



# IDAHO DEPARTMENT OF AGRICULTURE

## IMMUNOASSAY METHODOLOGY FOR VADOSE ZONE MONITORING OF CARBOFURAN UNDER SURGE AND CONTINUOUS FURROW IRRIGATED CONDITIONS

Groundwater Quality/Pesticide  
Technical Report

prepared by:

Daniel C. Whitney  
Gary L. Bahr

Division of Agricultural Technology



FEBRUARY, 1994

**IMMUNOASSAY METHODOLOGY FOR VADOSE ZONE MONITORING  
OF CARBOFURAN UNDER SURGE AND CONTINUOUS  
FURROW IRRIGATED CONDITIONS**

**Groundwater Quality/Pesticide  
Technical Report**

**prepared by:**

**Daniel C. Whitney  
Gary L. Bahr**

**IDAHO DEPARTMENT OF AGRICULTURE  
Division of Agricultural Technology**

**FEBRUARY, 1994**

## TABLE OF CONTENTS

	<u>page</u>
<b>INTRODUCTION</b>	<b>1</b>
Statement of the Problem	2
Purpose and Objectives	4
<b>GENERAL HYDROGEOLOGY AND SOIL CONDITIONS</b>	<b>5</b>
Hydrogeology	5
Soils	6
Site soils	7
<b>METHODS AND APPROACH</b>	<b>7</b>
Network Design and Sampling Methodology	7
Methodology	8
Laboratory Analyses	10
<b>RESULTS AND CONCLUSIONS</b>	<b>10</b>
<b>REFERENCES</b>	<b>12</b>
<b>FIGURES</b>	
Figure 1: HUA Location Map	
Figure 2: Study Field Layout	
Figure 2.5: Sampling Plot Layout	
Figure 3: Number of Detections vs. Field Location	
Figure 4: Pattern of Detections	
Figure 5: Magnitude of Detections	
<b>TABLES</b>	
Table 1: HUA Cropping Practices Survey	
<b>APPENDIXES</b>	
A. Immunoassay Analytical Laboratory Reports	

# IMMUNOASSAY METHODOLOGY FOR VADOSE ZONE MONITORING OF CARBOFURAN UNDER SURGE AND CONTINUOUS FURROW IRRIGATED CONDITIONS

## INTRODUCTION

The United States Department of Agriculture (USDA) is presently administering a water quality project in southwestern Idaho titled the Idaho Snake-Payette Water Quality Hydrologic Unit area (HUA). The Soil Conservation Service (SCS) and University of Idaho Cooperative Extension System (CES) are managing the implementation aspects of this project. The boundaries of the HUA extend approximately from Homedale, northeast to Crane Creek Reservoir and from Emmett, northwest to Weiser (figure 1). More than 500,000 farm acres within Canyon, Gem, Payette and Washington counties are included in the area (USDA, 1991). Over 40 different crops are grown on these acres of which small grains (wheat, oats, barley), alfalfa, and sugarbeets comprise approximately 70% of the average annual crop acreage (table 1).

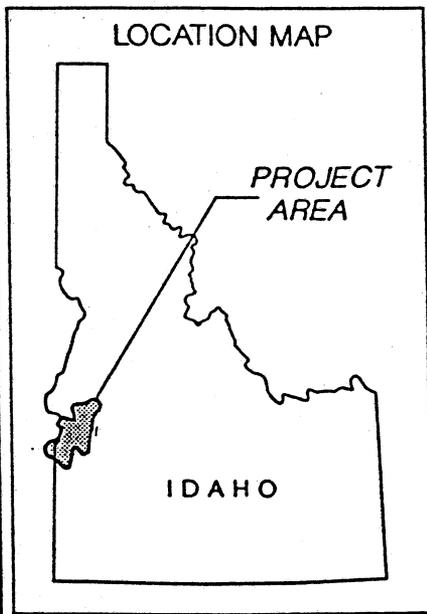
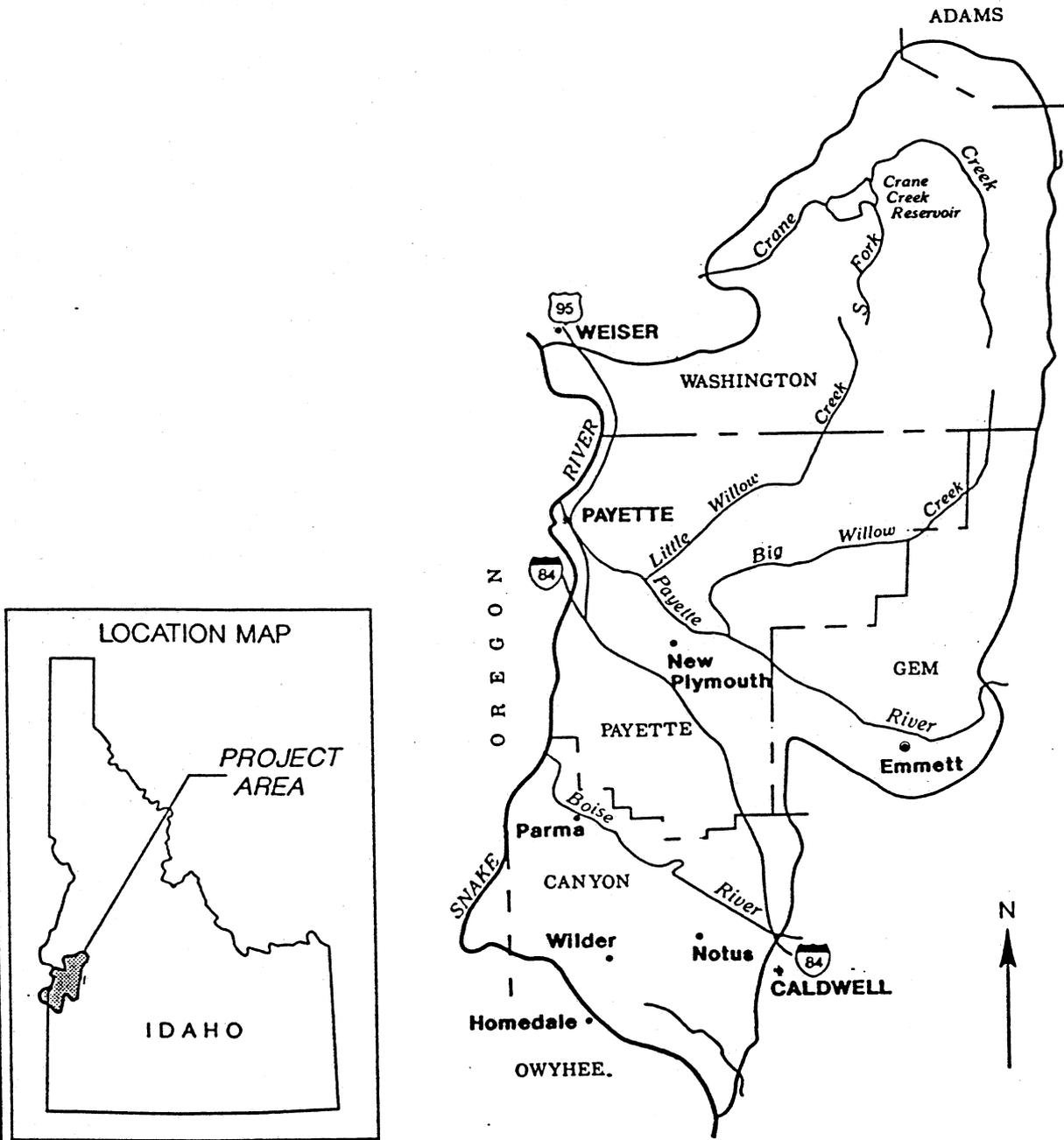
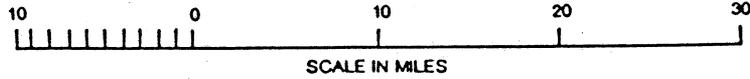
A major percentage of the HUA cropland is furrow irrigated (USDA, 1991). Furrow irrigation consists of applying water to cropland furrows under a continuous flow for a given irrigation set time (Yonts et al., 1991). Irrigation efficiency (amount necessary/amount applied) averages about 35 percent with this method and measurements as low as 20 percent have occurred on some farms (USDA, 1991). Extended durations of irrigation sets are common with furrow irrigation (usually 12 or 24 hours) resulting in excessive percolation below the crop root zone particularly at the upper end of the field (Goldhamer et al., 1987; Yonts et al., 1991). Such percolation may cause agrichemicals (fertilizers and pesticides) to move beyond the root zone and into the groundwater.

Pesticide usage is an integral and necessary component of crop production within the HUA. On average, a HUA area grower makes 3 to 12 different pesticide applications per growing season (Stieber et al., 1992). The majority of these applications consist of herbicides (Stieber et al., 1992).

The United States Environmental Protection Agency (EPA) is currently conducting a reregistration process for pesticides that were registered prior to current scientific and regulatory standards (USEPA, 1991a). As part of this process, the EPA is requiring registrants to submit environmental fate data of their pesticide products. The EPA will assess the groundwater leaching potential of the pesticides and their consequent health and environmental risks from this data.

Under the EPA's Pesticide and Ground-Water Strategy, use of

# IDAHO SNAKE-PAYETTE RIVERS HYDROLOGIC UNIT PLANNING PROPOSAL



SOURCE: Compiled by Interagency Water Quality Committee

MAY 1990

Map prepared by K. Gibbs, SCS, Boise, ID

FIGURE 1

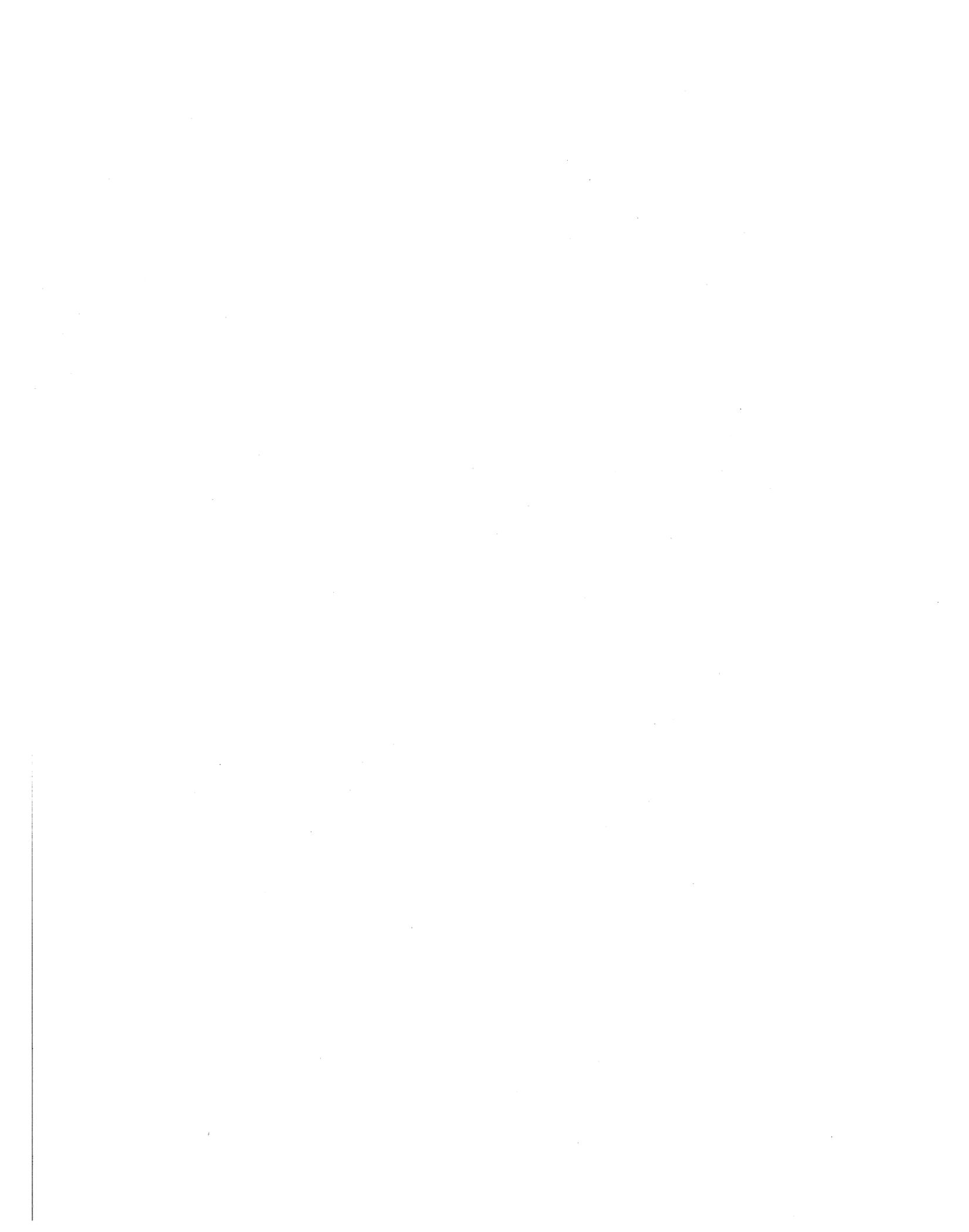


Table 1. Snake-Payette Rivers Hydrologic Unit Project 1992 cropping practices survey conducted in four southwest Idaho counties.

CROP	FOUR COUNTY ACREAGE*	PROJECT ACREAGE	SURVEY ACREAGE	GROSS ECONOMIC DOLLAR VALUE	NUMBER OF MANAGEMENT UNITS SURVEYED	ESTIMATED NUMBER OF FIELDS SURVEYED
	----- acres -----			\$ per Year x 10 <sup>6</sup>  ----- # -----		
Alfalfa hay	78,600	74,700	2,500	6.7	36	58
Alfalfa seed	24,000	14,000	652	13.5	17	32
Bean-dry edible	21,800	12,100	722	10.9	20	38
Corn-grain	11,900	11,900	458	2.8	12	22
-silage	21,100	14,000	652	2.9	18	34
-sweetcorn	3,600	3,000	1,065	1.9	40	75
-seed	10,500	4,000	951	14.0	17	32
Hops	2,800	1,800	397	8.4	9	9
Mint**	18,000	13,000	318	19.8	12	23
Onion	7,900	7,700	700	24.9	23	43
Orchard	12,000	7,800	647	21.2	19	35
Potato	9,000	5,000	608	17.7	15	28
Smallgrain***	91,500	82,000	2,429	17.2	57	107
Sugarbeet	41,000	39,000	875	49.2	31	58
Total	354,000	290,000	12,974		328	594

\* Canyon, Gem, Payette and Washington counties estimated 1991 acreages  
 \*\* Peppermint and spearmint  
 \*\*\* Smallgrain includes barley, oats and wheat

pesticides which are determined to "generally pose unreasonable effects to the environment" due to groundwater leaching will be restricted to those states which develop a State Pesticide Management Plan (SMP) (USEPA, 1991b). SMPs are to focus on areas of the state that are vulnerable to groundwater contamination, and include prevention and response measures such as best management practices (BMPs) that address the risks to groundwater posed by the pesticide (USEPA, 1991b).

The Idaho Department of Agriculture (IDA) speculates that SMPs may be required for several pesticides beginning with the 1996 growing season. The most likely candidates include atrazine, cyanazine, simazine, alochlor, and metolachlor.

Evaluation monitoring (i.e., groundwater and vadose zone monitoring) to assess the effectiveness of BMPs on protecting groundwater quality will be required when such practices are chosen for a SMP labeled pesticide. A BMP is defined in the Idaho Ground Water Quality Plan as a practice or combination of practices determined to be the most effective and practical means of preventing or reducing contamination to ground water and/or surface water from nonpoint and point sources to achieve water quality goals and protect the beneficial uses of the water.

#### **Statement of the Problem**

A majority of the HUA has been ranked as very vulnerable to groundwater contamination (Rupert et al., 1991). This ranking is due in part to the extensive use of gravity-fed irrigation methods, in particular, continuous furrow. Previous groundwater quality studies conducted near the towns of Weiser, New Plymouth, and Fruitland indicate the occurrence of groundwater contamination by nitrates and Dacthal (Baldwin, personal comm.). Dacthal is a herbicide commonly used in the area for weed control on onion acreage. Such findings support the vulnerability ranking and are of much concern as groundwater is a major source of drinking water for the area (USDA, 1991).

An alternate approach to continuous furrow irrigation entails the use of a two-way tee valve installed in gated pipe which distributes water to the furrows in a surge or pulse-like manner. This method of water delivery is referred to as surge irrigation. The surge technique has been used for a number of years in California as a means for improving water advance to the end of the field (Goldhamer et al., 1987) and ultimately conserving water.

Surge differs from conventional furrow in that water is applied intermittently from one set of furrows to another during the irrigation set (Miller et al., 1991; Bartholomay and Champion, 1991). Studies have shown that this process results in an increase of irrigation efficiency (Miller et al., 1991; Goldhamer et al., 1987; Kemper et al., 1988) and a more uniform wetting along the

furrow (Miller et al., 1987). Miller et al. (1991) showed a decrease in water usage and infiltration of more than 50% with surge as compared to conventional furrow. Consequently, surge irrigation is considered by SCS to be a BMP with respect to water quantity for furrow irrigated cropland (Stack, personal communication). It also has the potential to be a groundwater quality BMP with the supposition that less water usage results in less movement of agrichemicals below the crop root zone. However, groundwater quality benefits of surge over conventional furrow have not been well documented nor quantified with respect to the leaching of pesticides.

The SCS and CES would like to promote surge irrigation as both a water quantity and water quality BMP to HUA area growers (Stack, personal communication). Monitoring the water quality benefits of surge with respect to the leaching of pesticides is of interest to the IDA due to the relatively near future SMP requirements for several of these compounds.

The IDA, SCS, and CES recognize that vadose zone monitoring is an essential component for evaluating the effectiveness of surge irrigation in protecting the quality of groundwater. However, an inherent limitation of this type of monitoring is that the soil pore water collection rates of the sampling equipment (i.e., vacuum lysimeters) generally are in the milliliters per day range (reference). Conventional analytical laboratory methods such as gas chromatography and mass spectrometry (GC/MS) commonly require several milliliters (ml) of sample for a pesticide analysis.

A recently developed pesticide analytical technique entails the use of immunoassays. Immunoassays operate on the principles of antibody responses to a given chemical compound and its enzyme conjugate (Immunosystems, product pamphlet). An advantage that this method has over other analytical methods is that only approximately one half milliliter of sample is required to perform an analysis. Other benefits are that immunoassays are more sensitive, take less time per analysis, and are much less expensive (approximately 10 times less) than convention methods (Bushway et al., 1988a).

Aldicarb, carbofuran, and atrazine are registered for many of the crops grown in the HUA area (CPCR, 1992). However, carbofuran is the only one registered for small grains, alfalfa, and sugarbeets (by special registration in Idaho). Consequently, it has the potential for extensive use in the area.

Immunoassay test kits have been developed for triazines (i.e., atrazine), aldicarb, 2,4-D, carbofuran, cyclodienes (i.e., chlordane), benomyl, and alachlor. Studies conducted by Baumann et al. (1991) and Bushway et al. (1988b) using the atrazine and chlordane immunoassay test kits, respectively, indicate that immunoassays are a viable method for vadose zone monitoring.

However, vadose zone monitoring studies utilizing the carbofuran test kit are lacking. Therefore, the IDA and USDA have organized a study, funded by the EPA, to examine the application of such a kit for evaluating and comparing the migration of carbofuran under surge and conventional furrow irrigation within the Snake-Payette Hydrologic Unit Area. The information obtained from this study is intended to provide insight on the water quality benefits of surge irrigation.

### **Purpose and Objectives**

The purpose of this study is to evaluate the effectiveness of the immunoassay analytical technique for monitoring the movement of carbofuran within the vadose zone of furrow irrigated cropland. The study was conducted at a HUA area growers sugarbeet field located near Payette, Idaho.

The general objective of the study is to identify and quantify soil pore water quality changes with respect to carbofuran by immunoassay methodology under both surge and conventional furrow irrigated conditions.

The specific objectives are to:

1. Describe the general hydrogeology and soil conditions of the Snake-Payette Hydrologic Unit Area,
2. Design a vadose zone monitoring network utilizing suction lysimeters and soil cores to monitor the soil-pore water within the root zone of the test field.
3. Compare immunoassay and conventional laboratory data of the soil-pore water to evaluate the effectiveness of the carbofuran immunoassay test kit.
4. Evaluate the water quality benefits of surge irrigation.

## GENERAL HYDROGEOLOGY AND SOIL CONDITIONS

### Hydrogeology

The Snake-Payette Hydrologic Unit Area is located within the Columbia Intermontane Plateau Province. The geology of the HUA generally consists of three units: Uppermost Unit, Sand and Gravel Unit, and Glenss Ferry Formation (USDA, 1991). The uppermost unit consists of a soil mantle of sand and silt that overlies most of the area. This unit is of variable thickness. Underlying the soil mantle is a sand and gravel deposit. This unit was deposited by the ancestral Snake, Boise, and Payette Rivers during periods of glacial runoff. The unit was deposited in valleys eroded into the underlying Glenss Ferry Formation. As the ancestral rivers continued to erode into the underlying deposits, the sand and gravel material was deposited at successively lower elevations, forming terrace deposits. The unit is up to 200 feet in thickness in some areas. Underlying the sand and gravel unit is a region-wide deposit of lake sediments referred to as the Glenss Ferry Formation. This unit is at least 5,000 feet thick and consists of sand, silt, and clay, with some interbedded gravel.

According to Steed et al. (1993), there are two different geologic regimes within the HUA: lacustrine and fluvial, and volcanic. The lacustrine and fluvial deposits are extensively utilized for agriculture, whereas the volcanic deposits are utilized as open range. The following is a description of these regimes as presented in Steed et al. (1993).

The lacustrine deposits are geologically located within the Western Snake River Plain which is an elongate feature that stretches from King Hill on the east to the Idaho-Oregon border on the west. The Western Snake River Plain is a fault-bounded depression with normal northwest-trending fault systems forming major segments of both edges of the plain (Malde, 1965). The depression of this area is believed to be aided by the weight of dense Miocene basalts. Above the basalts are sediments from Pliocene stream and lake deposits of the Glenss Ferry Formation and younger alluvium and outwash. The Glenss Ferry Formation is the oldest and deepest unit in the lacustrine regime. The top of this unit had been eroded prior to the deposition of the overlying sediments. Above the unconformity produced by this erosion are Quaternary alluvium and outwash from the erosion of the adjacent uplands. Overlying the alluvium and outwash is the soil mantle which is described below.

The volcanic deposits are geologically located on the foot wall of the Western Snake River Plain. They consist of Miocene basalt flows and Miocene stream and lake deposits associated with volcanic episodes. The landforms produced by these deposits are rounded with low topographic relief.

The principle aquifers in the basin are in the Miocene basaltic rocks, the overlying Tertiary sediments (Glenns Ferry Formation), and Quaternary sediments. Groundwater occurs under artesian and water table conditions in these aquifers. Shallow water table conditions exist throughout the hydrologic unit.

The Miocene basaltic aquifer is located in the northeastern portion of the hydrologic unit. This aquifer is not highly productive and receives a small portion of the water use from the water users of the HUA.

The Tertiary sedimentary aquifer is located in the lacustrine, southwestern portion of the HUA. Within this aquifer are two producing water units. The first unit consists of gravel which underlies the soil mantle. This unit is a major source of groundwater for much of the HUA. In some areas, it is 200 feet thick and is generally saturated throughout most of the thickness. The second water producing unit is the Glenns Ferry Formation. Well yields from the Glenns Ferry are variable and generally have lower yields than the overlying unit.

### **Soils**

The soils of the HUA are described in the Soil Survey of Payette County, Idaho (SCS, 1976), the Soil Survey of Canyon County, Idaho (SCS, 1972), and the Soil Survey of Adams/Washington County (unpublished). The following discussion is based on these references as well as Steed et al. (1993).

There are five general soil regions within the HUA. The first soil region (region 1) is in the northernmost section of the HUA and is derived from basalt residuum. It is well drained and occurs on gently to steeply sloping uplands. A prominent characteristic of the soils of this region is a well developed clayey subsoil with high shrink-swell potential. Soils in region 1 are generally deep. Typical soil classifications include the Gem, Glasgow, Newell, and Brownlee Series.

The next region (region 2) is located southwest of region 1 and interfingers with soil regions 3 and 4. Soils in region 2 are generally loams derived from alluvial sediments. Soils are well drained and are very deep. Typical soils in soil region 2 include the Haw, Payette, Power, Purdam, and Van Dusen Series.

Soil region 3 is located further to the southwest and is proximal to the Payette and Snake rivers in the HUA. The soils in this region are derived from lacustrine sediments and mixed alluvium and are typically silt loams and silty clay loams. drainage class ranges from poorly to well drained. Typical soils in soil region 3 include the Moulton, Baldock, Chilcoot, and Greenleaf Series.

Soil region 4 is located on either side of the upper terraces of

the Payette River. This soil region is derived from alluvium and loess. The soils in the region are distinguished from the other soil regions by the dominance of fragmented duripans. Soil profiles are shallow to moderately deep and these soils are of the well drained classification in the areas without the duripan horizon. Typical soils in soil region 4 include the Elijah, Lanktree, Vickery, Chilcoot, and Letha Series.

The last region is located in the southern part of the HUA. Soils are derived from well mixed sediments, and are very deep. Textures are generally more sandy than the other soil regions and the drainage class ranges from somewhat poorly drained to well drained. Typical soils in soil region 4 include the Harpt, Turbyfill, Cashmere, Cencove, and Feltham Series.

### Site soils

The dominant soil in the field is a Power-Purdam silt loam with a water holding capacity of 2.4 inches per foot of depth. This soil is deep with no field evidence of pan layers. Texture changed slightly around 30 to 36 inches toward a fine sand fraction. No water table was evident in these Snake River Plain soils. Soil characteristics appear relatively consistent throughout the top, middle, and lower portions of the field as evidenced by table 2.

## METHODS AND APPROACH

### Network Design and Sampling Methodology

The vadose zone monitoring network was devised to evaluate the differences in the vertical migration of the carbofuran between the upper, middle, and lower portions of the field. The layout of the network consisted of three blocks, equally dividing the length of the field into an upper, middle, and lower section of the field with each block divided into two equal plots as depicted in figure 2. The three blocks are intended to represent three homogenous sections of the field with respect to wetting front characteristics of furrow irrigation (i.e., greater infiltration occurs in the upper portion of the field than the middle and lower portions). Dividing the blocks was necessary due to likely heterogeneities (i.e., soil characteristics) across the field.

Each irrigation treatment will be paired within each block. The two far left (east) plots of the field were irrigated using the surge technique, whereas the two far right (west) plots were irrigated using the continuous furrow method. This pairing approach allows a treatment comparison evaluation across the width of the field. Each treatment ran the entire length of the field.

Soil-water quality monitoring was accomplished via soil core sampling and vacuum lysimetry. The soil sampling occurred at the

# FIELD LAYOUT

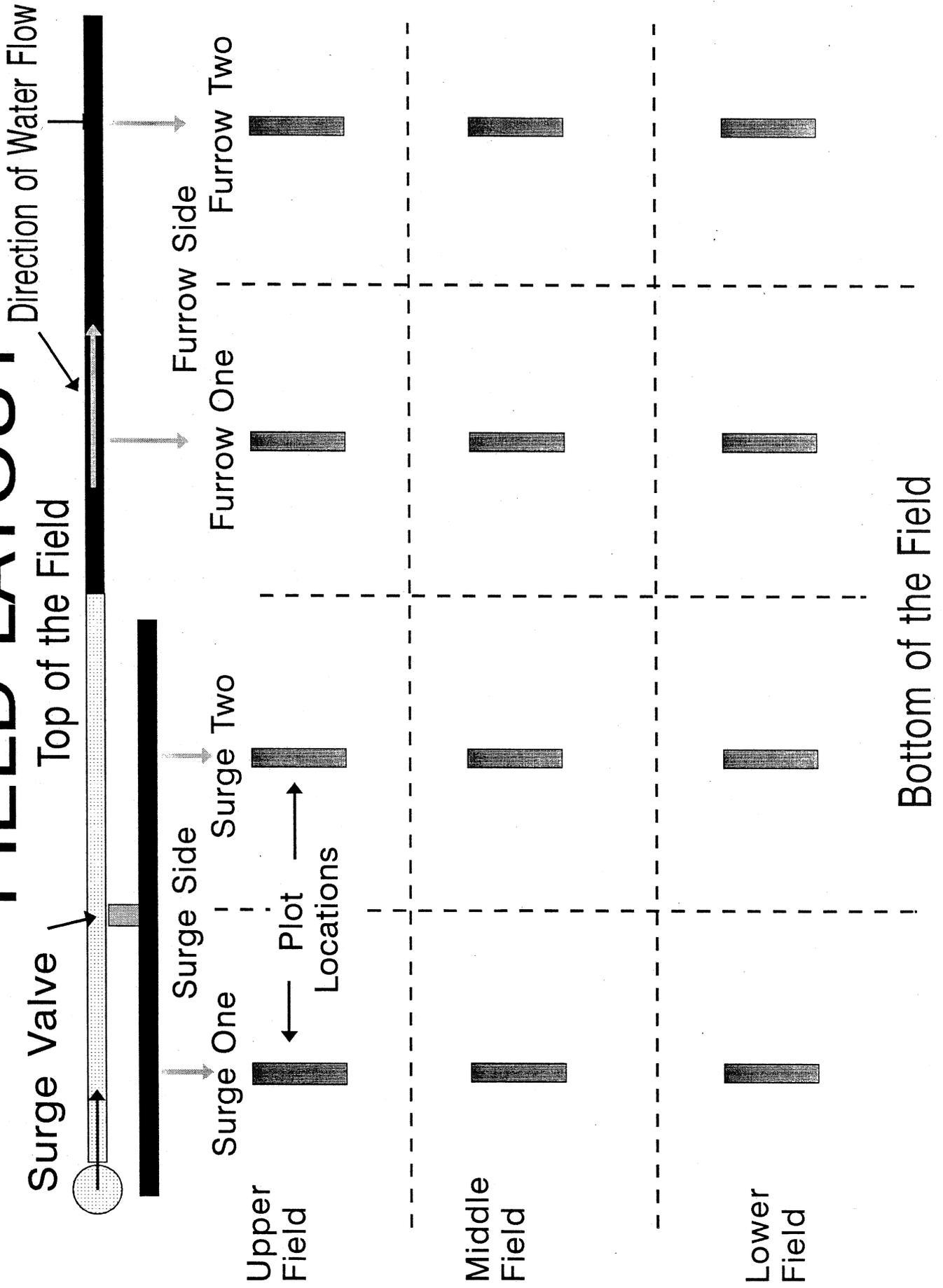


FIGURE 2

beginning and end of the study: 1. pre-1993 growing season before lysimeter installation, and 2. late 1993 growing season after crop harvest. The initial sampling provided assurance on the lack of any residual carbofuran from previous growing seasons. The owner/grower stated that he has never applied carbofuran on the test field. However, trace quantities of carbofuran may have been present in the irrigation water applied to this field in prior years due to the possible use of carbofuran in fields upstream of the test field and the return of the irrigation water used on these fields to the irrigation distribution system of the area. The end sampling event provide soil-water quality comparison data on the concentrations of carbofuran in the soil matrix versus soil-pore water of the last vacuum lysimeter sampling event.

Sampling with the vacuum lysimeters occurred five times during the 1993 growing season. The first sampling occurred after the first irrigation event and the subsequent samplings occurred after every other event. All soil and soil-pore water samples were collected and handled according to standard EPA QA/QC sampling protocol.

### **Methodology**

The pre-1993 growing season soil sampling event consisted of collecting samples at two depths and six locations within each plot for each irrigation method. The depths from which the samples were collected were from 0-1 foot and 1-2 feet. The soil samples were combined into one composite sample for each plot for a total of six soil samples. This sample represents the average chemical concentration of any residual carbofuran from previous years at a depth of 0-2 feet for any given plot. This sampling strategy considers the heterogeneities in the hydraulic properties (i.e, preferential flow paths) and physical properties of the soil that may occur within each plot.

The post-1993 soil sampling event consisted of collecting samples at three depths and two locations for each lysimeter network location. The depths were from 0-1, 1-2, and 2-3 feet. The two locations within the network were 2.5 feet and 5.0 feet from the northernmost lysimeter. A total of 72 samples were collected.

The vacuum lysimeters were installed shortly before planting. It is important to note that the carbofuran was applied at planting. The installation involved placing the top of the lysimeters approximately six inches below land surface. This placement was selected to: 1. allow the grower to plant his field without the interference and possible damage of the instrumentation, and 2. avoid inadvertently transferring carbofuran below the soil surface during lysimeter installation. The vacuum tubing of the lysimeters were covered in plastic prior to burial and retrieved shortly after plant emergence.

The lysimeters were installed at three depths in the far east

lysimeter row of each plot and at two depths in the far west lysimeter row. They were installed approximately in the center of each split plot within the crop root zone at depths of 1.5 and 2.5 feet for all lysimeter network locations and just below the root zone at a depth of 5 feet for the far east lysimeter row of each plot (figure 2.5). The depths were replicated 3 times in order to statistically assess and accurately quantify the spatial variability of carbofuran concentrations at each depth. Consequently, a total of nine lysimeters were linearly installed within each plot. The designation for each network was as follows: 1) 1SU, 1SM, 1SL, 2SU, 2SM, 2SL for the surge side of the field; 2) 1FU, 1FM, 1FL, 2FU, 2FM, 2FL for the continuous furrow side of the field. An example of a complete array of lysimeters for the 1FU network is as follows: From south to north, 1FU2.5C, 1FU2.5B, 1FU2.5A, 1FU5.0C, 1FU1.5C, 1FU5.0B, 1FU1.5B, 1FU 5.0A, 1FU1.5A. The lysimeters in each network were separated by three feet. The total monitoring network consisted of 90 lysimeters. A buffer consisting of 15 to 16 furrows was incorporated between the lysimeter network rows to avoid cross-over effects from one treatment to the other.

The lysimeters were also installed in the same plant hill for the length of the field. This arrangement allowed the grower to cultivate his field without interference from the monitoring instrumentation and maintained lateral wetting front consistency between the blocks. This consistency was important for comparing infiltration/leaching differences along the length of the field. In addition, the lysimeters were spaced approximately three feet from each other to avoid tension induced flow path interferences among the lysimeters. Warrick and Amoozergar-Fard (1977) have shown the maximum radial distance a lysimeter can draw water to be about one meter.

SoilMoisture Equipment Corporation Jet Fill Tensiometers which measure in-situ soil-water tensions (suctions) were installed at depths of two feet and four feet near each lysimeter network location. A total of twenty-four tensiometers were installed. These devices were used to detect the wetting front after an irrigation event and determine the optimum time to draw a soil-pore water sample. For practical purposes, sampling occurred 24 hours after the corresponding irrigation events.

A summary of the design and sampling plan is tabulated below:

Variables;

1. Treatments:
  - Surge vs. Conventional Furrow = 2
2. Blocks (field furrow lengths) = 3
3. Plots (within each split block) = 2
4. Pesticide (carbofuran) = 1

# SAMPLING PLOT LAYOUT

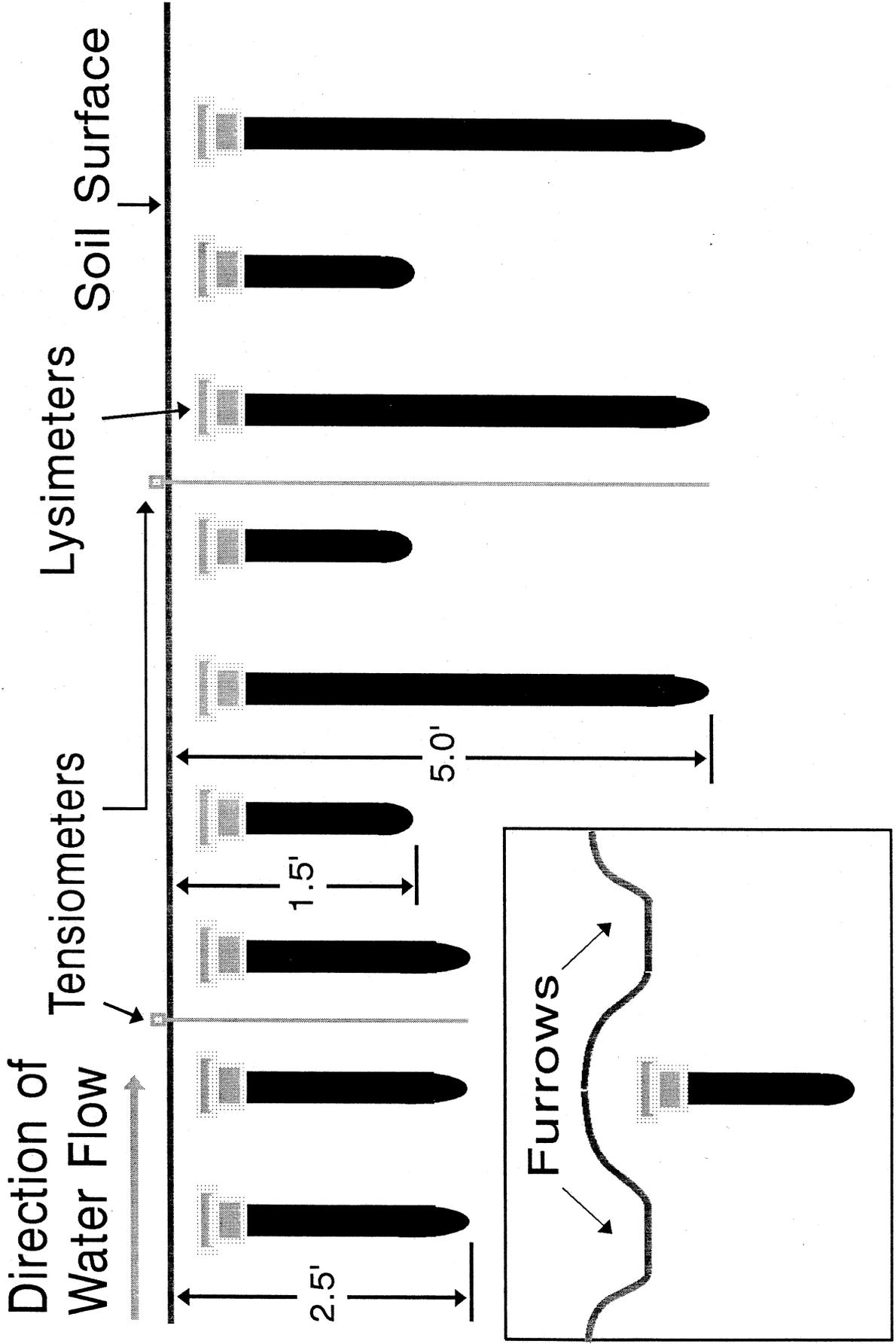


FIGURE 2.5

- 5. Replications of Treatments  
(within each block) = 2
- 6. Maximum Sampling Depths  
(within each plot) = 3
- 7. Lysimeter Replications at Each  
Sampling Depth = 3
- 8. Number of Lysimeters:  
(Blocks x plots x Sampling  
Depths x Lysimeter Replications) = 90
- 9. Lysimeter Sampling Events = 5
- 10. Number of Soil Sampling Events = 2
- 11. Total Number of Soil Samples  
for Stages 1 and 2 = 78 (6 + 72)

Water quality monitoring of the incoming irrigation water was conducted to identify unintended or unforeseen contributions of carbofuran in the test field. Irrigation return water from fields on which carbofuran is applied may contain the pesticide as a result of chemical dissolution and/or adsorption on suspended sediment. Consequently, irrigation supply water down stream from such fields may contain small concentrations of carbofuran. The incoming water will be sampled from the point at which it enters or is diverted to the test field.

#### Laboratory Analyses

The laboratory analysis for this study was contracted through the EPA Environmental Monitoring Systems (EMS) Laboratory at Las Vegas, Nevada. Midwest Research Institute at Mountain View, California was subcontracted through the EPA EMS laboratory to perform the laboratory analyses.

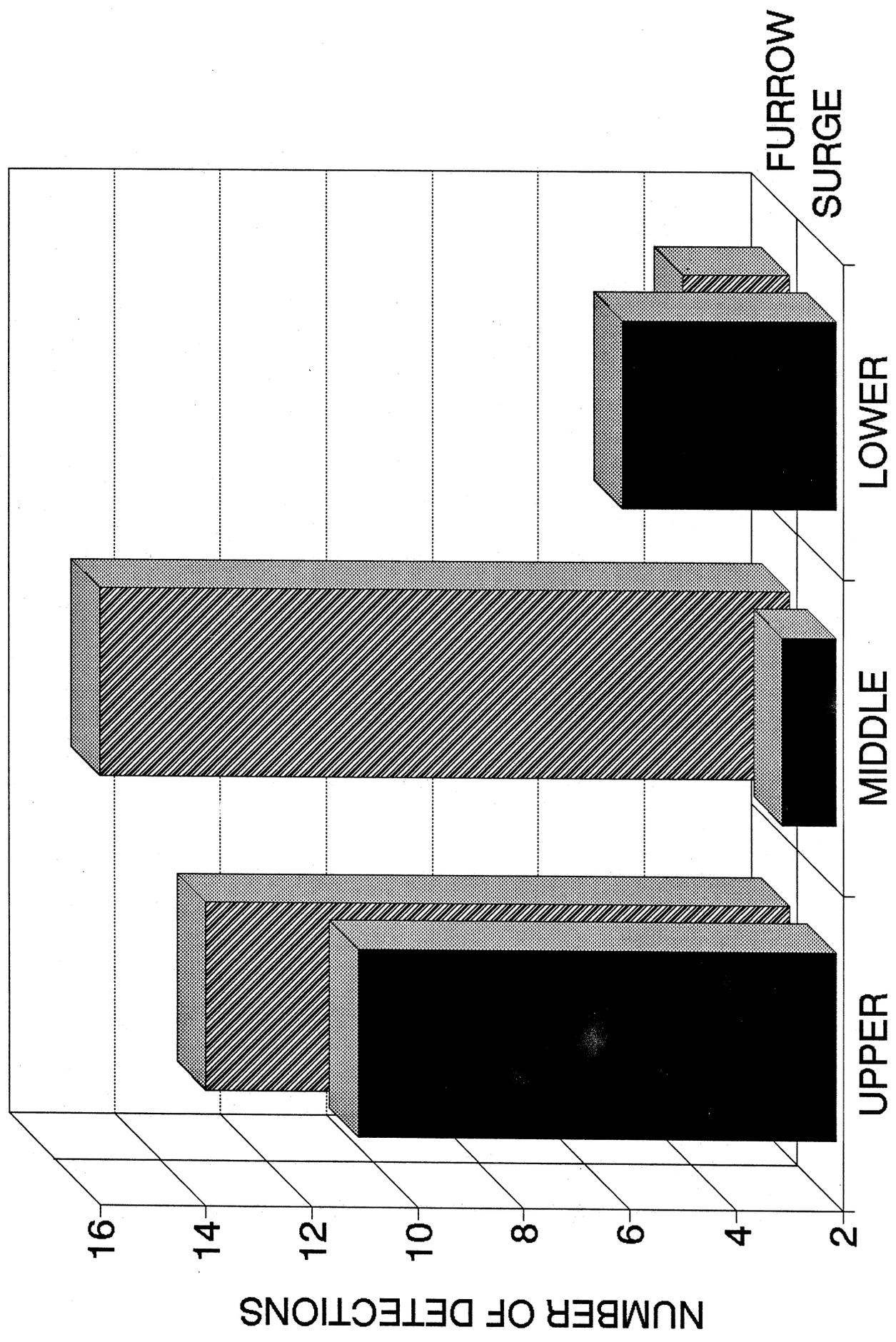
All samples (water and soil) were analyzed for carbofuran utilizing the immunoassay methodology. A minimum of 20 grams of soil was necessary for each analysis. A small percentage of the soil-pore water samples were analyzed with the electron capture method as a verification process for select samples. Several samples were analyzed in replicate with immunoassay.

#### RESULTS AND CONCLUSIONS

A total of 217 soil-pore water samples were collected as well as 78 soil samples. Carbofuran was detected in 52 of the soil-pore water samples and 34 of the soil samples. Of the soil-pore water detections, 32 accounted for the continuous furrow samples, whereas 20 accounted for the surge samples (figure 3).

The laboratory reports for the soil and soil-pore water sampling events are presented in Appendix A. The pre-1993 growing season

# NO. OF DETECTS VS. FIELD LOCATION

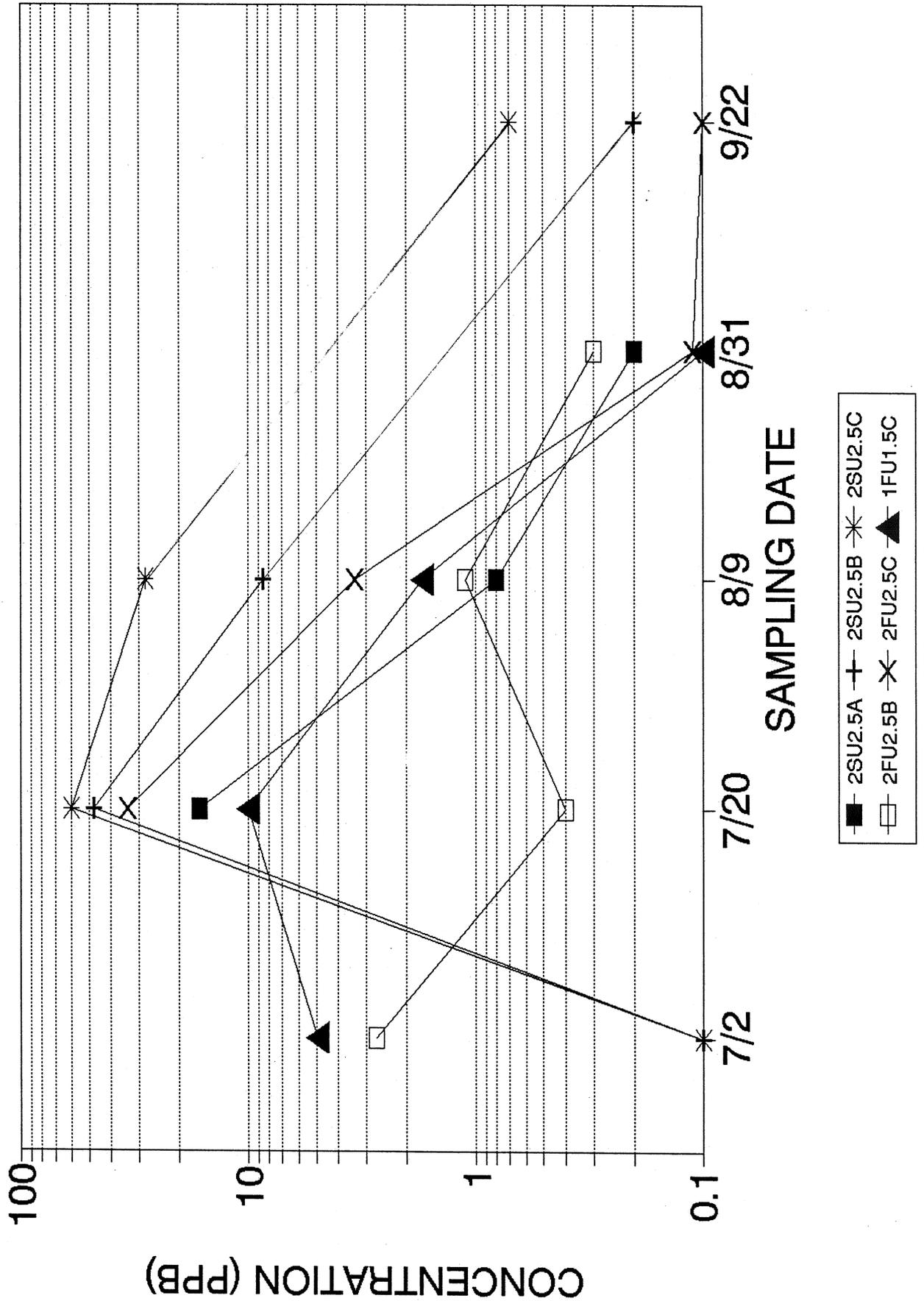


FIELD LOCATION

FIGURE 3

soil sampling results reveal the possibility of trace amounts of carbofuran in the soils. The post-1993 growing season soil sampling results reveal that carbofuran is still present in the soils after harvest. The soil-pore water sampling results reveal an increase in concentrations up to the second sampling event and then a linear decrease to trace concentrations by the last sampling event (figure 4). The magnitude of these detections was generally the greatest in the upper portion of the field (figure 5). Overall the data indicate that there are water quality benefits associated with surge irrigation when compared to the continuous furrow method.

# 2SU2.5A, B, C & 2FU2.5B, C & 2FU1.5C



# MAGNITUDE OF DETECTIONS

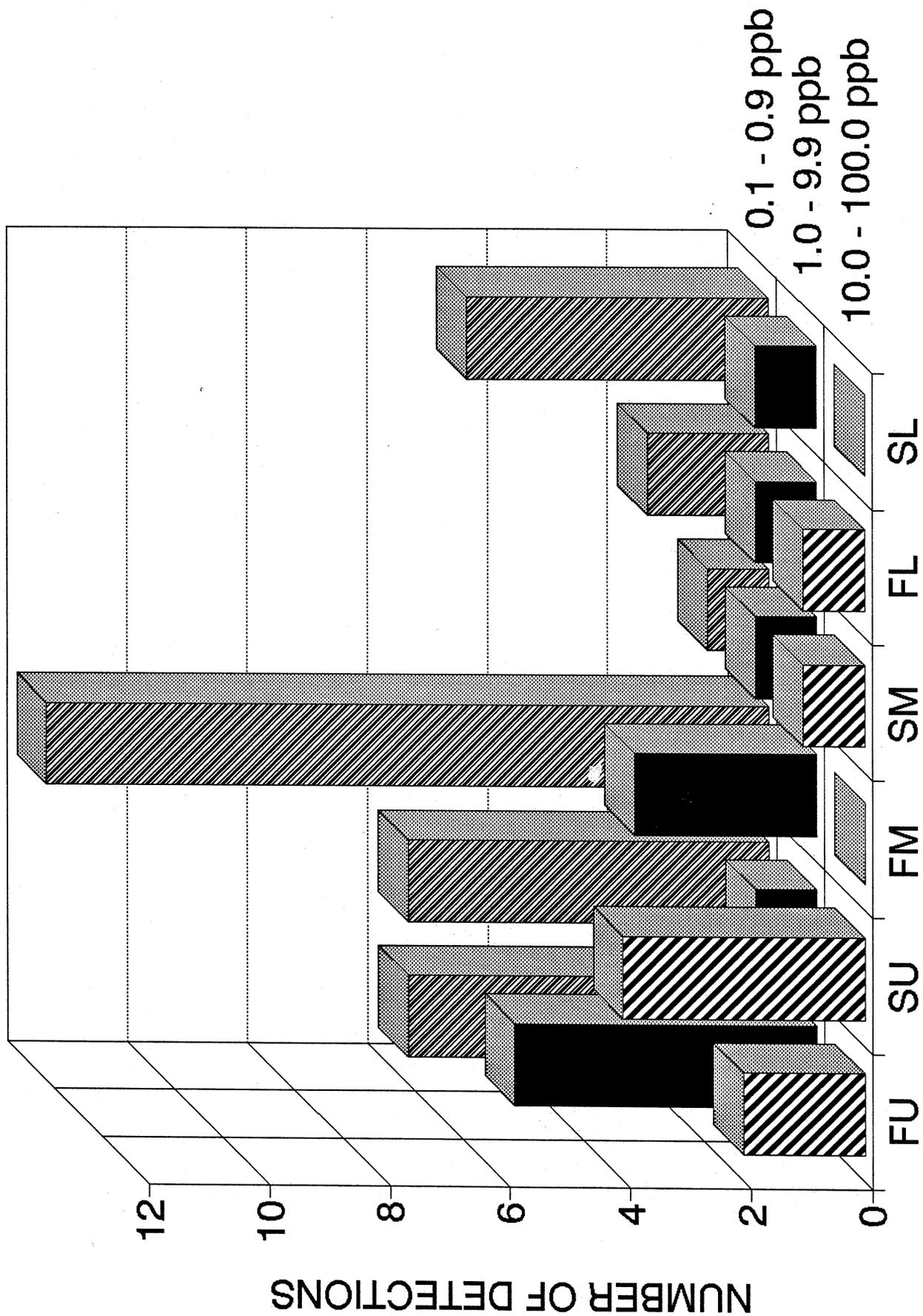


FIGURE 5

## REFERENCES

- Baldwin, J. 1992. Personal communication. Hydrogeologist, Water Quality Bureau, Division of Environmental Quality, Idaho Department of Health and Welfare, Boise.
- Baumann, T., Merkel, B., Ruppert, T., and R. Neissner. 1991. Problems Related to Pore Water Sampling for Pesticide Determination. 7th International Congress of Pesticide Chemistry. Hamburg 5.-10.8.9.
- Bushway, R.J., Perkins, B., Savage, S.A., Lekousi, S.J., and B.S. Ferguson. 1988a. Determination of Atrazine Residues in Water and Soil by Enzyme Immunoassay. *Bull. Environ. Contam. Toxicol.* 40:647-654.
- Bushway, R.J., Pask, W.M., King, J., Perkins, B., and Bruce S. Ferguson. 1988b. Determination of Chlordane in Soil by Enzyme Immunoassay. *In* Symposium Proceedings, October 11-13, 1988. Field Screening Methods for Hazardous Waste Site Investigations. p. 433-437.
- Bartholomay, R.C., and D.F. Champion. 1991. Grand Valley Surge Demonstration Project: A Report to the United States Department of the Interior, Bureau of Reclamation. Cooperative Extension, Colorado State University. 14 pp.
- CPCR. 1992. Crops Protection Chemicals Reference, Eighth Edition. Chemical and Pharmaceutical Press, John Wiley & Sons, Inc. and Chemical and Pharmaceutical Publishing Corp., New York, N.Y. pp. 1892.
- Goldhamer, D.A., Alemi, M.H., and R.C. Phene. 1987. Surge vs. Continuous-Flow Irrigation. *California Agriculture*. September - October, 1987. p. 29-32.
- Kemper, W.D., Trout T.J., Humpherys, A.S., M.S. Bullock. 1988. Mechanisms by which Surge Irrigation Reduces Furrow Infiltration Rates in a Silty Loam Soil. *Transactions of the ASAE*. 31(3): 821-829.
- Maulde, H.E. 1965. Snake River Plain *in* H.E. Wright, Jr. and D.G. Frey., *The Quaternary of the United States*. Princeton University Press. pp. 255-263.
- Miller, J.G., Shock, C.C., Stieber, T.S., and L.D. Saunders. 1991. Surge Irrigation of Bliss Spring Wheat, 1991. American Society of Agronomy. 83rd Annual Meeting, Denver, Co. October 27 - November 1, 1991. p. 120-123.

Miller, D.E., Aarstad, J.S., and R.G. Evans. 1987. Control of Furrow Erosion With Crop Residues and Surge Flow Irrigation. Soil Science Society of America Journal. 51:421-425.

Rupert, M., Dace, T., Maupin, M., and B. Wicherski. 1991. Ground Water Vulnerability Assessment Snake River Plain, Southern Idaho. Idaho Department of Health and Welfare, Division of Environmental Quality, Boise. 25 pp.

Soil Conservation Service. 1972. Soil Survey of Canyon Area, Idaho. USDA SCS in cooperation with University of Idaho, College of Agriculture, Idaho Agricultural Experimental Station. 126 pp.

Soil Conservation Service. 1976. Soil Survey of Payette County, Idaho. USDA SCS in Cooperation with University of Idaho College of Agriculture, Idaho Agricultural Experimental Station. 97 pp.

Soil Conservation Service. Soil Survey of Adams County and Washington County, Idaho. USDA SCS in Cooperation with University of Idaho College of Agriculture, Idaho Agricultural Experimental Station. Unpublished.

Stack, T. 1992. Personal communication. Project Leader, Snake-Payette Rivers Hydrologic Unit Project, Soil Conservation Service, United States Department of Agriculture, Payette, Idaho.

Steed, R., G. Winter, and J. Cardwell. 1993. Idaho Snake-Payette River Hydrologic Unit Ground Water Quality Assessment, West Central Idaho. Ground Water Quality Technical Report No. 3. Idaho Department of Health and Welfare, Division of Environmental Quality. Boise, Idaho.

Stieber, T.D., Stack, T.J., and N. Hutchison. 1992. Idaho Snake-Payette Rivers Hydrologic Unit Area Project, Cropping Practices Survey. 9 pp.

U.S. Environmental Protection Agency (EPA). 1991a. EPA's Pesticide Programs. 21T-1005. May, 1991. Office of Pesticide Programs, Washington, D.C. 25 pp.

U.S. Environmental Protection Agency (EPA). 1991b. Pesticides and Ground-Water Strategy. 21T-1022. October, 1991. Office of Pesticide Programs, Washington, D.C. 78 pp.

U.S. Environmental Protection Agency (EPA). 1991c. Pesticides in Ground Water Database. November, 1991. Office of Pesticide Programs, Washington, D.C. 126 pp.

U.S. Department of Agriculture (USDA). 1991. Idaho Snake-Payette Rivers Hydrologic Unit Plan of Work. March, 1991. 47 pp.

Warrick, A.W. and A. Amoozergar-Fard. 1977. Soil Water Regimes Near Porous Cup Water Samplers. Water Resources Research, Vol. 13. p.203-207.

Yonts, C.D., Eisenhauer, D.E., and J.E. Cahoon. 1991. Fundamentals of Surge Irrigation. NebGuide G91-1028. Cooperative Extension, Institute of Agriculture and Natural Resources, University of Nebraska-Lincoln.

## APPENDIX A

---

Dr. Werner F. Beckert  
July 26, 1993

Page 4

PRE-1993 GROWING SEASON

TABLE 2. ANALYSIS OF SOIL SAMPLES

Sample ID	Concentration (ng/g)
Furrow, top	ND, ND <sup>a</sup>
Surge, top	0.4
Furrow, middle	0.13
Surge, middle	2.0
Furrow, bottom	0.2
Surge, bottom	1.3

<sup>a</sup> ND - Not detected; approximate detection limit is 0.2 ng/g. The carbofuran recoveries for this sample are 100 and 85.9 percent.

Dr. Werner F. Beckert  
November 3, 1993

Page 2

POST-1993 GROWING SEASON

**TABLE 1. RESULTS OF SOIL ANALYSES**

Sample ID	Concentration (ng/g)
1FL2.51	8.1
1FL2.52	4.2
1FL2.53	4.0
1FL5.51	20.2 <sup>a</sup> , 17.1 <sup>a</sup> , 17.2 <sup>a</sup>
1FL5.52	10.0
1FL5.53	1.6
1FM2.51	3.1
1FM2.52	ND <sup>b</sup>
1FM2.53	ND
1FM5.51	3.5
1FM5.52	ND
1FM5.53	ND
1FU2.51	8.3
1FU2.52	2.6
1FU2.53	0.8
1FU5.51	1.4
1FU5.52	0.7
1FU5.53	0.9
1SL2.51	44.4 <sup>a</sup> , 31.2 <sup>a</sup> , 29.7 <sup>a</sup>
1SL2.52	1.2
1SL2.53	12.6
1SL5.51	10.6
1SL5.52	2.5
1SL5.53	1.8
1SM2.51	16.7 <sup>c</sup> , 14.9 <sup>c</sup>
1SM2.52	1.5
1SM2.53	0.9
1SM5.51	16.1
1SM5.52	10.8
1SM5.53	1.0
2SL2.51	1.5
2SL2.52	ND
2SL2.53	ND
2SL5.51	1.5
2SL5.52	0.9
2SL5.53	ND

Dr. Werner F. Beckert  
November 3, 1993

Page 3

TABLE 1. (CONCLUDED)

2SM2.51	4.6
2SM2.52	1.1
2SM2.53	0.7
2SM5.51	8.4
2SM5.52	1.2
2SM5.53	ND <sup>a</sup> , ND <sup>a</sup> , ND <sup>a</sup>
2SU2.51	8.6
2SU2.52	1.0
2SU2.53	1.6
2SU5.51	6.6
2SU5.52	ND
2SU5.53	ND
2FL2.51	5.8
2FL2.52	2.2
2FL2.53	1.1
2FL5.51	7.5
2FL5.52	2.2
2FM2.51	0.9
2FM2.52	3.0
2FM2.53	ND
2FM5.51	1.4
2FM5.52	ND
2FM5.53	1.3
1SU2.51	2.0 <sup>a</sup> , 2.3 <sup>c</sup>
1SU2.52	1.0
1SU2.53	0.7
1SU5.51	18.0
1SU5.52	ND <sup>a</sup> , ND <sup>a</sup>
1SU5.53	ND
2FU2.51	13.7
2FU2.52	1.5
2FU2.53	0.8
2FU5.51	2.2
2FU5.52	ND
2FU5.53	1.4

- <sup>a</sup> This replicate sample was subjected to extraction.
- <sup>b</sup> ND - not detected; approximate detection limit is 0.5 ng/g.
- <sup>c</sup> Only one extraction was performed for this sample. The two values represent duplicate ELISAs.

Dr. Werner F. Beckert  
July 26, 1993

Page 5

TABLE 3. ANALYSIS OF FIRST BATCH OF WATER SAMPLES (RECEIVED 7/7/93)<sup>a</sup>

Sample ID	Concentration ( $\mu\text{g/L}$ )
1FL1.5A	ND <sup>b</sup>
<del>1FL1.5C</del>	<del>37.2, 37.8, 39.5</del>
1FL2.5A	ND
1FL5.0B	ND
1FM1.5B	ND
1FM1.5C	ND
1FM2.5A	ND
1FM2.5B	ND
1FM2.5C	ND
<del>1FM5.0B</del>	<del>0.5, 0.4</del>
1FM5.0C	ND
1FU1.5A	ND
1FU2.5A	ND
1FU2.5B	ND
2FL1.5A	ND
2FL1.5B	ND
2FL2.5B	ND
2FL2.5C	ND
2FM1.5A	ND
2FM1.5C	ND
2FM2.5C	ND
<del>2FM5.0A</del>	<del>3.9, 3.9</del>
<del>2FM5.0B</del>	<del>4.3, 4.3</del>
<del>2FU1.5C</del>	<del>5.4, 4.3</del>
<del>2FU2.5B</del>	<del>2.8, 2.6</del>
2FU2.5C	ND
1SL1.5A	ND
1SL1.5C	ND
1SL2.5B	ND
1SL5.0A	ND
1SL5.0C	ND
1SM2.5A	ND
1SM5.0A	ND
1SM5.0B	ND
1SM5.0C	ND
1SU1.5B	ND
1SU5.0A	ND
1SU5.0B	ND
2SL1.5B	ND
2SL1.5C	ND
2SL2.5A	ND
2SL2.5C	ND
2SM2.5A	ND
2SU2.5B	ND
2SU2.5C	ND
Irrigate	ND, ND
Trip	ND, ND
Transfer	ND

<sup>a</sup> ND - Not detected; approximate detection limit is 0.1  $\mu\text{g/L}$ .

<sup>b</sup> When more than one value appears in a table, a replicate analysis was performed.

TABLE 1. ELISA RESULTS FOR THE SECOND BATCH OF SAMPLES (RECEIVED 7/23/93)

Sample ID	Concentration ( $\mu\text{g/L}$ )
1SL1.5A	ND <sup>a</sup>
1SL1.5C	ND
1SL5.0A	ND
1SL5.0B	ND
1SL5.0C	ND
2SU1.5B	52.4
2SU1.5C	15.6
2SU2.5A	16.8
2SU2.5B	42.6
2SU2.5C	59.5
<del>2SU1.5A</del>	<del>7.3</del>
1FL2.5A	ND
1FL2.5B	ND
1FL2.5C	ND
<del>1FL5.0A</del>	<del>5.2</del>
1FL5.0B	ND
1FL5.0C	ND
2FM1.5A	ND
2FM1.5B	ND
<del>2FM1.5C</del>	<del>2.7, 2.7</del>
<del>2FM2.5A</del>	<del>0.2, 0.2</del>
<del>2FM2.5B</del>	<del>1.6, 1.6</del>
<del>2FM2.5C</del>	<del>3.0, 3.0</del>
Trip blank	ND, ND
1FU2.5A	ND
1FU2.5B	ND
1FU2.5C	ND
1FU5.0B	ND
1FU5.0C	ND
<del>2FU1.5B</del>	<del>11.1</del>
<del>2FU1.5C</del>	<del>10.7</del>
<del>2FU2.5A</del>	<del>1.4, 1.4</del>
<del>2FU2.5B</del>	<del>0.3, 0.4</del>
<del>2FU2.5C</del>	<del>33.7</del>

<sup>a</sup> ND - not detected; the approximate detection limit is 0.1  $\mu\text{g/L}$ .

TABLE 1. (CONCLUDED)

Sample ID	Concentration ( $\mu\text{g/L}$ )
2FL1.5C	ND
2FL2.5A	ND
2FL2.5B	ND
2FL2.5C	ND
1FM1.5B	ND
1FM1.5C	ND
1FM2.5A	ND
1FM2.5B	ND
1FM2.5C	ND
1FM5.0A	ND
1FM5.0B	ND
1FM5.0C	ND
2FL1.5A	ND
2SM1.5A	26.3
2SM1.5B	24.3
2SM2.5A	ND
2SM2.5B	0.1, 0.1
1SM1.5B	ND
1SM1.5C	ND
1SM2.5A	ND
1SM5.0A	ND
1SM5.0B	ND
1SM5.0C	ND
1SU1.5A	ND
1SU1.5C	ND
1SU2.5A	ND
1SU5.0A	ND
1SU5.0B	ND
1SU5.0C	ND
2SL1.5A	ND
2SL1.5B	ND
2SL2.5A	ND
2SL2.5C	ND

\* ND - not detected; the approximate detection limit is 0.1  $\mu\text{g/L}$ .

**TABLE 2. RESULTS FOR QC SAMPLES ANALYZED WITH THE SECOND BATCH OF WATER SAMPLES**

Type of sample	True concentration ( $\mu\text{g/L}$ )	Date analyzed	Measured concentration ( $\mu\text{g/L}$ )	Percent RSD
Control	2.0	7-23-93	2.13	5.2
		7-23-93	2.14	
		7-27-93	1.93	
		7-27-93	1.98	
MRI wash buffer	ND <sup>a</sup>	7-23-93	ND	
Trip blank	ND	7-27-93	ND	
		7-27-93	ND	

<sup>a</sup> ND - not detected; the approximate detection limit is 0.1  $\mu\text{g/L}$ .

TABLE 1. ELISA RESULTS FOR THE THIRD BATCH OF SAMPLES (RECEIVED 8/12/93)

Sample ID	Carbofuran concentration (µg/L)
<del>1FL2.5A</del>	<del>ND<sup>a</sup></del>
1FL2.5A	ND <sup>a</sup>
1FL2.5B	ND
1FL2.5C	ND
1FL5.0A	ND
1FL5.0B	ND
1FL5.0C	ND
<del>1FM2.5A</del>	<del>ND</del>
1FM2.5A	ND
1FM2.5B	ND
1FM2.5C	ND
1FM5.0A	ND
1FM5.0C	ND
<del>2FL2.5A</del>	<del>ND</del>
2FL2.5A	ND
2FL2.5B	ND
2FL2.5C	ND
<del>2FM1.5A</del>	<del>ND</del>
2FM1.5A	ND
<del>2FM1.5B</del>	<del>ND</del>
2FM1.5B	ND
<del>2FM1.5C</del>	<del>ND</del>
2FM1.5C	ND
<del>2FL2.5A</del>	<del>ND</del>
2FL2.5A	ND
<del>2FL2.5B</del>	<del>ND</del>
2FL2.5B	ND
<del>2FL2.5C</del>	<del>ND</del>
2FL2.5C	ND
<del>1SL5.0A</del>	<del>ND</del>
1SL5.0A	ND
1SL5.0B	ND
1SL5.0C	ND

<sup>a</sup> ND - not detected; the approximate detection limit is 0.1 µg/L.

TABLE 1. (CONCLUDED)

Sample ID	Concentration ( $\mu\text{g/L}$ )
1SM2.5A	ND
1SM2.5C	ND
1SM5.0A	ND
1SM5.0B	ND
1SU2.5A	ND
1SU5.0A	ND
1SU5.0B	ND
1SU5.0C	ND
2SL1.5A	1.4
2SL1.5B	ND
2SL2.5A	0.1
2SL2.5B	0.1
2SL2.5C	0.1
2SM1.5A	1.0
2SM2.5A	ND
2SM2.5B	ND
2SM2.5C	5.0 <i>SPIKE</i>
2SU1.5A	ND
2SU1.5C	4.3
2SU2.5A	0.8
2SU2.5B	8.6
2SU2.5C	28.3

\* ND - not detected; the approximate detection limit is 0.1  $\mu\text{g/L}$ .

TABLE 1. (CONCLUDED)

Sample ID	Concentration ( $\mu\text{g/L}$ )
1FM1.5A	ND
1FM1.5B	ND
1FM1.5C	ND
<del>1FM2.5A</del>	<del>ND</del>
1FM2.5B	ND
1FM2.5C	ND
1FM5.0A	ND
1FM5.0B	ND - Dup of 5C
1FM5.0C	ND
Spike — 1FL1.5C	0.3, 0.3
1FL2.5A	ND
<del>1FL2.5B</del>	<del>ND</del>
1FL2.5C	ND
1FL5.0B	ND
2FU1.5A	ND - dup of 1.5C
2FU1.5B	ND - dup of 1.5C
2FU1.5C	ND
2FU2.5A	ND
<del>2FU2.5B</del>	<del>ND</del>
<del>2FU2.5C</del>	<del>0.1</del>
2FM1.5A	ND
2FM1.5B	ND, ND
2FM1.5C	ND
2FM2.5A	ND
<del>2FM2.5B</del>	<del>ND</del>
2FM2.5C	ND
2FL1.5A	ND - Dup of 1FU 5.0B
2FL2.5A	ND - Dup of 2FM 2.5A

<sup>a</sup> ND - not detected; the approximate detection limit is 0.1  $\mu\text{g/L}$ .

TABLE 1. ELISA RESULTS FOR THE FOURTH BATCH OF SAMPLES (RECEIVED 9/3/93)

Sample ID	Carbofuran concentration (µg/L)
1SU1.5A	ND <sup>a</sup> - Dup for 5.0A
1SU1.5B	ND
1SU1.5C	ND - Dup for 5.0B
1SU2.5A	0.1
1SU5.0A	ND
1SU5.0B	ND
1SU5.0C	ND
<i>15m 2.5B</i> <i>is dup for 15m 5.0A</i>	
Spike — 1SM1.5B	0.4, 0.4
1SM5.0B	ND ←
1SM5.0C	ND
1SL1.5A	ND Dup for 5.0A
1SL2.5B	ND Dup for 15m 5.0B
1SL5.0A	ND
1SL5.0B	ND
1SL5.0C	ND
2SU1.5A	ND Dup for 1.5A
2SU1.5C	ND - Dup for 1.5A
2SU2.5A	0.2
2SU2.5B	0.2 - Dup for 2.5A
2SM2.5A	ND
2SM2.5B	ND
2SM2.5C	ND
2SL1.5B	0.1
2SL2.5B	ND
2SL2.5C	ND - Dup for 2.5B
<del>1FU1.5A</del>	<del>0.7</del>
<del>1FU1.5B</del>	<del>0.2</del>
1FU2.5A	0.1 - actual result for 2FU2.5C
1FU2.5B	ND
1FU2.5C	ND
1FU5.0B	ND
1FU5.0C	ND - Dup of 5.0B

<sup>a</sup> ND - not detected; the approximate detection limit is 0.1 µg/L.

**TABLE 7. ELISA RESULTS FOR THE FIFTH BATCH OF SAMPLES (RECEIVED 9/24/93)**

Sample ID	Carbofuran concentration (µg/L)
1FL2.5A	ND <sup>a</sup>
1FL2.5B	ND
1FL5.0B	ND
1FL5.0C	ND
1FMS.0A	ND
1FUS.0B	ND
2FM1.5B	ND
<del>2FM1.5C</del>	<del>2.2, 2.5, 2.5<sup>b</sup></del>
2FM2.5B	ND
2FU2.5C	ND
1SL1.5A	ND
1SL5.0A	ND
1SL5.0B	ND
1SL2.5A	ND
1SL2.5B	ND
1SL5.0C	ND
<i>11</i> <del>1SM1.5A</del>	<del>3.9, 3.6, 3.5<sup>b</sup></del> <i>SLIKE</i>
1SM1.5B	ND
1SM2.5A	ND
1SM2.5B	ND
1SM5.0A	ND
1SM5.0B	ND
1SM5.0C	ND
1SU2.5B	ND
1SU5.0A	ND
1SU5.0B	ND
1SU5.0C	ND
2SL1.5A	ND
2SL1.5B	ND
2SL1.5C	ND
<del>2SL2.5A</del>	<del>0.1</del>
2SL2.5B	ND
2SL2.5C	ND
<del>2SU1.5A</del>	<del>0.1</del>
2SU1.5C	ND
<del>2SU2.5B</del>	<del>0.2, 0.2, 0.2<sup>b</sup></del>
<del>2SU2.5C</del>	<del>0.7, 0.7, 0.7<sup>b</sup></del>
TRIP	ND

<sup>a</sup> ND - not detected; the approximate detection limit is 0.1 µg/L.

<sup>b</sup> ELISA performed in triplicate.