 2, T82N, R24W	46, cornfield	100
III	Inadequate Action Site	NE 1/4, Sec. 35, T83N, R24W	32, cornfield	120
	Adequate Action Site	NE 1/4, Sec. 35, T83N, R24W	32, cornfield	120
	Creek	NW 1/4, Sec. 36, T83N, R24W	64, cornfield	120
IV	Inadequate Action Site	NE 1/4, Sec. 33, T83N, R24W	45, cornfield	100
	Adequate Action Site	NE 1/4, Sec. 33, T83N, R24W	45, cornfield	120
	Creek	NE 1/4, Sec. 33, T83N, R24W	45, cornfield	120
V	Inadequate Action Site	NW 1/4 Sec. 32, T83N, R24W	64, seed cornfield	120
	Adequate Action Site	NE 1/4, Sec. 32, T83N, R24W	64, seed cornfield	120
	Creek	NE 1/4, Sec. 30, T83N, R24W	64, cornfield	120

Table 2. Trap locations and descriptions of European corn borer study in 1993 sites in Walnut Creek watershed.

Replicate	Location	Trap Spacing (m)
I	NE 1/4, Sec. 32 T82N, R24W	100
II	NW 1/4, Sec. 32 T82N, R24W	100
III	SW 1/4, Sec.28 T82N, R24W	100
IV	NE 1/4, Sec 27 T82N, R24W	100
V	SE 1/4, Sec 27 T82N, R24W	100

Sampling Techniques

1992 Studies

European corn borer summer flight and egg mass deposition on corn plants were monitored in Walnut Creek watershed, Story County, Iowa during late July and August 1992 under three habitats: corn with adequate action sites (dense grass or soybeans) nearby, corn without adequate action sites, and corn adjacent to a creek. Two pheromone-baited traps, the Texas 70-50 (70 cm height, 50 cm diameter) (Hartstack) cone trap and the Scentry *Heliothis* trap (similar dimensions) were placed in each habitat for comparison. Traps were baited with a commercial ECB lure (septum) Pherocon™, Trece Insect Monitoring Systems (Salinas, California). Each trap had a removable trap basket placed on top of the cone to collect adult ECB males.

Traps were monitored daily, baskets emptied, and captures recorded by an ISU researcher, graduate students, or student workers in the Entomology department. In addition, three black light traps were placed within the watershed. The black light traps were wing type standing 1.2 m high with a 15-W fluorescent black light tube as the light source. The power source was a 12-V, deep cycling, golfcart battery, recharged with a solar panel (MSX-50 Solarex, Rockville, Maryland).

Site selection was determined by appropriate habitat, proximity to other habitats within a replication, and similar corn maturity. Each habitat was replicated five times throughout the watershed. Within a cornfield or a portion of a cornfield representing a given habitat there were three, 20-plant samples for observing egg masses deposited by ECB females. Sites were delineated on July 21 and 22, 1992 and pheromone traps placed along the cornfields. Black light traps were set out July 24, 1992. Daily trap monitoring began immediately upon placement in the field. Black light trap captures were returned to the lab daily and ECB adults sexed. The females were classified as mated or unmated by rupturing the abdomen and exposing the bursa copulatrix. This procedure allowed determination of spermatophore within the corpus bursa, indicating a female had mated (Pesho, 1961; Drecktrah and Brindley, 1967; Showers et al., 1974b). Corn plant sampling for egg masses began August 4, 1992. Egg masses were circled with permanent marker upon finding. Replication, habitat, and plot location were recorded, as well as plant number, leaf number, and upper or lower leaf surface. Plants were scouted every three or four days until no new egg masses were found. In 1992, fields were scouted until August 21, 1992.

1993 Studies

European corn borer summer flight was monitored using two pheromone-baited trap types, the Texas 70-50, (Hartstack), and the commercial clone Sentry *Heliothis* trap and two types of pheromone lures (septum), one produced in the ISU Entomology department and a commercial lure (septum) Pherocon, Trece Insect Monitoring Systems, Salinas, California. A black light trap was also set up in each replication to monitor both male and female activity. A split plot design was used with five replications. Trap captures were monitored and recorded daily by students working with a researcher in the ISU Entomology department. Black light trap captures were returned to the laboratory to sex and count European corn borer adults. Females were classified as previously described, using a four class system, I, II, III, IV (unmated, just mated, laying eggs, and finished laying eggs) (Showers et al., 1974b).

Observation Schedule

1992 Studies

Corn plant sampling for egg masses began after ECB adults began to emerge. This was determined from monitoring the black light traps daily. All traps were monitored daily and fields were searched for egg masses every three or four days. Pheromone lures were replaced every two weeks. All egg mass scouting, trap monitoring, and data recording were made by Iowa State Agricultural Experiment Station researchers, graduate students, hourly workers or NSTL scouts.

1993 Studies

Traps were placed in the field on July 28, 1993. Monitoring began immediately on a daily basis and continued until August 27, 1993. Pheromone lures were replaced every two weeks. All traps were monitored daily by ISU Entomology department students.

Quality Assurance and Quality Control

Blacklight traps are a relative sampling method used to monitor European corn borer populations and can reliably predict when peak egg deposition in corn fields will occur. Females must be classified, with peak egg mass deposition occurring one-three days after the peak of class II females (Showers et al., 1974b). Plant maturity is also an important factor in the choice of an oviposition site; second-flight females are attracted to late planted corn and oviposit on silking and tasseling plants (Showers et al., 1989). Pheromone traps cannot be used reliably to predict egg mass deposition and ECB populations (Oloumi-Sadeghi et al., 1975). Feral ECB females compete with the synthetic pheromone lures for male moths, thus reducing trap efficiency. Pheromone trap captures increase after most female moths are classes III and IV, and egg mass deposition has already occurred in the field (Oloumi-Sadeghi et al., 1975).

Data Format and Processing

Trap data from 1992 and 1993 studies were initially recorded in field notebooks and later stored in Quattro Pro spreadsheet files. Egg mass data and trap data from 1992 were analyzed using Statistical Analysis Systems (SAS) (SAS Institute, 1985) and are stored in SAS files.

Data processing was conducted by an ISU researcher and graduate research assistant.

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Section 5-R Weed Surveys

M. Smith ISU

Overview

Weed surveys were conducted on 17 fields (9 farms) within Walnut Creek watershed during the summer of 1992. The surveys established base-line populations of species present in the watershed.

Site locations

Seventeen fields were surveyed, which included 418 ha of corn and 89 ha of soybeans. Field descriptions and locations are provided in Table 1.

Sampling techniques

All fields received a preplant or preemerge herbicide application before scouting began. Fields were scouted twice during the growing season. The first scouting trip was a general evaluation of weed populations. During the survey a zigzag pattern was walked through each field so that all portions of each field could be viewed. Species were identified, but plant numbers were not quantified. Maps were drawn highlighting areas in fields where weed plant populations varied from the rest of the field.

During the second scouting trip, detailed weed counts were taken. Weed species were counted and heights recorded at 10 randomly selected sample sites per field. Sample site dimensions were 3-m long and the width of a crop row. Survey forms (Attachment I) were completed, after all scouting trips, by a field scout for each field and copies were provided to cooperating farmers.

Table 1. Field sites used for weed survey in Walnut Creek watershed (1992).

Field Size (ha)	Crop	ASCS Tract	Location
21	corn	3080	S 1/2, NE 1/4, Sec. 30, T83N, R24W, Story Co.
7	corn	2966	N 1/2, NE 1/4, NE 1/4, Sec. 35, T83N, R24W, Story Co.
10	corn	2697	N 1/2, N 1/2, NW 1/4, Sec. 35, T83N, R24W, Story Co.
20	soybeans	2697	S 1/2, N 1/2, NW 1/4, Sec. 35, T83N, R24W, Story Co.
32	corn	1909	E 1/2, SW 1/4, Sec. 1, T82N, R24W, Story Co.
14	corn	1909	SW 1/4, SW 1/4, Sec. 1, T82N, R24W, Story Co.
36	corn	2012	N 1/2, SE 1/4, Sec. 2, T82N, R24W, Story Co.
23	soybeans	2012	S 1/2, NE 1/4, Sec. 2, T82N, R24W, Story Co.
15	corn	2449	SE 1/4, SW 1/4, Sec. 5, T82N, R23W, Story Co.
13	corn	2449	SE 1/4, SE 1/4, Sec.6, T82N, R23W, Story Co.
42	corn	2802	NE 1/4, Sec. 31, T83N, R24W, Story Co.
30	corn	3010	E 1/2, SE 1/4, Sec. 25, T83N, R25W, Boone Co.[1]
45	corn	3016	SE 1/4, Sec. 24, T83N, R25W, Boone Co.[2]
46	soybeans	3016	E 1/2, NE 1/2, Sec. 24, T83N, R25W, Boone Co.
60	corn	9002	SE 1/4, Sec. 29, T83N, R24W, Story Co.[3]
59	corn	8999	S 1/2, SW 1/4, and S 1/2, SE 1/4, Sec. 28, T83N, R24W, Story Co.[4]
34	corn	8087	N 1/2, NW 1/4, and N 1/2, NE 1/4, NE 1/4, Sec. 33, T83N, R24W, Story Co.

[1]Bassett's conventional tillage "pothole field"; [2]Bassett's no-till; [3]Black's ridge till (west) and no-till; [4]Black's "manured"

Observation Schedule

Weed scouting began on June 11 and final scouting was completed on September 22.

Data Format and Processing

Survey information from the detailed weed counts, such as weed numbers and heights, for each field and sample location have been entered into a Lotus 1-2-3 spreadsheet. The data is used to provide an indication of weed pressure in those areas that were surveyed. No attempt was made to recommend weed control options based on these scouting trips.

ATTACHMENT I

WALNUT CREEK WATERSHED FIELD CROP HISTORY---1994 CROP YEAR

Field Number________________ **Total Acres**________________

Soil test results (photocopy if possible)

Year sampled________________ Laboratory used______________________

Organic matter:__________ pH__________ P____________ K____________

Ca____________ Mg____________ Zn__________

Cropping history

Crop acres____________ Set-aside acres________________

TILLAGE (Please note all tillage passes. If an implement was used more than once, record all dates on line provided.)

Fall 1993 field passes:	Date(s):	Spring 1994 field passes:	Date(s):	Spring/summer 1994 field passes	Date(s):
Chop stalks	________	Chop stalks	________	Rotary hoe	________
Moldboard plow	________	Moldboard plow	________	Rotary hoe	________
Chisel plow	________	Chisel plow	________	Row cult.	________
Disk (offset)	________	Disk (offset)	________	Row cult.	________
Disk (tandem)	________	Disk (tandem)	________	Sidedress N (record sidedress N here if soil was disturbed, i.e. N was injected)	________
Apply anhydrous	________	Apply anhydrous	________		
Other	________	Field cultivator	________		
		Harrow	________	Other	________
		Other	________		

CROP PLANTING

Crop____________________ Hybrid or cultivar________________

(set-aside crop)____________________________

Type of planter/drill____________________ Row width (inches)__________

Seeding rate/A__________________ Date of planting________________

PESTICIDE USE

Product name and formululation (eg. Extrazine DF [or 4L])	Rate/A (lb, pt, qt, oz)	Time of application (date)	Method of application (band or broadcast) (PPI, PRE, or POST)	Band width (inches)

Herbicides:

custom or self applied?____________________

Insecticides:

Others: (e.g. fungicides)

FERTILIZER and LIME

Product (eg. dry, liquid, or anhydrous)	Analysis/grade (eg. 0-0-60 for N-P-K)	Rate lb/A actual fert. material	Method of application (with planter, broadcast, injected, or dribbled) (incorporated or not?)	Time (fall or spring and date)

custom or self applied?____________________

MANURE or SLUDGE

Animal source	Analysis (eg. 5-5-10 for N-P-K)	Rate lb or ton/A	Method of application (see above)	Time (fall or spring and date)

Other products used:
eg. nitrification inhibitor
or soil additives

SUPPORT PROTOCOLS

Section 5-S Analytical Procedures for Water, Soil, Air, and Plant Samples

R. Pfeiffer NSTL

The Analytical Laboratory at the National Soil Tilth Laboratory is responsible for the analysis of water and soil samples for atrazine, metribuzin, alachlor, metolachlor, and nitrate. Air samples are analyzed for the same herbicides. Plant samples are also analyzed for kjeldahl nitrogen and nitrates. All samples are analyzed using state-of-the-art analytical equipment according to established quality assurance and quality control (QA/QC) criteria that includes an external review by another analytical laboratory.

Sample Log-in Procedures and Storage

Upon receipt by the Analytical Laboratory, samples are assigned a case number and recorded in a submissions book. Each sample is assigned a log number (unique to each sample). This log number and the corresponding sample description are recorded in logbooks.

Soil and plant samples are stored at -20°C until analysis. Water samples are refrigerated at 5°C until analysis. Air sample storage procedures are provided in Section 5-E of this report.

Analytical Methodologies

Herbicides from Water (Thurman et al., 1990)

<u>General Summary</u>

Herbicides are extracted from water using solid phase extraction cartridges followed by elution with ethyl acetate. Extracts are analyzed by gas chromatography/mass spectroscopy (GC/MS) using selected ion monitoring (SIM).

Extraction Procedure (Robotic)

1. 500 mg C-18 cartridge is activated with 2 ml methanol followed with 2 ml water, the cartridge must remain wet
2. 250 ml of sample containing 0.5% methanol and 250 ng propazine (surrogate) is passed through the cartridge at a flow rate of approximately 10 ml/min
3. Air is pushed through the cartridge for 10 minutes to remove residual water (after the sample has passed through)
4. 100 ul of terbutylazine (internal standard; 10 ng/ul) in methanol is added
5. Elution with 2 ml of ethyl acetate into a small test tube
6. Small amount of pesticide-free sodium sulfate is added to eluate, shake and let stand
7. Transfer ethyl acetate to a GC vial, seal, and store at -20°C until analysis

Instrumental Analysis (GC/MS using SIM)

1. GC Conditions

   Column: HP Ultra-1 (Cross-linked 100% methyl silicone), 12 m by 0.2 mm i.d. with 0.33 μm film thickness
   Carrier Gas: He
   Head Pressure: 25 kPa (gives flow rate of 1 ml/minute)
   Temperature Program: 50°C for 1 minute, ramp at 6°C/minute to 250°C, hold 15 minutes
   Injector Temperature: 260°C
   Splitless injection (2 ul)

2. MS Conditions

   Ionization Voltage: 70 eV
   Ion Source Temperature: 250°C
   Electron Multiplier: 600V above autotune value
   Tuning: Autotune daily using PFTBA (perfluorotributylamine). Minimum acceptable criteria for tuning are determined using ions at m/z 69, 215, and 502. Using 69 as base peak (100%), 502 must exceed 2% and 215 must exceed 35%.
   Dwell Time: 50 millisecond/ion
   Analysis: SIM
   Confirmation: Based upon the presence of two confirming ions (with area counts ± 20%), and a retention time match of ± 0.2% relative to terbuthylazine

3. Instrument Performance

Sensitivity: 0.05 ng atrazine injected gives s/n < 3.
Chromatographic Performance: 1.0 ng atrazine injected gives a PGF value greater than 0.8, but less than 1.2
Column Performance: 1.0 ng atrazine and terbuthylazine injected gives a R value > 0.7

4. Instrument Calibration

GC/MS is calibrated using four calibration levels (0.08, 0.18, 0.5, 0.75, 1.25, and 2.0 ng/ul). For calibration to be accepted, r > 95%. Prior to each analysis, a check standard will be run, it must agree within 20% of known value. If not, it must be recalibrated before analyzing samples.

5. Method Quantitation Limit

Quantitation limit is 0.2 ppb for atrazine and metolachlor, 0.5 ppb for metribuzin and alachlor.

Nitrate from Water (Quickchem, 1993a)

General Summary

Nitrate is quantitatively reduced to nitrite by the passage of the sample through a copperized cadmium column in an autoanalyzer. The nitrite is then determined by diazotizing with sulfanilamide followed by coupling with N-(1-naphthyl) ethylendediamine dihydrochloride. The resulting solution has a magenta color which is read at 520 nm.

Instrumental Analysis

1. Instrument:
Lachet AE autoanalyzer configured with Manifold #10-107-04-I-E using cadium reduction column, 520 nm. filter, 80 ul flow cell, microloop, and proportioning pump
2. Reagents:
Ammonium chloride buffer, pH 8; Sulfanilamide color reagent, 15 M sodium hydroxide; Stock standard at 1000 ppm NO_3-N

3. Instrument Performance:
   Sensitivity: 1 ppm NO_3-N at s/n > 3
   Cadmium Column Performance: 100 ppm NO_3-N gives value greater than 0.6 absorbance units
4. Instrument Calibration:
   Calibrate prior to each run using four levels (80, 50, 20, and 5 ppm)
   Acceptable calibration is r $\geq$ 0.9
5. Method Quantitation Limit is 1.0 ppm NO_3-N

Ammonia from Water (Quickchem, 1993b)

General Summary

Water samples are analyzed for ammonia using the salicylate method that gives a green color that is read at 660 nm. Samples must be preserved at pH=3 with sulfuric acid to prevent the loss of ammonia.

Instrumental Analysis

1. Instrument:
   Lachet AE autoanalyzer configured with Manifold #10-107-06-2-A using 660 nm. filter, 80 ul. flow cell, microloop, and proportioning pump
2. Reagents:
   6% EDTA, Sodium phosphate dibasic heptahydrate, Salicylate-Nitroprusside Color Reagent, 2M potassium chloride, and Hypochlorite solution.
3. Instrument Performance:
   Sensitivity: 1 ppm NH_3-N at s/n > 3
   Cadmium Column Performance: 100 ppm NO_3-N gives value greater than 0.6 absorbance units
4. Instrument Calibration:
   Calibrate prior to each run using four levels (80, 50, 20, and 5 ppm)
   Acceptable calibration is r $\geq$ 0.9
5. Method Quantitation Limit is 1.0 ppm NH_3-N

Herbicides from Soil (Koskinen et al., 1991 and U.S.EPA, 1993)

General Summary

Soil samples are extracted with methanol/water followed by cleanup on a solid phase extraction cartridge with elution using ethyl acetate. Extracts are analyzed by gas chromatography using nitrogen-phosphorus (NP) detection.

Extraction Procedure (Robotic)

1. Weigh 10 g of soil into a 50 ml centrifuge tube (manual)
2. Add 20 ml of extraction solvent, vortex and let stand 12 hours at room temperature to facilitate partitioning (manual)
3. Position the centrifuge tube on the Zymark robotic system rack
4. Centrifuge at 2700 rpm for 10 minutes. Transfer the extraction solvent to another centrifuge tube
5. Repeat with an additional 14 ml of extraction solvent
6. Evaporate the combined extracts under nitrogen at 50°C for 65 minutes.
7. Transfer the extract to a C-18 cartridge activated with 2 ml of methanol followed by 2 ml of water
8. Elute the herbicides with 2 ml ethyl acetate containing the internal standard (terbuthylazine at 0.55 ng/ml)

Instrumental Analysis

1. GC Conditions

   Column: HP-5 (cross-linked 5% phenyl, 95% methylsilicone), 25 m by 0.32 mm. i.d. with a 0.52 um film thickness
   Head Pressure: 80 kPa
   Carrier Gas: He, flow rate of 1 ml/minute
   Temperature Program: 60°C (hold 1 minute) to 260°C (hold 5 minutes) at 10°C/minute
   Injector Temperature: 250°C
   Detector Temperature: 280°C
   Splitless injection (2 ul)
   Detector: Hydrogen: 3 ml/minute; Air: 120 ml/minute; Helium, make-up gas: 30 ml/minute

2. Instrument Performance

   Sensitivity: 0.2 ng atrazine on column gives s/n <3
   Chromatographic Performance: 1.0 ng atrazine on column gives a PGF value greater than 0.8, but less than 1.2
   Column Performance: 1.0 ng atrazine and terbuthylazine on column gives a R greater than 0.7

3. Instrument Calibration

The gas chromatograph is calibrated using four calibration levels (0.5, 1.0, 2.0 , and 4.0 ng/ul). For calibration to be accepted, r > 95% Prior to each analysis, a check standard is run, it must agree within 20% of known value; if failure, recalibration is required.

4. Method Quantitation Limit

Detection limits are 5 ng/g (ppb). Attenuation and injection volume are adjusted to give full scale response for a 1 ng of atrazine on column.

Nitrate from Soils (Quickchem, 1993c)

General Summary

Soil samples are extracted using 2N KCl. Nitrate is quantitatively reduced to nitrite by the passage of the sample through a copperized cadmium column in an autoanalyzer. The nitrite is then determined by diazotizing with sulfanilamide followed by coupling with N-(1-naphthyl) ethylendediamine dihydrochloride. The resulting solution has a magenta color which is read at 520 nm.

Extraction Procedure

1. 20 g of soil is weighed into a 250 ml Erlenmeyer flask
2. 100 ml of 2 M potassium chloride is added, shaken for 1 hour
3. Extract is filtered through Whitman #40 into a 20 ml scintillation vial

Instrumental Analysis

1. Instrument:
   Lachet AE autoanalyzer configurated with Manifold #12-107-04-1-B using cadium reduction column, 520 nm filter, 80 ul flow cell, microloop, and proportioning pump

2. Reagents:
   15 M sodium hydroxide, ammonium chloride buffer, pH=8; sulfanilamide color reagent, 2M potassium chloride

3. Instrument Performance:
   Sensitivity: 0.5 ppm NO_3-N at s/n > 3

   Cadmium column performance: 20 ppm NO_3-N gives absorbance of >0.10

4. Instrument Calibration:
   Calibrate prior to each run using 0.2, 0.5, 1.0, 5.0, 10.0 ppm standards
   Acceptable calibration is r $\geq$ 0.9

5. Method Quantitation Limit:
   0.5 ppm NO_3-N in soil

Ammonia from Soils (Quickchem, 1993d)

General Summary

Exchangeable ammonium is extracted from soil with 2M KCl. The extract is filtered and the filtrate is analyzed for ammonia by the salicylate method. The resulting green solution is read at 660nm.

Extraction Procedure

1. 20 g of soil is weighed into a 250 ml Erlenmeyer flask
2. 100 ml of 2 M potassium chloride is added, shaken for 1 hour
3. Extract is filtered through Whitman #40 into a 20 ml scintillation vial

Instrumental Analysis

1. Instrument:
   Lachet AE autoanalyzer configurated with Ma. ifold #12-107-02-A using 660 nm filter, 80 ul flow cell, microloop, and proportioning pump

2. Reagents:
   6% EDTA, sodium phosphate dibasic heptahydrate, Salicylate-Nitroprusside Color Reagent, 2M potassium chloride, and hypochlorite solution

3. Instrument Performance:
   Sensitivity: 0.5 ppm NH_3-N at s/n > 3

Cadmium column performance: 20 ppm NO_3-N gives absorbance of >0.10

4. Instrument Calibration:
   Calibrate prior to each run using 0.2, 0.5, 1.0, 5.0, 10.0 ppm standards
   Acceptable calibration is r $\geq$ 0.9

5. Method Quantitation Limit:
   0.5 ppm NH_3-N in soil

Soil Dry Weight

General Summary

Soil dry weight is defined on a wet-weight basis and is determined gravimetrically on one-20 g sample dried at 105°C for 12 hours in an oven. It is calculated according to the following formula:

$$\%H_2O = \{(Wet - Dry)/Wet\}\ 100$$

Kjeldahl Levels in Corn Plants

General Summary

Plant samples are air dried and ground using a Wiley Mill. Samples are digested at 350°C using sulfuric acid with selenium as a catalyst. Samples are diluted with water and analyzed using flow injection analysis on an autoanalyzer where the ammonia is heated with salicylate and hypochlorite in an alkaline phosphate buffer. An emerald green color is produced and measured at 660 nm.

Procedure

1. Weigh 0.1 gram dried plant material into digestion tube
2. Add 2 mls concentrated sulfuric acid
3. Add catalyst (Kjeldahl tab, Cat. #KC-S1, SCT, Inc., Littleton, CO)
4. Digest at 325°C for 2 hours or until solution is clear
5. Dilute to 50 ml with water

6. Four standards 20, 40, 60, and 80 ppm NH_3-N are digested with each group of samples

Instrument Analysis

1. Instrument:
   Lachet AE autoanalyzer using Manifold #13-107-06-2-A, proportionating pump, 80 ul flow cell and microloop

2. Reagents:
   Buffer (pH=13.5), Salicylate-Nitroprusside Color Reagent, and hypochlorite

3. Instrument Performance:
   Sensitivity: 2.5 mg N/L as NH_3 with s/n > 3

4. Instrument Calibration
   Digested standards of 20, 40, 60, and 80 mg N/L are run with each group of 25

5. Method Quantitation Limit:
   2.5 mg N/L as NH_3

Corn Stalk Nitrate Test

General Summary

Samples are extracted with KCl and analyzed for NO_3-N using a Lachat autoanalyzer.

Procedure

1. Weigh 0.25 grams of dried stalks (40°C for 24 hours) into 250-ml erlenmeyer flask
2. Add 100 ml 2M KCl
3. Shake for 30 minutes
4. Filter through Whatman #42 filter paper into 20 ml scintillation vial

Instrument Analysis

Analytical procedures used for the corn stalk nitrate test are the same as soil nitrate analytical procedures.

Herbicides in Air

General Summary

Herbicides are trapped on XAD, eluted with ethyl acetate and analyzed by GC with NPD detection.

Procedure

Sampling procedures for herbicides in air are provided in Section 5E of this report.

Instrument Analysis

Analytical procedures for herbicides in air are the same as those used for herbicides in soil samples.

Laboratory Quality Assurance and Quality Control

Herbicides from Water

1. Each sample set contains at least one blank, one duplicate, and one control.
2. Each sample will contain a surrogate compound spike.
3. Every tenth GC/MS injection will be a recalibration standard for the purpose of updating the calibration table.
4. First and last GC/MS injection will be check standards. They must be within 20% of known values; if not, the GC/MS will be recalibrated before starting analysis.

Nitrate and Ammonia from Water

1. Samples are run in sets of 60.
2. The instrument is recalibrated at the beginning of each sample set.
3. Calibration standards are run after each ten samples. If the value varies from the known value by more than 10%, the instrument is recalibrated.
4. A check sample is run with each sample set and the value must agree within 10% of true value.

Herbicides from Soil

1. Samples are run in sets of 40.
2. One blank is used to measure method contaminants and will be an extract of soil representative of the field site. A reagent blank may be run as a substitute if pesticide-free soil cannot be found.
3. Four matrix spikes on soils representative of the site are added. Spiking levels will vary to bracket the expected herbicide values.
4. A surrogate is added to each sample.
5. Five percent of all positive samples are confirmed by GC/MS using SIM. The same parameters are used for soil as for water analysis.

Kjeldahl Nitrogen in Plants

1. Samples are run in groups of 25.
2. Four standards are digested with each group of samples.
3. One control of known NH_3-N concentration is digested with each group

Nitrate Corn Stalk Test

Quality assurance and quality control procedures used for the nitrate corn stalk test are the same as those used for nitrates in soil samples.

External Laboratory Review

Water samples and soil extracts representing 1% of the total are sent to Twin Cities Testing, an EPA certified laboratory in Minneapolis, Minnesota for analysis. This laboratory, following the criteria established by the contract, analyzes the samples and verifies accuracy of NSTL's analytical methodologies.

Data Format

Data is entered into and processed in Quattro Pro 4.0 files. Hard and disk copies of the analytical results are provided to each scientist who has submitted samples to the NSTL Analytical Laboratory.

References

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Section 5-T Temporary Benchmarks and Surveys

D. Schmitz NSTL

Temporary Benchmarks

Temporary benchmarks were established by the National Soil Tilth Laboratory (NSTL) throughout Walnut Creek watershed at section (and road) intersections every 1 mile and at points (every 1/4-1/2 mile) in-between these intersections using level-line surveys to establish sea-level elevations. Level lines were commenced and terminated at third-order benchmarks established by the United States Geological Survey (USGS) and adjusted by the United States Coast and Geodetic Survey to mean sea level and referenced to the North American Datum established in 1927.

Benchmarks consist of either a 20-penny pole spike inserted through a short piece of 0.32 cm-diameter galvanized pipe and driven horizontally into utility poles or a square chiseled in concrete at bridges or culverts. Temporary benchmark locations and elevations are provided in Table 1. Each benchmark is assigned an identification number that consists of the Congressional township, range, section number and quarter-section in which they are located. For example, the index number; 8325-15 SW-1 identifies a benchmark located in the SW¼ of section 15, T83N, R25W. The number 1 after the hyphen indicates that this is the first benchmark located in this quarter section. This information is also stored in ASCII files at the NSTL.

Simultaneous double-level lines were run between the temporary bench-marks using a Wild Nak2 self-adjusting level and two Philadelphia stadia rods using techniques described in Kissam (1971). The results from these runs were compared for accuracy according to third order standards. An average was computed for the two runs and used as the difference in elevation between two bench marks. A closure error (difference between actual and computed bench mark elevation) was determined upon completion of runs and compared to the final bench mark established by USGS. This error was distributed along the level line to all temporary bench marks based on the proportion of run length to the total mileage from USGS benchmark to benchmark to obtain adjusted values.

Table 1. Temporary benchmarks established in Walnut Creek watershed.

BM #	ID #	Elevation	Description
BM 1	8325-15 SW-1	1058.936	Luther, 2.3 mi N, 3 mi E of; T83N, R25W, near S sixteenth corner between sections 15 and 16; 700 ft S of private driveway E, on top of and in center of E concrete headwall; and 0.7 ft higher than center of road at culvert; a standard tablet stamped "20 WMC 1964 1059"
TBM 2	8325-22 NE-1		Pole, Spike and Collar (PSC) in N side of the 7th utility pole east of the NW corner of sec 22, T83N, R25W, at the NW corner of the farmstead, near the NW corner of NE 1/4 of Sec 22, T83N, R25W. (Destroyed - 5-28-92)
TBM 2A	8325-22 NE-2		PSC in N side of 6th utility pole east of the NW corner of Sec. 22, T83N, R25W, at the NW corner of the farmstead, near the NW corner of NE 1/4 of Sec 22, T83N, R25W.
TBM 3	8325-22 NE-3	1057.627	Pole, Spike and Collar in north side of the utility pole located at the NE corner of Sec. 22, T83N, R25W.
TBM 4	8325-23 NE-1	1049.620	Pole, Spike and Collar in north side of the 9th utility pole to the east of the NW corner Sec. 23, T83N, R25W, near the NE corner of NW 1/4, Sec. 23.

BM #	ID #	Elevation	Description
TBM 5	8325-24 NW-1	1039.868	Pole, Spike and Collar in the west side of the utility pole located in the NW corner, Sec. 24, T83N, R24W.
TBM 6	8325-24 SW-2	1049.393	Pole, Spike and Collar in the west side of the 13th utility pole south of the NW corner, Sec. 24, T83N, R25W, near the NW corner of SW 1/4, Sec. 24.
TBM 7	8325-24 SW-3	1051.697	Pole, Spike and Collar in the west side of the utility pole located in the SW corner, Sec. 24, T83N, R25W.
BM 8	8325-25 SW-1	1047.824	Pole, Spike and Collar in west side of the 7th utility pole from the south, located in the NW corner of the SW 1/4, Sec. 25, T83N, R25W.
TBM 9	8325-25 SW-2	1049.897	Pole, Spike and Collar in the south side of the utility pole located in the SW corner, Sec. 25, T83N, R25W.
WC 22-14	8325-36-1	1045.952	Top of most northern PVC in well nest of two (measured with cap off), located in the NE corner of the NW 1/4, Sec. 36, T83N, R25W. Well nest is located to the south of pasture.
WC 5-14	8325-25-3	1040.108	Top of western PVC in well nest of two (measured with cap off), located in the SW corner of the SE 1/4 of the SE 1/4, Sec. 25, T83N, R25W.
TBM 10	8325-25 SE-4	1040.174	Pole, Spike and collar in the west side of the utility pole at SE corner of Sec. 25, T83N, R25W, near intersection of E-W county road and N-S gravel road.
TBM 11	8325-31 NW-1	1037.258	Pole, Spike and Collar in the south side of the 4th utility pole, east of the NW corner of Sec. 31, located in the NE corner of the NW 1/4 of the NW 1/4, Sec. 31, T83N, R24W.

BM #	ID #	Elevation	Description
TBM 12	**8325-31 NE-2**	**1033.008**	Pole, Spike and Collar in the south side of the 9th utility pole west of the NE corner of Sec. 31, located in the NE corner of the NW 1/4 of the NE 1/4, Sec. 31, T83N, R24W.
TBM 13	8324-31 NE-3	**1022.298**	Pole, Spike and Collar in the north side of the 9th utility pole from the east in the NW corner of the NE 1/4 of the NE 1/4 of Sec. 31, T83N, R24W.
TBM 14	**8324-31 NE-4**	**1028.823**	Established high point 3/8 lag bolt, located in the utility pole on the SW corner at junction R38 and E57, Story County, NE corner of Sec. 31, T83N, R24W.
WC 33-16	**8324-29 SE-1**	**1009.173**	Top of most eastern well in a well nest of two (measured with cap off), located in the SW corner of SE 1/4, Sec. 29, T83N, R24W.
WC 35-6	**8324-29 SE-2**	**1005.835**	Top of PVC of the middle well in a well nest of three (measured with the cap off), located in the SW corner of the SE 1/4 of the SE 1/4, Sec. 29, T83N, R24W.
TBM 17	**8324-33 NW-1**	**1001.582**	Pole, Spike and Collar in the north side of the utility pole at ground level at SE corner of the road intersection, NW corner of Sec. 33, T83N, R24W.
TBM 18	**8324-28 SW-1**	**999.172**	Pole, Spike and Collar in the upstream side of the middle wingwall piling on left upstream side of the timber and piling bridge over Walnut Creek (SW corner of Black East field basin), located in the SW corner of the SE 1/4, SW 1/4, Sec. 28, T83N, R24W.
WC 3-4	**8324-28 SW-1**	**1003.088**	Top of the most western well in a well nest of three (measured with the cap off), located in the SE corner of the SE 1/4, SW 1/4, Sec. 28, T83N R24W.

BM #	ID #	Elevation	Description
WC 1-6	8324-28 SW-2	1010.798	Top of most western well in a well nest of three (measured with the cap off), located in SW corner of SE 1/4, Sec. 28, T83N, R24W.
TBM 21	8324-34 NW-1	1019.702	Pole, Spike and Collar located in the west side of the utility pole, located in the NW corner of Sec. 34, on the SE corner of the T-intersection, Sec.34, T83N, R24W.
TBM 22	8324-34 NW-2	1009.070	Located on the west side of the utility pole, located south of the T-intersection on the SW corner of the NW 1/4, Sec. 34, T83N, R24W.
TBM 23	8324-34 SW-1	982.456	Chiseled square on the north corner of the downstream culvert headwall, located on the east side of the road in the SW corner of the NW 1/4, SW 1/4, Sec. 34, T83N, R24W.
TBM 24	8324-33 SE-2	998.279	Located in the east side of the utility pole in the NW corner of the intersection of Elwood Drive and Kelley "Blacktop" Road, located in the SW corner of Sec. 33, T83N, R24W.
TBM 25	8324-34 SE-1	1005.119	PSC in SE side of utility pole located in the NW corner of Timber Road and Kelley Road intersection in the SW corner of the SE 1/4 of section 34, T83N, R24W.
TBM 26	8224-2 NW-1	999.702	PSC in S side of the 11th utility pole east of the Timber Road-Kelley Road intersection, located in the NW corner of Sec. 2, T82N, R24W.
TBM 27	8224-2 NE-2	972.896	PSC in W side of utility pole located in SW corner of "T" intersection of Kelley Road and Highway 69 in NW 1/4 of Sec 2, T82N, R24W.

BM #	ID #	Elevation	Description
TBM 28	8224-2 NE-3	981.481	PSC in W side of 2nd utility pole to the south of the SE corner of the intersection of Highway 69 and gravel road to the east in the NW corner of the SW 1/4 of the NE 1/4, Sec. 2, T82N, R24W.
TBM 29	8224-2 NE-4	960.507	PSC in northern 1x6 base on USGS gaging station located on the south side of the road in the NW corner of the SE 1/4 of the NE 1/4 of Sec. 2, T82N, R24W.
TBM 30	8224-1 NW-1	993.201	PSC in N side of 7th utility pole to the east of USGS gaging station in the NW corner of the SW 1/4 of NW 1/4 of Sec. 1, T82N, R24W.
TBM 31	8224-1 NE-2	923.832	PSC in N side of the 6th pole to the east of the "T" intersection with the gravel road coming from the north. Utility pole is located at the bottom of the valley and curve and is in the SW 1/4 of the NE 1/4 of Sec. 1, T82N, R24W.
TBM 32	8224-1 NE-3	898.853	PSC in N side of utility pole located in the SW corner of the "T" intersection in the NE corner of the SE 1/4 of the NE 1/4 of Sec. 1, T82N, R24W.
TBM 33	8224-1 SE-4	927.846	PSC in E side of the 9th utility pole south of the "T" intersection (TBM 32) at the NE corner of the SE 1/4 of Sec. 1, T82N, R24W.
TBM 34	8224-12 NE-1	943.143	PSC in N side of utility pole located in the SW corner of the intersection in the NE corner of Sec. 12, T82N, R24W.
TBM 35	8223-7 NE-1	904.375	Chiseled square in cement in the southwestern corner of the I-35 bridge overpass. Located in the NW corner of NE 1/4 of Sec. 7, T82N, R23N.

BM #	ID #	Elevation	Description
TBM 36	8223-7 NE-2	868.169	**(Destroyed - 10-19-93)** PSC in the N side of the 3rd utility pole east of the I-35 bridge overpass on the south side of the road in the NE corner of NW 1/4 of the NE 1/4 of Sec. 7, T82N, R23W.
TBM 36A	8223-7 NE-3	867.458	PSC in the N side of the third utility pole east of the I-35 bridge overpass on the south side of the road in the NE corner of the NW 1/4 of the NE 1/4 of Sec. 7, T82N, R23W.
TBM 37	8223-8 NW-1	863.933	**(Destroyed - 10-19-93)** PSC in the S side of the utility pole approx. 1/3 mile east of TBM 36 on the south side of the road in the NW corner of Sec. 8, T82N, R23W. This PSC has been removed by the utility company.
TBM37A	8223-8 NW-2	862.063	PSC in the S side of the 5th utility pole past TBM 36 approx. 1/3 mile E of TBM 36 on the south side of the road in the NW corner of Sec. 8, T82N, R23W.
TBM 38	8223-8 N-2	860.164	PSC in the N side of the eighth utility pole from TBM 37. It is on the south side of the road on the north side of Sec. 8, T82N, R23W.
TBM 39	8223-8 NE-3	857.814	PSC in the S side of the utility pole closest to the Askew Bridge. The pole is leaning towards the north and has a electric meter shell on the front of the pole. It is on the south side of the road on the NE corner of Sec. 8, T82N, R23W.
TBM 40	8223-8 NW-4	868.196	The benchmark is a square carved into the cement on the SW corner of the Askew Bridge. It is in the NW corner of Sec. 9, T82N, R23W.
TBM 41	8223-8 NE-5	855.967	PSC in No Passing Zone sign on the East side of the road.

BM #	ID #	Elevation	Description
TBM 42	8223-16 NW-1	859.953	Benchmark is a brass plug in the NE corner of the bridge approx. 1 mile south of the Askew Bridge on Cambridge Road. It is on the WSW corner of Sec. 16, T82N, R23W.
TBM 43	8223-16 SW-1	865.525	Benchmark is a brass plug on the second bridge south of the Askew Bridge on the Cambridge blacktop. The plug is on the NW corner of the bridge. The bridge is on the SW corner of Sec. 16, T82N, R23W.
TBM 44	8223-21 NW-1	859.124	PSC is in the E side of the utility pole on the Cambridge blacktop after the road branches. It is the seventh pole after the bridge on the east side of the road. The pole is in the SW 1/4 of the NW 1/4 of Sec. 21, T82N, R23W.
TBM 45	8223-21 NW-2	875.550	PSC is in the E side of the utility pole on the NW corner of Park and West 4th St. in Cambridge. The pole is on the S side of the NW 1/4 of Sec. 21, T82N, R23W.
TBM 46	8223-21 NW-3	870.235	PSC is on the S side of the utility pole on the SW corner of 4th St. and Water in Cambridge. The pole is on the SW 1/4 of the NW 1/4 of Sec. 21, T82N, R23W.
TBM 47	8223-21 SW-1	868.187	Benchmark is the NW corner of the light pole on the E side of Water St. across from the Bank in Cambridge. The light pole is in the central part of the NE 1/4 of the SW 1/4 of Sec. 21, T82N, R23W.
TBM 48	8223-21 SW-2	870.579	At Cambridge, IA, Story County on State Highway 211, at the old State Bank building, in the east brick wall, 1.4 feet north of the southeast corner, 29 feet west of the centerline of the highway, and 2.9 feet above the ground. a United States Geological Survey standard disk, stamped "872" and set vertically.

Surveys

Level line surveys were run to the following sampling locations in the watershed using techniques described earlier:

1. Meteorological stations (Tim Hart)
2. Bowen ratio stations (John Prueger and Tim Hart)
3. Stream gaging and runoff stations (Donna Schmitz)
4. USGS groundwater monitoring wells (Karen Keck/Donna Schmitz)
5. Groundwater monitoring wells (Dan Jaynes)
6. Groundwater monitoring wells (Bill Simpkins)
7. Groundwater monitoring wells (Tom Steinheimer and Sally Logsdon)
8. Grid soil sample locations (Tom Moorman)
9. Neutron access tube and time domain reflectrometry (TDR) locations (Sally Logsdon)

Survey information is stored in ASCII files managed by Donna Schmitz at the NSTL. Individual ASCII files for surveyed sampling sites are also managed by the researchers and technicians mentioned above.

References

Kissam, P. 1971. Surveying practice; The Fundamentals of Surveying. McGraw Hill, New York, NY. 482 pp.

Section 5-U Global Positioning System

K. Keck and J. Cook NSTL

Introduction

The National Soil Tilth Laboratory (NSTL) uses a Global Positioning System (GPS) that relies on a network of satellites to provide geographical reference. The system is used in the Walnut Creek watershed to reference particular monitoring sites. This information, along with sampling data collected from these sites, is entered into a Geographic Information System (GIS). The GIS is used to generate field-scale or watershed-scale maps that show monitoring sites and data collected at these sites.

GPS Equipment and Post-Processing Operation

The NSTL uses the Pathfinder™ GPS system, manufactured by Trimble Navigation (Sunnyvale, CA). This system has two components, a mobile field receiver system and a stationary receiver system. The mobile receiver system includes a satellite antenna, GPS receiver, and datalogger, that as a unit can be easily carried by one person in the field. The stationary receiver system consists of a satellite antenna, a GPS receiver, and a computer that functions as a data storage module. The stationary unit is usually located at NSTL or at the Iowa State University Agronomy Agricultural Engineering Research Center, Ames, Iowa.

During operation of the GPS system, the mobile unit is attached to a vehicle or carried by a person in the field. After communication is established between the mobile receiver and the satellites, the datalogger lists the satellites in view, the satellites being used, and which satellites are operational and enabled. Latitude and longitude coordinates for unknown locations can then be received and recorded. This information is transferred from the receiver to the mobile unit's datalogger and stored along with manually-entered attribute data such as sample number, site number, field number, and site descriptions.

The stationary receiver is operated concurrently with the mobile unit. It's antenna stays fixed at an accurately surveyed point, but is otherwise set up in a similar way to the mobile unit. Since this receiver views the same satellites as the mobile receiver it is used to determine the amount of signal error from the mobile receiver that is being transmitted by the satellites.

After a data-collecting session with the mobile unit has been completed, data is downloaded from the mobile unit's datalogger and the stationary unit's computer to a personal computer (PC) at NSTL. Stationary receiver data is used to correct the mobile receiver data in an activity called post-processing. The calculated errors detected during post-processing are called differential corrections. The data can be output to plotters, printers, and as ASCII files in a variety of formats using Pathfinder™ post-processing software. The ASCII files in common GIS interchange formats can be imported into nearly any GIS system.

The data is stored in a series of corrected files specific to the PFINDER™ software and in ASCII files. One of the streamlined versions of the ASCII files is shown in Figure 1. The top part of the print-out describes the parameters used to define the data processing. For example, to compare this GPS locational data with other GPS or surveyed data, it is important to know that the NSTL data is in the NAD-83 datum with

```
Input Files:       1
                   1. 080993.D3D
Output File:       d:\pfpro\DATA\PFINDER\soil\080993.GEN
Printer Output:    Disable
Data Collected:    Aug 09 17:14:44 1993
GIS:               Arc/Info-Info
Datum:             NAD-83
Ellipsoid:         GRS80
Coords:            Universal Transverse Mercator
Projection:        Universal Transverse Mercator
UTM Zone Used:     15T
Units:             METERS HAE
Reference Alt:     3D Above Ellipsoid
Altitude Unit:     METERS
Position Source:   Features Only
Filter Used:       None
Attr. to output:   Attribute Values, Notes, User Code 1

1,,,pothle cntrl pt
2,,,ew1
3,,,ew2
4,,,ew3
5,,,ew6
6,,,ew7
7,,,ew8
8,,,ns2
9,,,ns1
10,,,ht
                                                   ---------std dev------
       easting      northing    hae       #pts   easting   northing    hae
    1,441752.54, 4646141.18, 288.32    182    2.2       2.3         6.1
    2,442137.87, 4646337.17, 290.80    193    2.7       1.7         6.2
    3,442081.20, 4646335.60, 288.03    180    2.8       2.4         3.2
    4,442018.70, 4646333.57, 285.43    181    1.5       3.5         4.7
    5,441837.61, 4646325.45, 296.77    182    1.5       3.3         8.7
    6,441775.11, 4646323.77, 295.44    182    1.4       3.1         7.3
    7,441748.70, 4646325.44, 298.70    181    2.2       5.5         8.9
    8,442019.11, 4646391.56, 293.08    181    1.9       3.4         4.7
    9,442017.61, 4646451.89, 296.19    182    1.4       3.2         4.1
   10,442061.06, 4646438.19, 298.66    182    2.7       5.1         6.5
END
```

Figure 1. Differentially-corrected GPS data that are stored in ASCII files for GIS applications. The top portion of the printout describes the parameters used to define the data and the bottom portion lists the locational data and their standard deviations.

a Universal Transverse Mercator (UTM) projection. Instead of latitude and longitude, the NAD-83 datum with a UTM projection produces eastings (equivalent to longitudes) and northings (equivalent to latitudes), and heights above ellipsoid (equivalent to heights above mean sea level). The bottom part of the print-out includes the data with their standard deviations.

In ASCII format, the data can be transferred into a GIS that uses geographical positions as a relational attribute. Positions can be differentially corrected and output files can be exported to GIS programs or plotted on maps. The soil map shown in Figure 2 was generated from GPS soil core geographic references using the ARC-INFO GIS system at NSTL.

Geographical references are collected using GPS at new sample sites during each field season. Post-processed, differentially-corrected geographical references have been collected at the following monitoring sites in the watershed:

1. Meteorological stations (Jerry Hatfield and Tim Hart)
2. Rain gage stations (Tim Hart and Donna Schmitz)
3. Eddy correlation and Bowen ratio stations (John Prueger and Tim Hart)
4. Stream gaging stations (Donna Schmitz)
5. Bird Census sites (Lou Best and Tim Bergin)
6. USGS monitoring well network (Karen Keck/Donna Schmitz)
7. Monitoring wells (Dan Jaynes)
8. Monitoring wells (Bill Simpkins)
9. Monitoring wells (Tom Steinheimer and Sally Logsdon)
10. Soil sample sites (Tom Moorman and Cynthia Cambardella)
11. Soil sample sites (Karen Keck/Donna Schmitz)
12. Insect trap sites (Bill Showers)
13. Spore trap sites (Nader Vakili)

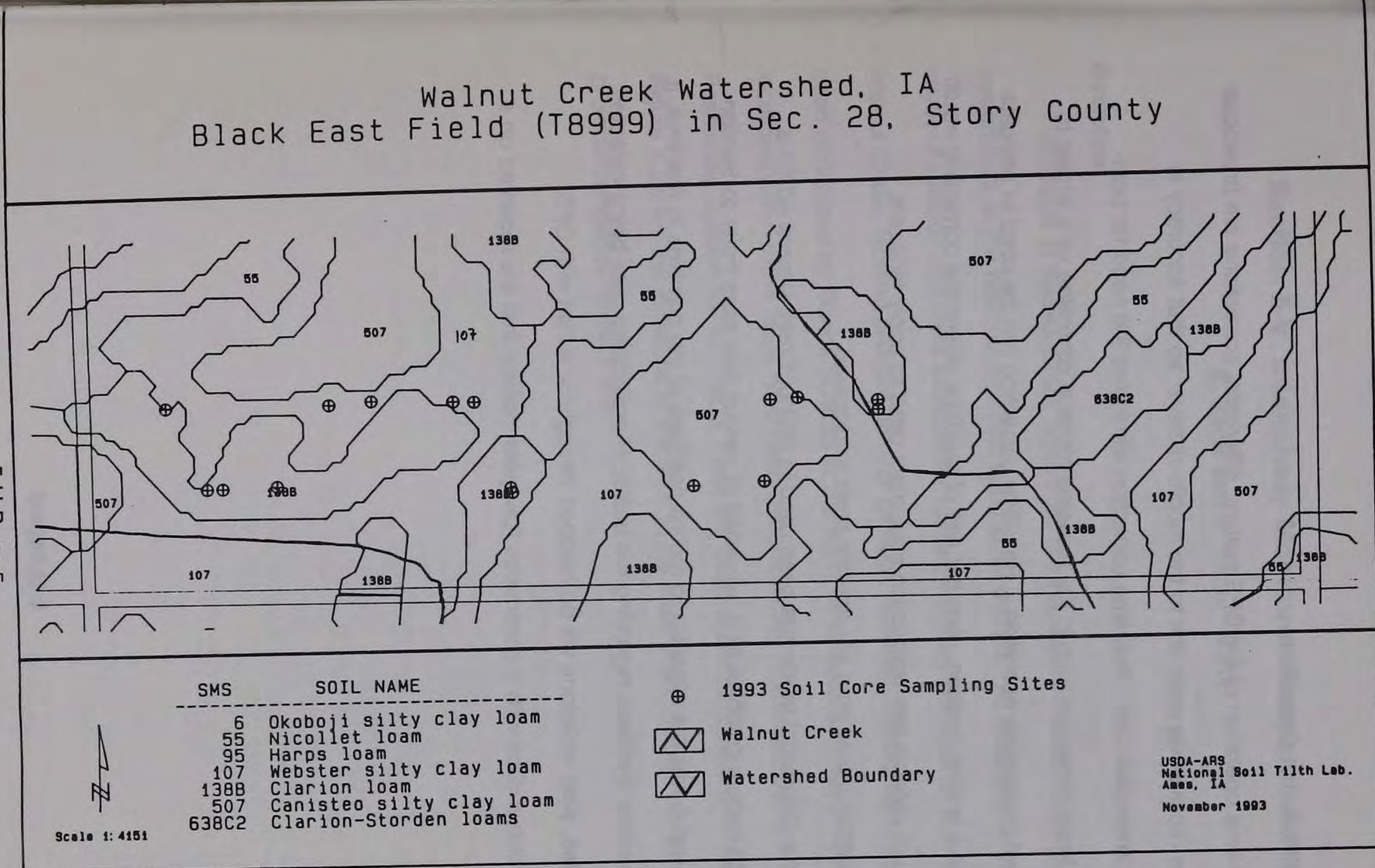

Figure 2. A soil core positions map generated by super-imposing GPS and soil core data on a soil type map of a field in Walnut Creek watershed, using the ARC-INFO GIS system at the NSTL.

Real-Time Differential Operation

In real-time operation of the GPS system, differential corrections are broadcast from the base receiver via radio link to the mobile receiver so that accuracy is improved for immediate use. Real-time correction eliminates the need for post-processing. Equipment operation in the real-time mode is otherwise very similar to that of the post-processing operation. Real-time correction can be used to navigate the receiver to a known location. Another use of real-time differential correcting would be for control of variable rate application equipment used to apply fertilizers, pesticides, or other inputs on a site-specific basis to cropland.

Real-time differential mode has been used in Walnut Creek watershed on a limited basis to track a combine as it harvested at various field sites (refer to Section 5-O.1). Although it was not essential to record positions of the combine in real-time, it provided immediate feedback regarding the quality of positioning data being collected. In future studies, yield variations will be mapped throughout a field with GPS equipment in conjunction with a continuous flow yield monitor that are mounted on a combine.

Section 5-V Intensively Monitored Research Sites

K. Keck and P. Sauer NSTL

Overview

Six fields in Walnut Creek watershed are intensively monitored by many researchers at the National Soil Tilth Laboratory (NSTL). All fields are in a corn-soybean rotation and were selected for research studies because of their proximity to Walnut Creek, farming practice, and/or geologic features. Topographic surveys have been conducted by Donna Schmitz at the NSTL in all fields and many sample locations within these fields have been geographically referenced using a Global Positioning System (GPS). Table 1 lists the fields and their locations in the watershed. Figure 1 shows the locations of the sites in the watershed. Tables 2-7 list the research projects conducted at each site.

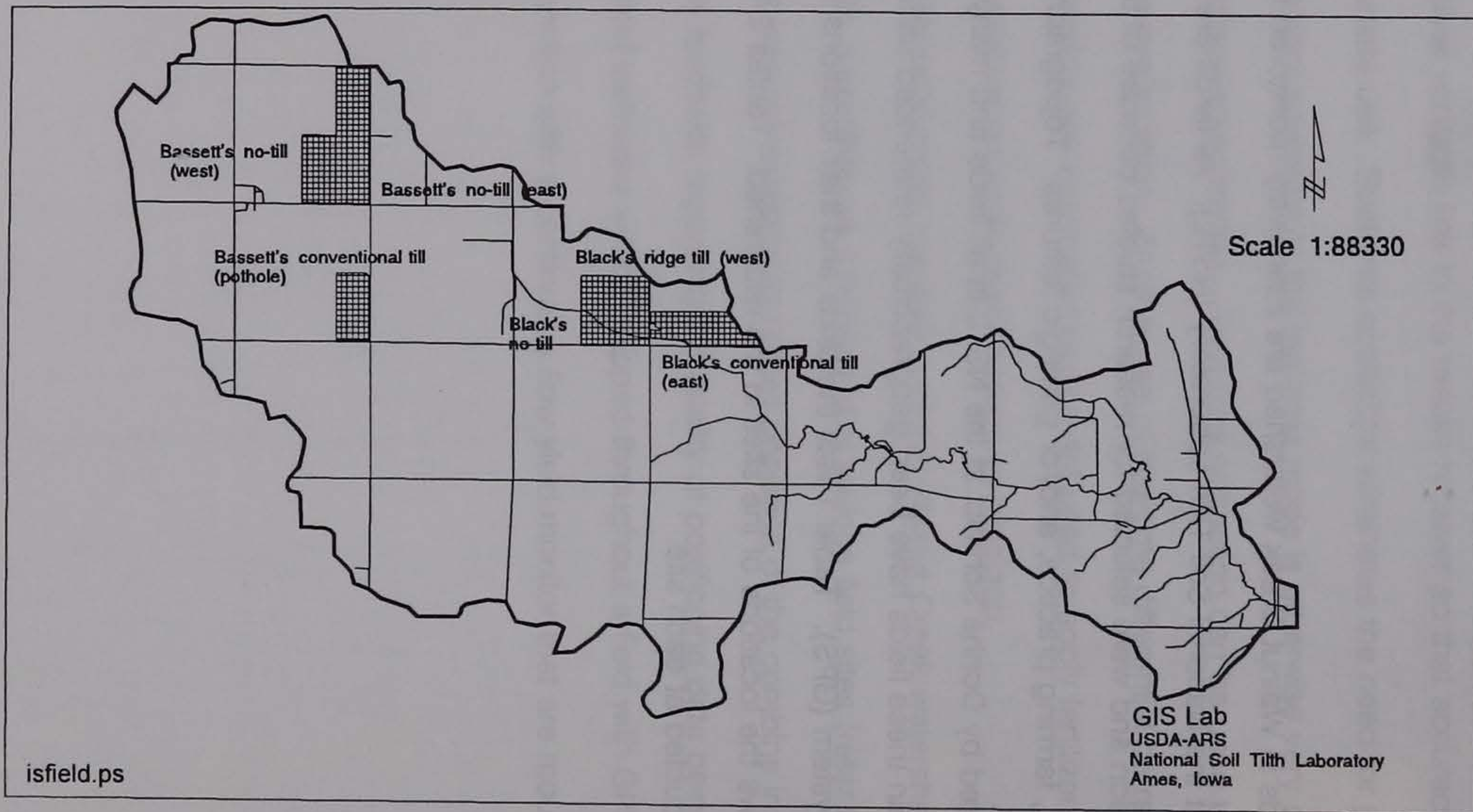

Figure 1. Intensively monitored fields in Walnut Creek Watershed.

Table 1. Intensively monitored sites in Walnut Creek watershed.

Site Name	ASCS Tract	Location
Bassett's no-till (west) field	3016-W	W 1/2, E 1/2, SE 1/4, Sec. 24 and W 1/2, SE 1/4, Sec. 24, T83N, R25W, Boone Co.
Bassett's no-till (east) field	3016-E	E 1/2, NE 1/4, Sec. 24 and E 1/2, E 1/2, SE 1/4, Sec. 24 T83N, R25W, Boone Co.
Bassett's conventional tillage field "pothole field"	3010	E 1/2, SE 1/4, Sec. 25, T83N, R25W, Boone Co.
Black's ridge till (west) field	9002	N 1/2, SE 1/4, Sec. 29, T83N, R24W, Story Co.
Black's conventional tillage (east) field	8999	S 1/2, Sec. 28, T83N, R24W, Story Co.
Black's no-till field	9002-S	S 1/2, SE 1/4, Sec. 29, T83N, R24W, Story Co.

Table 2. Studies in Bassett's no-till west field in Walnut Creek watershed.

Research Study	Researcher/Technician	Equipment
Energy balance and evapotranspiration	John Prueger	Bowen ratio and eddy correlation stations including thermocouples and a net radiometer
USGS groundwater monitoring wells	Karen Keck/Donna Schmitz	Monitoring wells
Groundwater quality and hydraulic heads	Tom Steinheimer and Sally Logsdon	Monitoring wells
Soil physical parameters	Sally Logsdon	Neutron access tubes, tensiometers, soil cores (hydraulically-collected)
Soil properties	Cambardella, Moorman, Parkin, Karlen, Novak	Soil cores (manually- and hydraulically-collected)
Soil sampling for pesticides	Karen Keck/Donna Schmitz	Soil cores (hydraulically-collected)
Crop yields and grain quality	Doug Karlen, Tom Colvin	Combine-collected crop samples
Crop characteristics	Karen Keck	Manually-collected crop samples
Farm surveys	Karen Keck/Donna Schmitz	Farmer interview
Weed surveys	Margaret Smith	Observations

Table 3. Studies in Bassett's no-till east field in Walnut Creek watershed.

Research Study	Researcher/Technician	Equipment
Energy balance and evapotranspiration	John Prueger	Bowen ratio and eddy correlation
USGS groundwater monitoring wells	Karen Keck/Donna Schmitz	Monitoring wells
Groundwater quality and hydraulic heads	Tom Steinheimer and Sally Logsdon	Monitoring wells
Soil physical parameters	Sally Logsdon	Neutron access tubes, tensiometers, soil cores (hydraulically-collected)
Soil properties	Cambardella, Moorman, Parkin, Karlen, Novak	Soil cores (manually- and hydraulically-collected)
Soil sampling for pesticides	Karen Keck/Donna Schmitz	Soil cores (hydraulically-collected)
Crop yields and grain quality	Doug Karlen, Tom Colvin	Combine-collected crop samples
Crop characteristics	Karen Keck	Manually-collected crop samples
Farm surveys	Karen Keck/Donna Schmitz	Farmer interview
Weed surveys	Margaret Smith	Observations

Table 4. Studies in Bassett's conventional tillage field "pothole field" in Walnut Creek watershed.

Research Study	Researcher/Technician	Equipment
Energy balance and evapotranspiration	John Prueger	Bowen ratio and eddy correlation
Tile flow	Donna Schmitz	Flow meter, inverted siphon, water sampler
USGS groundwater monitoring wells	Karen Keck/Donna Schmitz	Monitoring wells
Groundwater and landscape position	Dan Jaynes	Monitoring wells, neutron access tubes
Soil physical parameters	Sally Logsdon and Dan Jaynes	Soil cores (hydraulically-collected), tracers, infiltrometers
Soil properties	Cindy Cambardella, Tom Moorman, Tim Parkin, Doug Karlen, Jeff Novak	Soil cores (manually- and hydraulically-collected)
Herbicide sorption and biodegradation	Tom Moorman	Soil cores (manually- and hydraulically collected)
Soil sampling for pesticides	Karen Keck/Donna Schmitz	Soil cores (hydraulically-collected)
Crop yields and grain quality	Doug Karlen, Tom Colvin	Combine-collected crop samples
Crop characteristics	Karen Keck	Manually-collected crop samples
Farming surveys	Karen Keck/Donna Schmitz	Farmer interviews
Corn rootworm surveys	Jon Tollefson	Insect traps
Weed surveys	Margaret Smith	Observations

Table 5. Studies in Black's ridge till (west) field in Walnut Creek watershed.

Research Study	Researcher/Technician	Equipment
Energy balance and evapotranspiration	John Prueger	Bowen ratio and eddy correlation
Pesticide volatilization and soil gases	John Prueger	Air samplers
Surface water runoff	Donna Schmitz	Flow meter, flume
Bird census and landscape structure	Lou Best and Tim Bergin	Observations
USGS groundwater monitoring wells	Karen Keck/Donna Schmitz	Monitoring wells
Soil sampling for pesticides	Karen Keck/Donna Schmitz	Soil cores (hydraulically-collected)
Farming surveys	Karen Keck/Donna Schmitz	Farmer interviews
Corn rootworm surveys	Jon Tollefson	Insect traps
Weed surveys	Margaret Smith	Observations

Table 6. Studies in Black's conventional tillage (east) field in Walnut Creek watershed.

Research Study	Researcher/Technician	Equipment or Samples
Energy balance and evapotranspiration	John Prueger	Bowen ratio and eddy correlation
Pesticide volatilization and soil gases	John Prueger	Air samplers
Surface water runoff	Donna Schmitz	Flow meter, flume
Tile flow	Donna Schmitz	Flow meter, water sampler
USGS groundwater monitoring wells	Karen Keck/Donna Schmitz	Monitoring wells
Soil sampling for pesticides	Karen Keck/Donna Schmitz	Soil cores (hydraulically-operated)
Crop yields and grain quality	Doug Karlen	Combine-collected crop samples
Crop characteristics	Karen Keck	Manually-collected crop samples
Farming surveys	Karen Keck/Donna Schmitz	Farmer interviews
Corn rootworm surveys	Jon Tollefson	Insect traps
Weed surveys	Margaret Smith	Observations

Table 7. Studies in Black's no-till field in Walnut Creek watershed.

Research Study	Researcher/Technician	Equipment or Samples
Energy balance and evapotranspiration	John Prueger	Bowen ratio and eddy correlation
USGS groundwater monitoring wells	Karen Keck/Donna Schmitz	Monitoring wells
Soil sampling for pesticides	Karen Keck/Donna Schmitz	Soil cores (hydraulically-operated)
Farming surveys	Karen Keck/Donna Schmitz	Farmer interviews
Corn rootworm studies	Jon Tollefson	Insect traps
Weed surveys	Margaret Smith	Observations