A METHOD TO ESTIMATE PESTICIDE USED IN AGRICULTURE AND GROUNDWATER IMPACT POTENTIAL IN MICHIGAN

By

Yi-Yu Yen

A PLAN B PAPER

[1995]

ACKNOWLEDGMENTS

I wish to express my sincere thanks to my major advisor, Dr. Roy Black, for his guidance and help through my research work and the writing of this paper. I would also like to express my thanks to Dr. Scott Swinton and Dr. James Kells for serving as committee members and providing helpful suggestions and direction.

Special thanks are extended to my family and friends for providing support and encouragement. Finally, a heartfelt thank to my husband, Sung-Yuan, without his continued support, vision, and understanding, I could have never finished this paper.

ABSTRACT

A METHOD TO ESTIMATE PESTICIDE USED IN AGRICULTURE AND GROUNDWATER IMPACT POTENTIAL IN MICHIGAN

By

Yi-Yu Yen

Pesticide contamination of groundwater has been linked to intensive agricultural activity. Several federal legislations have been applied to protect groundwater quality from on-farm pesticide contamination, but results have not been notable. The environmental protection agency has mandated that states develop management plans based on area-specific differences in groundwater use, value, and vulnerability. The Michigan Department of Agriculture (MDA) has been structuring its programs based on a combination of aquifer sensitivity and groundwater impact potential; and attempting to estimate aquifer sensitivity based on soil type and sub-surface geology. This paper is to define the method to estimate total mass of "likely to leach" pesticides applied in each county in Michigan.

Survey data collected from Michigan Agricultural Statistics Service, National Agricultural Statistics Service, Michigan County Food and Agricultural Development Statistics, and pesticide-use-site codes were used to identify pesticide use site type and distribution. The pesticide use activities and practices which may contaminate groundwater were also identified. Seventy-two site types have been identified. Two types of matrices describing the magnitude of each site type in a county and the available pesticide use information associated with each site type were developed. An estimate of the total mass of likely to leach pesticides applied in each county were computed by combining these matrices, and the missing information was also identified. The possible methodology of completing the prototype matrices and the potential uses of matrix was discussed.

Table of Contents

Chapter 1

Introduction

1.1 Groundwater Contamination

Groundwater is a vital and irreplaceable resource in the United States that we increasingly rely upon for a lot of different uses. Approximately half of our population, including 90 percent of our country's rural residents, obtain drinking water from underground sources (U.S. GAO, 1992). Seventy-five percent of American cities derive their water supplies, either totally or at least partially, from groundwater (U.S. GAO, 1992). Groundwater is also essential to agriculture and industry in many areas. It provides 40 percent of irrigation water and 26 percent of industrial demand (O'Neil and Raucher, 1990). It also has been estimated that nearly one third of the flow in streams and supplied much of the nation's other surface water is provided by groundwater discharges (Buchholz, 1992). Moreover, as major surface water development alternatives become fully developed, groundwater becomes the major source for development of new supplies of potable water.

However, groundwater is also a natural resource that can be contaminated easily in many ways and from many sources, both natural and human-induced. Groundwater is "out-of-sight," and groundwater systems are complex. Groundwater moves very slowly, it may take tens to thousands of years to reach discharge point in deeper aquifer. Thus, contamination often is not readily apparent, and its extent and importance are often uncertain. By the time contamination is discovered, it may have already moved through an aquifer extensively enough that very little can be done about it. Unlike surface water, groundwater's self-cleansing capability is limited. Once groundwater has become contaminated, it may not be economically or technically feasible to clean the resource. In recent years, widespread reports of bacteria, nitrate, synthetic organic chemicals, and other pollutants in groundwater have increased the public's concern about its quality. In 1982, the EPA found that 45 percent of the large public water systems served by groundwater were contaminated with synthetic organic chemicals that posed potential health threats (Buchholz, 1992). In 1984, at least 8,000 water wells throughout the nation were considered to have unusable or degraded water (Buchholz, 1992). Protection of groundwater quality clearly has become a higher priority in the United States.

1.2 Pesticide Contamination of Groundwater

1.2.1 Introduction

The major groundwater contamination sources include natural pollution, waste-disposal practices, and nonpoint disposal sources due to man's activities. Nonpoint source pollution derives from multiple sources spread over wide areas and cannot be traced readily to particular individuals or locations. Agriculture is one of the most pervasive contributors to nonpoint source pollution of groundwater. Irrigation return-flow, use of pesticides, fertilizers, and manure, changes in vegetative cover through conservation tillage, and application of waste effluents have all been known to cause changes in groundwater quality (Fairchild, 1987). And agriculture groundwater contamination is potentially the most serious long-term problem because the area vulnerable to pollution is extensive. About 50 million people rely on groundwater in areas identified as vulnerable to agricultural groundwater pollution (Johnson et al., 1991).

Awareness is increasing that modern agricultural practices have the potential to cause serious environmental problems, including groundwater contamination. Well water survey results from a number of states have indicated the presence of agricultural chemicals in groundwater. The purposeful application of agricultural chemicals to land is distinct from most other sources of groundwater contamination. Contamination of groundwater due to agricultural chemicals poses serious problems. Some chemicals may degrade slowly, therefore, effects may persist over long periods of time. Chemicals of particular concern in groundwater quality degradation by agriculture are pesticides and nitrates.

Recent developments in the technology for pesticide detection have contributed as well to increased public concern about chemical residues in the environment, and in particular, pesticides in groundwater. The term "pesticide" covers any material used to control, destroy or mitigate pests; and includes insecticides, herbicides, fungicides, nematocides, rodenticides, bactericides, growth regulators and defoliants (Fuhriman and Barton, 1971). In the United States, about 700 biologically active ingredients and 1,200 inert ingredients are used in the formulation of some 50,000 individual pesticide products (Buchholz, 1992). The adoption of pesticides by U.S. agriculture since World War II has kept food cost relatively low. Thus, pesticides have become an integral part of modern farming operations. Between 1964 and 1982, the amount of active ingredients applied to croplands increased 170 percent (Moody, 1990). The percentage of herbicide-treated cropland planted to corn, cotton, and wheat in the U.S. climbed from about 10 percent in 1952 to nearly 95 percent by 1980 (OTA, 1990). Farmers use an estimated 320 million kg (700 million lb) of pesticides annually at an approximate cost of $4.1 billion (Pimentel et al., 1991).

The extensive use of pesticides has produced benefits, in reducing pest infestations and crop loss, but has also resulted in various "non-target" impacts, such as the appearance of pesticides in groundwater.

1.2.2 The Extent of Contamination

Depending upon the dose or exposure level, pesticides may produce acute or chronic toxic effects in nontarget organisms, including humans. For pesticides, in addition to potential adverse impacts of the pesticide's active ingredient, risks involve impacts by metabolites, by breakdown products, and by "inert ingredients."(OTA, 1990). The occurrence of pesticides in groundwater, even in low concentration, is a serious concern because of the potential for long-term chronic health effects (e.g., birth defects, cancer, immune system damage, etc) caused by the indigestion of pesticides in drinking water and the effects on aquatic organisms (Adams and Tryens, 1988). Although agricultural pesticides have been used for many years, it is only recently that widespread attention has focused on their potential environmental effects. This is due in a large part to recent publicity surrounding the discovery of pesticides in some wells that provide drinking water to households (Segerson, 1990). Groundwater contamination from field-applied pesticides was almost entirely unexpected, particularly since the pesticides being found in groundwater included those generally assumed to degrade or volatilize rapidly. For years it was believed that pesticides would adhere to soils or be degraded by natural processes and therefore would not migrate to such depths as to contaminate groundwater. Then, in the mid- to late-1970s, increasing numbers of wells tested with more sensitive analytical equipment resulted in increasing reports of pesticide in groundwater (Bouwer, 1990). Tests detected aldicarb in Long Island, Florida, and Wisconsin; ethylene dibromide (EDB) in Georgia and Hawaii; and dibromochloropropane (DBCP) in California and Arizona (Bouwer, 1990). Now the problem is widespread, and pesticides detected in groundwater has occurred at many locations, and many wells have been closed.

In 1984, EPA documented the presence of 12 pesticides in groundwater of 18 states (Ditschman et al., 1990). In 1986, EPA scientist Stuart Cohen and colleagues report that 17 pesticides were detected in the groundwater of 23 states; the concentrations typically ranged from trace amounts to several hundred parts per billion (ppb) (The Freshwater Foundation, 1987). A particularly disturbing aspect of the study was the common identification of nematocides in the groundwater. These chemicals are designed to be mobile, persistent and toxic. Recent studies have demonstrated that several nematocides including ethylene dibromide (EDB) and dibromochloropropane (DBCP) are mutagenic, carcinogenic and toxic to the reproductive system in laboratory animals (The Freshwater Foundation, 1987). By 1988, 46 pesticides had been detected in groundwater, and one or more of these that can be attributed to normal agricultural use have been detected in the groundwater of 26 states (Moody, 1990). Recently, the EPA has documented groundwater contamination by 74 different kinds of pesticides in 38 states (Buchholz, 1992). The most comprehensive, EPA's National Pesticide Survey of Drinking Water Wells (1990), concluded that pesticides were present in 10.4 percent of wells serving public water systems and in 4.2 percent of private wells (U.S. GAO, 1992).

Pesticide contamination is a serious problem in many areas of the country. In Long Island, New York, almost 2,000 private drinking water wells have been contaminated with aldicarb (trade name Temik), an insecticide and nematicide (National Research Council, 1986). About 1,000 of these wells have aldicarb concentrations that exceed the New York water quality standard of 7 ppb (National Research Council, 1986). Aldicarb is of particular concern because of its high acute toxicity, neurological damage from cholinesterase inhibition, and a steep dose-response curve. Nine other pesticides have been detected in Long Island wells (National Research Council, 1986). Since 1979 almost 2,500 wells in California have been found to be contaminated with DBCP including at least 1,473 wells that exceed the California Department of Health Services standard of 1 ppb (National Research Council, 1986). Aldicarb has also been found in 24 wells in Del Norte County, California (National Research Council, 1986). Groundwater contamination from EDB, 1,2-dichloropropane and simazine has been traced to lawful agricultural use in California. In a sampling of 70 public wells in Iowa, atrazine was found in 24 wells (34.2 percent) of 14 water supplies (35.96 percent). Monitoring also detected cyanazine, alachlor, metolachlor, and fonofos (National Research Council, 1986) in Iowa. Overall, major regions of high pesticide contamination potential include the Atlantic Coastal Plain, the Mississippi Delta, the northern Corn Belt, and California's Central Valley (Batie et al., 1989).

Studies, focused on vulnerable regions and on individual chemicals or small groups of chemicals, have found at least 5,500 wells with pesticide concentrations exceeding some health advisory level (OTA, 1990). A recent report by the Public Interest Research Group using U.S. EPA data indicates that, of 45,000 wells (primarily located in problem areas) tested for pesticides, 5,500 had harmful levels of at least one pesticide (Bouwer, 1990). A 1985 EPA briefing reported that at least 100,000, and possibly more than 200,000, people have consumed water from wells known to be contaminated with DBCP, aldicarb, and EDB (Conservation Foundation, 1985). They suggested that this number would increase if an investigation of other pesticides were included.

1.2.3 The Major Parameters Affecting Pesticide Pollution in Groundwater

Impacts of pesticide use on the environment are determined by the transport of the chemicals; their persistence, degradation, and dissipation in the environment; and the hazards associated with pesticides and their metabolites. Pesticides that are not degraded, immobilized, detoxified, or removed with the harvested crop are subject to movement away from the point of application. There are a variety of factors involved in pesticide groundwater contamination issues. These factors include the sources of contamination, the physical and chemical properties of the pesticides, vulnerability of groundwater to contamination, and agricultural practices (The Water Resources Management Program, 1988).

The chemical characteristics of a pesticide can significantly affect its leaching potential. Properties such as solubility, density, volatility, and half-life all help determine the likelihood that a pesticide will leach. The significance of these chemical characteristics depends upon the local soil conditions (including pH and percent organic matter), temperature, moisture, precipitation, and groundwater flow patterns. Once a pesticide enters the soil, its fate is largely dependent on sorption and persistence. Sorption is commonly evaluated by use of a sorption (partition) coefficient (K_{oc}) based on the organic carbon content of soils. Persistence is commonly evaluated in terms of half-life, which is the time that it takes for 50 percent of a chemical to be degraded or transformed. Pesticides with low sorption coefficients are likely to leach. Pesticides with long half-lives could be persistent.

In general, leaching ability of a pesticide to groundwater increases with decreasing adsorption to soil or organic matter, increasing solubility, decreasing volatility, and increasing half-life of the pesticide in the underground environment.

Based on these properties, numerical classification systems can determine which pesticides are safe to use and which are likely to move to underlying groundwater. The following are the important physical and chemical characteristics of a pesticide that may make it conducive to leaching, based on current scientific understanding: (1) Water solubility greater than 30 ppm; (2) The propensity coefficient of a pesticide to adhere to soil particles (K_d; which defined as the ratio of the pesticide concentration in soil to the pesticide concentration in water) less than 5, and usually less than 1; (3) Organic carbon partition coefficient (K_{oc}) less than 300 - 500; (4) Henry's law constant (used for calculating K_{oc} pesticide volatilization) less than 10^{-2} atm-m^{-3} mol; (5) Speciation negatively charged, fully or partially at ambient pH; (6) Hydrolysis half-life greater than 25 weeks; (7) Photolysis half-life greater than 1 week; and (8) Field dissipation half-life greater than 3 weeks (U.S. EPA, 1988). The most commonly found pesticide residues in the U.S. groundwater include alachlor, aldicarb, atrazine, bromacil, carbofuran, cyanazine, DBCP, dimethyltertra-chloroterephthalate (DCPA), 1,2-dichloropropane, dinoseb, dyfonate, ethylenedibromide (EDB), metolachlor, metribuzon, oxamyl, simazine, and 1,2,3-trichloropropane (National Research Council, 1993).

The potential for pesticides to leach directly through soils and rock to groundwater also depends on other numerous factors. Natural site characteristics can enhance or reduce the potential for pesticides to leach and to contaminate groundwater. There are several natural factors affecting leaching ability of pesticides to groundwater. Local topography and landforms can favor surface runoff over downward soil seepage or vice versa. Vegetation and climatic parameters (temperature, precipitation, air movement, and solar radiation levels) affect the environmental fate of contaminants as well. Roots and sunlight can interact directly with the contaminant (e.g., photochemical degradation of chemical exposed to sunlight, root uptake of pesticides); vegetation and climate also have impacts on soil properties (OTA, 1990).

Groundwater systems vary and are not equally vulnerable to contamination. Vulnerability of groundwater is determined by the amount, the physical properties, and the thermodynamic properties of compounds applied to the hydrologically connected land (Carlson et al., 1990). Vulnerability of groundwater to contamination varies according to the depth of groundwater, soil characteristics, vadose zone information, basic geologic/ hydrogeologic data, and aquifer or groundwater maps with conductivity information. In general, shallow, permeable, unconfined aquifers overlain by thin, sand, or gravel soils in humid regions are the most susceptible to pesticide contamination from the land surface because short flow paths to the water table and rapid infiltration reduce the opportunity for physical, chemical, and biological reactions to decompose contaminants. To assess the likelihood that a pesticide will reach groundwater, it is important to know its chemical characteristics and the local soil conditions. It is frequently difficult to predict which pesticides will contaminate groundwater just by evaluating individual quantitative measures of chemical and soil characteristics.

1.3 Review of Pesticide/Groundwater Legislation

Several federal legislations have some potential impact on groundwater quality protection from agricultural chemicals. These laws include Federal Insecticide, Fungicide and Rodenticide Act (FIFRA), Safe Drinking Water Act (SDWA), Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), Clean Water Act (CWA), Resource Conservation and Recovery Act (RCRA) and many others. Taken together these statutes provide for controls on the problem of pesticide contamination of groundwater. The five statutes will be each reviewed briefly

In 1986, EPA began to develop the Pesticide and Groundwater Strategy. This Strategy describes the polices, management programs, and regulatory approaches that the Agency will use in order to protect the nation's groundwater resources from risks of contamination by pesticides. The Strategy addresses EPA's authorities under a number of statutes, including FIFRA, SDWA, CWA, CERCLA, and RCRA (U.S. EPA, 1991). Emphasis should be placed on coordinating FIFRA, SDWA, CWA, CERCLA, and RCRA enforcement activities of delegated programs and those administered by EPA to identify parties responsible for groundwater contamination as a result of the misuse of pesticides, including illegal disposal or leaks and spills.

1.3.1 Federal Insecticide, Fungicide and Rodenticide Act (FIFRA)

Pesticides have been regulated under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) since it was enacted in 1947 to replace earlier legislation (Feitshans, 1990). FIFRA is perhaps the most important law constraining agriculture but designed specifically to correct the externality. The intention of original pesticide regulation was to protect farmers and, later, consumers, but not the environment (Fairchild, 1987). In 1972, FIFRA was amended with the passage of the Federal Environmental Pesticide Control Act (FEPCA). FEPCA gave EPA the authority to register pesticides for general and restricted use, to cancel or suspend registration, and to explicitly consider environmental protection in regulating pesticides, as well as socioeconomic cost and benefits (Just and Bockstael, 1991). Only minor amendments have been made to FIFRA since 1972.

A major control provided by FIFRA is a requirement that all pesticides (subject to specified exemptions) be approved by EPA through a mandatory registration process (Batie et al., 1989). EPA must certify that the use of a pesticide does not pose any "unreasonable adverse effect" in order to register a pesticide. The phrase "unreasonable adverse effects" is defined in Section 2(bb) as "any unreasonable risk to man or the environment, taking into account the economic, social, and environmental costs and benefits of the use of any pesticide" (National Research Council, 1980). EPA must also consider the impact of any regulatory action "on production, prices of agricultural commodities, retail food prices, and otherwise on the agricultural economy." Registration of products that pose unreasonable risks to human health or the environment can be denied, thereby preventing the distribution and use of such products. Registration requires the submission by the manufacturer of extensive data on the efficacy and human and environmental effects of the pesticide. EPA uses this data in deciding whether to register the pesticide and whether to impose conditions on its manufacture, processing, distribution, and use. The legislative history supports the Agency's position that FIFRA, as amended by FEPCA, requires the Agency to subject all pesticide uses to benefit-risk analysis (National Research Council, 1980).

The 1972 FIFRA amendments authorized EPA to set conditions for pesticide use through a two-tiered pesticide classification system (OTA, 1990). Classification occurs through the registration process; pesticides are registered for either general use or restricted use. EPA classifies pesticides for general-use if it determines that the pesticide will not cause unreasonable adverse effects on human health or the environment if applied according to label directions or commonly recognized practice. EPA classifies pesticides for restricted-use if they may cause unreasonable adverse effects under such conditions (OTA, 1990). FIFRA requires restricted-use pesticides (RUPs) to be applied only by persons who are: 1) certified as competent in handling pesticides, or 2) under direct supervision of a certified applicator (OTA, 1990).

After registering a pesticide, EPA retains regulatory control via the reregistration, cancellation, and suspension provisions of FIFRA. Section 6 (a) of FIFRA establishes that registrations are canceled after 5 years unless EPA receives a request for a new registration, at which point EPA may request new data about the pesticide and may, on the basis of this new information, alter the conditions of the registration. EPA may cancel a pesticide's registration or change its classification upon a finding that use in accordance with commonly recognized practice generally causes unreasonable adverse effects on human health or the environment. Registration may be suspended immediately in order to prevent an imminent hazard associated with use of a pesticide, provided that a notice to cancel registration or change classification has been issued or is issued at the same time as a suspension order (Batie et al., 1989).

For a long time the most important regulatory concerns under FIFRA have been the control of pesticide residues in food via the tolerance-setting process, and the control of direct exposure of pesticide applicators and field workers who may come into contact with pesticides during use (The Freshwater Foundation, 1987). But with the findings of aldicarb and dibromochloropropane in groundwater in 1979, the pesticide regulatory program increased its emphasis on the understanding and regulation of pesticide contamination of groundwater and other indirect pathways of environmental exposure. FIFRA authority is being used by EPA to evaluate the leaching potential of individual pesticide. Pesticides identified as potential leachers would, if they exceed guidance levels, trigger a coordinated Federal and state regulatory response. Regulatory actions such as label changes, restricted use classification, and cancellation will continue to be made when needed to protect groundwater (U.S. EPA, 1988). These actions on a chemical-by-chemical basis will define the chemical posing a risk to groundwater and establish requirement for using these chemicals. The first regulatory action taken against a pesticide registration due to groundwater contamination in the continental United States was EPA's ban of DBCP (1,2-bromo-3-chloropropane) in 1979 (OTA, 1990). Since that time, EPA has canceled other pesticides due to groundwater concerns, established an Office of Groundwater Protection in the Office of Water, and added requests for data on leaching for reregistration of a number of pesticides (OTA, 1990).

However, emphasis within the registration process on protection of human health and environment dates only to 1972, and many pesticide products were registered prior to that date when primary regulatory emphasis was on assuring product effectiveness. Many pesticides maintain federal registration without meeting existing data requirements or satisfying the toxicological and environmental standards that newer products must meet in order to gain registrations (National Research Council, 1986). In recognition of this problem, Congress has required EPA to initiate a reregistration process. Because of slow progress in reviewing and updating the registrations of older pesticides, EPA has not been able to complete the process in part because the scientific information available for many of the pesticides is inadequate to determine if they are safe. At the current time, there is an incomplete set of toxicological data for many pesticides currently in wide use. Environmental data that can be used to estimate the likelihood that pesticides will reach groundwater under certain soil and precipitation/ irrigation conditions are even more scarce. The lack of sufficient information and data, FIFRA has not been worked effectively to regulate pesticide contamination of groundwater problem at federal level.

Special Review

The Special Review process (formerly Rebuttable Presumption Against Registration (RPAR) which was the process in response to the Federal Environmental Pesticide Control Act (FEPCA)) developed by the EPA is to ensure a full gathering of scientific information on pesticide safety and a thorough assessment of risks and benefits of pesticide products. The Special Review process was adopted in 1988, and this process allowed EPA to study chemicals in depth before determining whether to cancel registrations or to place restrictions on the use of pesticides suspected or to possess one or more of the risk criteria or to trigger for Special Review.

A Special Review occurs when the EPA receives evidence of proved scientific tests that indicate possibly hazardous effects. Effects that trigger a review are: (1) Oncogenicity (tumor formation); (2) Heritable genetic mutations; (3) Teratogenicity (birth defects); (4) Fetotoxicity (fetal mortality); (5) Other adverse reproductive effects (e.g. sterility); (6) Chronic or delayed toxicity; (7) Effects on nontarget wildlife or aquatic species including risks to endangered species; (8) Other risks to humans or the environment (Ware, 1991, chap.14). These evidence data may come from the registrants, a registration standard review or an independent testing agency such as the National Cancer Institute.

Most risk rebuttals are normally conducted by the pesticide's registrant, however, rebuttals may also be submitted by anyone (e.g., the U.S. Department of Agriculture (USDA), individual states, grower or commodity groups, and private parties.) In fact, the EPA may contest its own Review when appropriate. Thus, in the Special Review process, risks may be challenged by any interested party.

Benefits assessment and determination of exposure under use conditions are determined as a standard policy by the National Agricultural Pesticide Impact Assessment Program's (NAPIAP) assessment teams (Ware, 1991, chap.14). The NAPIAP rebuttal, which involves every state, is at least as important as the EPA's Special Review process, for it provides a way for the people to be heard in the regulatory process. The assessment team is also charged with identifying short-term researchable data gaps.

1.3.2 Safe Drinking Water Act (SDWA)

The quality of drinking water is regulated by the SDWA of 1974 as amended in 1977 and 1986 (Buchholz, 1992). The SDWA states that primary drinking water regulations are to be published which: (1) specify contaminants which "in the judgment of the Administrator, may have any adverse effect on the health of persons;" (2) set for each contaminant either a Maximum Contaminant Level (MCL) or a treatment technique; and (3) specify monitoring/reporting requirements and public notification. These regulations are applied to all public water supplies which possess at least fifteen service connections or regularly serve at least twenty-five individuals (The Freshwater Foundation, 1987).

The SDWA gives the EPA authority to set two different kinds of standards for water used for human consumption: recommended maximum contaminant levels (RMCLs) and maximum contaminant levels (MCLs) for any contaminants, including pesticides, which may have adverse health effects in public water system (Carlson et al., 1993). The recommended maximum contaminant levels (RMCLs) represent maximum concentrations of pollutants based solely on health concerns. Under the SDWA, EPA may not enforce these limits, they are primarily informational and represent long-term goals. By contrast, the MCLs are enforceable. If a public water supply exceeds a MCL for a pollutant, the purveyor is required to take action to reduce concentrations of that pollutant below the MCL (National Research Council, 1986). In late 1984, EPA proposed RMCLs and MCLs for many additional organic and inorganic chemicals. The SDWA was reauthorized in June, 1986. The amended Act contains a number of elements which impact upon, and modify, the standard-setting process as administered by the Office of Drinking Water at EPA (The Freshwater Foundation, 1987). It also provides EPA with a statutory basis for promoting comprehensive protection of the nation's groundwater as a vital resource (U.S. EPA, 1988).

The SDWA was created as a scientifically based program that would efficiently achieve optimum water quality. It did not mandate a zero level of risk. The EPA relies heavily on state monitoring and enforcement of the SDWA. The states bear primary responsibility for enforcing drinking water standard assisted in part with federal funds (Buchholz, 1992). A water supply system that does not meet these standards must take whatever steps are necessary to bring the system into compliance at the earliest feasible time. States can impose their own MCLs as long as they are within the Federal limits (Baker, 1990). States have been notably inconsistent in implementation of the SDWA. To deal with the crisis, state governments have acted to set standards independently of EPA, rather than wait. Many of these state MCLs are based on Federal RMCLs (Baker, 1990).

The SDWA also established a Wellhead Protection Program to protect wells and wellfields that contribute drinking water to public supply systems (OTA, 1990). This program does not establish direct federal control measures but instead provides for creation of state programs (Batie et al., 1989). Each State must prepare and submit to EPA a Wellhead Protection Program delineating the recharge areas around public water, identifying potential sources of groundwater contamination within these areas, and addressing identified potential sources to protect the public water supply. Although funds have been appropriated for the WHP Program, the EPA Administrator testified to the Senate that only 30 States have submitted proposed programs for review and approval by EPA (OTA, 1990).

1.3.3 Comprehensive Environmental Response, Compensation and Liability Act (CERCLA)

CERCLA is best known as the creator of the Superfund Program for cleanup of hazardous substances released into the environment (Batie et al., 1989). The liability provisions of CERCLA are among its most important provisions. Subject only to specified defenses, strict liability for several costs associated with release of a hazardous substance is imposed on essentially all parties associated with the responsible activity. CERCLA gives EPA authority to compel responsible parties to clean up hazardous waste sites. EPA also has authority to conduct the cleanup itself and recover cleanup costs from responsible parties. Parties who have failed to comply with earlier EPA cleanup orders may be forced to pay three times EPA's actual cleanup costs (Feitshans, 1990).

Originally intended to clean up massive environmental problems caused by hazardous waste disposal, CERCLA may be increasingly used to correct pesticide contamination problem (Fairchild, 1987). The application, handling, and storage of pesticides registered under FIFRA are exempted from CERCLA coverage. Nonetheless, CERCLA cleanup liability may exist where unused portions of pesticides have been discarded improperly (Feitshans, 1990). Such cleanup costs could be quite large where the improper disposal has caused groundwater contamination. The addition of six wells drawing from groundwater contaminated by normal use of pesticide to EPA's priority list for cleanup action in October, 1984, has given CERCLA a role in pesticide contamination problems (Fairchild, 1987).

1.3.4 Resource Conservation and Recovery Act (RCRA)

The Resource Conservation and Recovery Act of 1976 (RCRA), also called the Solid Waste Disposal Act, regulates the generation, treatment, storage, and disposal of hazardous wastes (Conservation Foundation, 1985). RCRA requires most generators and handlers of hazardous waste to obtain permits (Feitshans, 1990). It also regulates underground storage tanks to prevent leaks. Specifically, the law provides for (1) federal classification of hazardous waste; (2) a "cradle-to-grave" manifest (tracking) system for waste material; (3) federal safeguard standards for generators and transporters, and for facilities that treat, store, or dispose of hazardous wastes; (4) enforcement of standards for facilities through a permitting system; and (5) authorization of state programs to replace federal program (Buchholz, 1992). The basic purpose of RCRA is to protect groundwater from toxic pollution. RCRA provides no exception for agricultural pesticide use . EPA has provided a limited exception, by regulation, for disposal of empty containers that held FIFRA-registered pesticides. Such containers must be triple-rinsed and disposed of on the farmer's own land in a manner consistent with the pesticide label (Feitshans, 1990). Otherwise, the exception does not apply.

1.3.5 Clean Water Act (CWA)

The direct regulatory provisions of CWA are limited to surface water. Another portion of CWA with potential to affect agricultural sources of groundwater contamination is the nonpoint source pollution control provision (sec.1329) (Batie et al., 1989). The 1972, 1977, and 1987 Clean Water Act (CWA) amendments specifically address nonpoint-source pollution, of which agriculture is a major contributor in most of the United States (Logan, 1990). These provisions do not establish direct federal controls for nonpoint sources but focus on development of state controls. Clean Water Act of 1987 section 319, EPA required states to submit plans for controlling sources of nonpoint pollution.

1.3.6 Groundwater Safety Act

The 1987 Groundwater Safety Act would give EPA an enforcement role. Manufacturers of pesticides on EPA's list of groundwater leachers would have to monitor selected sites where pesticides are used. Failure to do so could result in EPA's banning the pesticides altogether. The act would authorize $50 million per year for five years to support the program, which would also require that states develop programs to prevent pesticide contamination of groundwater (Bouwer, 1990). This act and associated state programs could have severe impacts on the use of pesticides in agriculture.

1.4 The Situation of Developing Pesticides and Groundwater State Management Plans in Michigan

In the past, EPA has sought to limit groundwater pesticide contamination largely through uniform national restrictions, using authority granted to it in the FIFRA (U.S. GAO, 1991). Under this authority, the most important regulatory decisions are made by the federal government and applied by states more or less uniformly throughout the nation (U.S. GAO, 1991). However, based on legislation reviewed previously, the recognition that current regulation strikes uniformly across the nation whereas vulnerability to contamination is not at all uniform has led EPA to conclude that the problem warrants a different approach. Because groundwater contamination problems are site specific, and the technical information on practices to reduce pesticide risks is needed in the design and implementation of programs addressing pesticide contamination at the state and local levels, EPA has mandated that states develop and implement management plans based on area-specific differences in groundwater use, value, and vulnerability.

Under this new regulatory scheme, the states will be granted a large degree of freedom to create individual "management plans" for controlling pesticide use to prevent groundwater contamination. This strategy is termed "differential management." There are two types of state management plans (SMPs): Generic and Pesticide-Specific. SMPs consist of components that must be addressed to varying degrees in such a way as to reflect the degree of risk represented by the differences in aquifer vulnerability, pesticide use, and agronomic practices in a particular state (U.S. EPA, 1991). Generic Plans provide basic information for each of the components regardless of a specific pesticide. While EPA encourages their development, Generic Plans are not required to be developed by states. A Pesticide-Specific Plan containing all the generic information appropriate to the Generic Plan plus all the information specific to the pesticide of concern is required. If states do not develop the management plans or the management plans do not address existing and potential ground and surface water contamination problems, EPA will intervene to restrict or regulate pesticides use (Just and Bockstael, 1991, Chap.3). In most cases EPA management will consist primarily of canceling the registration of the chemical in those states. If a management plan sufficiently addresses EPA criteria the state will continue to manage pesticide use.

With EPA giving the states the primary responsibility for groundwater policy and requiring the development of state groundwater strategies, states have begun to realize the deficit of information- both institutional and physical-they are now facing. Nearly all of the state strategies recognize the need to address pesticides as part of the groundwater protection program. However, because the pesticide contamination problem is a relatively recent discovery and involves complex technical and institutional questions, programs to address pesticides in groundwater are less developed than for other sources of contamination. States have been slow to initiate effective pesticide control/groundwater protection programs for a variety reasons, including: the lack of good data on pesticide use and occurrence in groundwater; poor understanding of the environmental fate and health effects of pesticides; coordination problems between the state agencies responsible for pesticide control and groundwater management and protection; and the absence of groundwater protection standards (Adams and Tryens, 1988).

Groundwater is an essential source of fresh water in many parts of Michigan. Approximately 44 percent of Michigan residents depend on groundwater for drinking (Dean et al., 1990). An estimated 14,000 public water supply agencies serving nearly 1.7 million people use groundwater in Michigan (Dean et al., 1990). Thousands of private drinking water wells are located throughout the state. Groundwater is also used for irrigation and industrial use, and replenishes streams, lakes and wetlands. Agricultural operations and practices in Michigan pose potential threats to groundwater. Particular concerns include runoff and infiltration from the application of pesticides and fertilizers. Although systematic testing of groundwater for contamination in Michigan agricultural areas has been extremely limited, well water surveys have confirmed the presence of both pesticides and nitrates in groundwater in areas highly susceptible to contamination (Black and Ditschman, 1991). In 1989, the Michigan Department of Public Health sampled water wells in the vicinity of agricultural chemical storage sites. Out of fifty wells sampled, nine wells were found to have detectable levels of pesticides (Dean et al., 1990).

Michigan is one of many states having vulnerable aquifer, extensive agricultural production, and no state regulatory management plan in place to protect groundwater quality from agrichemical contamination[1]. Unlike other states, Michigan does not have a systematic groundwater quality monitoring program which could serve to identify threats from particular types of land uses. The state is using the EPA required generic SMP as a springboard for

[1]Michigan Department of Agriculture (MDA) has submitted a draft Generic SMP to EPA for review.

developing concrete protection measures (Ditschman et al., 1990). To develop state management plans to avoid potential leaching pesticides contaminating groundwater, a necessary element is a description of methods for assessment and planning. The Michigan Department of Agriculture (MDA) is considering structuring its programs based on a combination of aquifer sensitivity and groundwater impact potential. "Aquifer sensitivity" is defined as the inherent ability of materials surrounding an aquifer to attenuate the movement of contaminants into that aquifer. "Groundwater impact potential" is defined as the risk to groundwater posed by activities conducted on the land surface. As such, groundwater impact potential is the surface management component of aquifer vulnerability assessment.

Because of the lack of valid methods of assessing aquifer sensitivity, the Michigan Department of Agriculture (MDA) is currently attempting to estimate aquifer sensitivity based on soil type and sub-surface geology. Another problem facing the development of planning tools for use by state government in groundwater protection is the lack of pesticide use information. There is a need to integrate information from secondary sources, such as surveys and sales records into a single measure of groundwater impact potential for each type of pesticide use.

1.5 Goal

In order to obtain the pesticide use information, the state should develop better data bases on pesticide usage. The overall goal of this study is to define the method to estimate total mass of "likely to leach" pesticides applied in each county in Michigan. In pursuit of this goal several objectives have been defined. These objectives are: (1) Identify available information sources regarding pesticide uses in Michigan; (2) Identify pesticide use activities and practices which may contaminate groundwater; (3) Develop prototype matrix structures for integrating and quantifying use-site and impact-potential relationship; (4) Evaluate methods using literatures reviews, survey methods or expert opinion in an attempt to calibrate or to complete of the prototype matrix.

Chapter 2

Methodology

2.1 The Reasons to Use Matrix Approach

As mentioned in the previous chapter, EPA has developed a strategy that embodies the notion of differentially protecting groundwater from pesticides on the basis of the value of the groundwater and the relative vulnerability of different geographic areas. This strategy has put a significant emphasis on the development and use of aquifer vulnerability assessment models to evaluate the pollution potential for pesticides to enter groundwater. There were three approaches models used for assessing groundwater vulnerability: parameter-weighing, empirical, and simulation-modeling. In the past, EPA assumed that the models approach could provide information accurate enough to predict the potential for contamination to occur. However, the performance of vulnerability assessment models is inconsistent, and there was no evidence that the models correlated with the field data (Fairchild, 1987).

For example, one model that EPA has particularly promoted as a tool to assess aquifer vulnerability is DRASTIC rating system. This system was designed by the National Water Well Association, under contract with the U.S. EPA, to provide a systematic numerical approach to evaluating the potential for groundwater pollution. The complete DRASTIC score is a weighted sum of seven DRASTIC component scores (Holden et al., 1992). Each component score is an index describing the influence, in the area under consideration, of a hydrogeologic factor considered relevant to groundwater contamination. The seven factors used in the DRASTIC system are depth to saturated zone, net recharge, type of aquifer media, type of soil media, slope of land surface, impact of vadose zone[2], and hydraulic conductivity of the aquifer. The larger values of each component score, and hence of the total DRASTIC score, predict a greater potential for groundwater contamination. Nevertheless, the most extensive tests of DRASTIC have found no positive relationship between DRASTIC scores and pesticide contamination (U.S. GAO, 1992). The failure of DRASTIC to perform acceptably is especially important since EPA had in the past promoted its use for conducting vulnerability assessments and many states have used DRASTIC when doing their own assessments. None of the other models have been sufficiently tested to gain an understanding of their usefulness.

Although many states have conducted vulnerability assessments, the states have generally used invalidate methods for their assessments. And in most cases, model predictions have not been verified with monitoring data. Thus the appropriateness of using them alone to predict at this scale is in doubt. Therefore, it is necessary to conduct a

---

[2]The impact of the vadose zone is expanded to include both the vadose zone and any saturated zones which overlie the aquifer. The significantly restrictive zone above the aquifer which forms the confining layer is used as the type of medium which has the most significant impact. For example, the rating of silt/clay is 1-2; the karst limestone is 8-10 (Garner, et al., 1986, Chap.6).

broader range of tools to assess the vulnerability of groundwater. The Michigan Department of Agriculture (MDA) is considering structuring its programs based on a combination of aquifer sensitivity and groundwater impact potential. Because of the lack of valid models of assessing aquifer sensitivity currently, we try to design a method to estimate the pesticide use mass data that predicts the groundwater impact potential.

To obtain the pesticide use mass (quantity) data, we need the pesticide use information at the state and county level. With the exception of restricted use pesticides, Michigan does not currently require registrants or distributors to submit pesticide sales records. Thus, we do not know the mass or the value of pesticide being used in Michigan. In order to develop a method for estimating groundwater impact potential associated with pesticide use, we developed a prototype groundwater impact potential matrix to estimate total mass of leachable pesticides applied in each county in Michigan.

The prototype matrix is used to organize information important to the quantification of groundwater impact potential and to provide a focal point for integration of alternative sources of information. Therefore, this prototype matrix can serve as a baseline. We can use it as an analytical device and as a common frame of reference for "experts" on pesticide use and groundwater protection. In addition, the research data that evaluate the relationship between aquifer sensitivity and soil structure affecting pesticides contamination of groundwater obtained from the current models and monitoring system conducted in Michigan do not match the expected results. The uncertainty of aquifer sensitivity and soil structure affecting pesticides contamination of groundwater suggests groundwater impact potential is an important issue to consider. We try to estimate the total mass of leachable pesticides applied and to evaluate their groundwater impact potential.

The matrix approach is a good method to deal with a complex system that combines multidimensional information. The advantages of using matrix approach include allocating of two dimension information in one table matrix, little to memorize, and ease of integrating information.

2.2 Identification of Available Information Sources Regarding Pesticide Uses (Site Types and Distribution) in Michigan

Survey data on pesticide use was collected from Michigan Agricultural Statistics Service (MASS), the National Agricultural Statistics Service (NASS), and other available surveys. These surveys were reviewed for information pertaining to the distribution and magnitude of pesticide use. Pesticide use sites indicated on pesticides labels were also identified and included as site types.

Pesticide uses mainly include production categories from Michigan Agricultural Statistics Service (MASS) and turf maintenance. Current distributed-source being considered includes total acreage or area being treated and a series of pesticide use estimates. Total acreage or area will provide a measure of the magnitude with which an activity is conducted and will therefore weight the significance of all associated practices and activities. Pesticide use estimates based on the results of the National Agricultural Statistics Service (NASS) agricultural chemical usage surveys have been collected for inclusion.

Site types were extracted from survey-categories (National Agricultural Statistics Service - Agricultural Chemical Usage Survey, Michigan Agricultural Statistics Survey, and Michigan County Food and Agricultural Development Statistics) and pesticide-use-site-codes (PESTBANK) and used to organize information on: units of quantification (acres, feet^2); minimum spatial resolution (county, state, national); frequency of information update (single study, annual etc); and the availability of pesticide use frequency and application rate information needed to estimate the magnitude of pesticide use. The presence, absence, and variability of information at given levels of resolution then guided our groundwater impact matrix design.

2.3 Identification of Pesticide Use Activities and Practices Which May Contaminate Groundwater

The pesticide use activities and practices which may contaminate groundwater were identified. According to U.S. EPA (U.S. EPA, April 3, 1990) 45 pesticides (Table 1.) have been detected in groundwater as a result of agricultural practices. The use of these products was assumed to increase the risk of groundwater contamination.

Table 1. Likely-to-leach pesticides as determined by confirmation in groundwater

2,4-D Acid	DCPA	Malathion
4-Nitrophenol	Diazinon	Methamidophos
Alachlor	Dicamba	Methomyl
Aldicarb	Dichlorobenzene,ortho	Metolachlor
Aldrin	Dichloropropane 1,2	Metribuzin
Atraton	Dichloropropane 1,3	Monuron
Atrazine	Dichloropropene 1,3	Oxamyl
Bentazon Sodium Salt	Diruon	Ethyl Parathion
Benzene Hexachloride	Ethylene Thiourea	Methyl Parathion
Bromacil	Ethoprop	Picloram
Carbofuran	Ethylene Dibromide	Prometon
Carbon Disulfide	Fonofos	Simazine
Chloramben Salts	Hexazinone	Sulprofos
Chlorothalonil	Lindane	Thiodan
Cyanazine	Linuron	Trifluralin

An initial site-type/pesticide interaction table was developed to organize information on pesticide use associated with each site type. Seventy-two crop site codes from PESTBANK were downloaded for each of the 45 pesticides and crosstabulated to form a 3,240 cell site-type/pesticide interaction table. Because pesticides are registered for use on specific site types only a subset of these cells represent legal pesticide applications and were therefore considered "valid" cells.

Pesticide use survey data (NASS) was then reviewed to determine the percentage of acres treated and average application rate for each of the "valid" site-type/pesticide interaction cells.

2.4 Development of Prototype Matrix Structures for Integrating and Quantifying Use-Site and Impact-Potential Relationships

The prototype matrix structures were developed for integrating and quantifying use-site and impact-potential relationships. Two types of preliminary matrices were developed describing: 1) the magnitude of each site type in a county, and 2) the available pesticide use information associated with each site type.

Information in the magnitude table was mainly obtained from the Michigan 1990 County Food and Agricultural Development Statistics publication. As such, the majority of the estimates are for 1989 production levels. Site types were represented as columns in the tables. Counties were represented by rows. Table cells or nodes contained the number of acres in a specific site type for each county in 1989. The pesticide use table associated with each site type was obtained from pesticide use survey data from the NASS chemical usage survey in 1990, 1991. Site types were represented as column in the tables. The pesticide use, percentage of acres treated and average application rate were represented by rows.

All available pesticide use estimates were summed to provide an estimate of the total mass of likely to leach pesticides applied in each county. The missing information was also identified.

2.5 Literature Review

In order to complete the prototype matrix, a literature search was conducted using the Magic system, Agricola data base, American Statistical Index (ASI), and Statistical Reference Index (SRI) at the Michigan State University Library. In the Magic system and Agricola data base program, the key words used are Pesticide(s), Pesticide(s) use, Pesticide(s) Survey, Pesticide(s) and Groundwater, Pesticide(s) and Crop(s), Pesticide(s) and Poultry, Pesticide(s) and Lawn, Pesticide(s) and Greenhouse, Pesticide(s) and Garden, Pesticide(s) and School zone, Pesticide(s) and airport, and Pesticide(s) and road. The ASI and SRI for the period 1985 to 1993 were searched using the keywords: pesticides or fertilizer. Title statements and abstracts for all articles were reviewed for relevance to prototype matrix completion.

2.6 Information Obtained from Michigan Agricultural Experiment Station/Extension Service CAT (Crop Advisory Team) Alerts

The CAT teams represent the principal crop growing areas in Michigan. Conference calls are held weekly during the growing season to review the stage of plant growth by crop, preconditions for nutrient deficiencies and weed, pest and disease problems, emerging weed, and the development of management strategies farmers should consider.

The information from CAT Alerts for the period from May, 1986 to July, 1993 was summarized to get the major pest problems which are related to the different field crop types. The registered pesticides and reported pesticides which are involved in elimination of major pests will be defined. The results of major pests and the pesticide use will be used as a reference for evaluating the opinions of expert team or developing the survey questionnaire. The opinions of experts and the results of survey can be obtained to estimate for completion of the matrix.

Chapter 3

Results

3.1 Site Types and Distributions

Seventy-two site types were identified from survey-categories and pesticide-use-site-codes (Swartz, 1993). State and county level estimates of magnitude (Table 2) were available annually for 11 and 60 percent of the site-types respectively. No sub-county information was available.

Table 2. Spital resolution and update frequency of information on site type magnitude.[3]

Level of Spatial Resolution	Single Study	Annual Update
Sub-County	0%	0%
County	50%	11%
State	72%	59%

Both county and state level estimates are available annually for major crops such as corn and soybeans (Appendix A, Table 1). For less commonly produced or lowest interest crops such as rye, forage, and spearmint the 1990 County Food and Agricultural

[3]The frequency of information from the Appendix A Table 1:
For the single study - county is 36/72=50%, the state is 52/72=72%
For the annual update - county is 8/72=11%, the state is 43/72=60%

Development Statistics (CFADS) provide the only county level estimate. However, statewide estimates are available annually for these crops. Annual statewide production estimates for site-types such as fur bearing animal production and covered green house operations are available from MASS, but no county level information is currently available.

The 1990 County Food and Agricultural Development Statistics provided the most consistent county level estimates for 44 of the 72 site types. As such, it was the most comprehensive collection of site distribution information was used as the base for a site-type/county distribution matrix (Appendix A, Table 1).

3.2 Groundwater Impact Potential

Pesticide use estimates were available for 30 of the 72 site types (Appendix A, Table 2) (Swartz, 1993). The NASS pesticide surveys for field, fruit, and nut crops provide both national estimates of pesticide use and state estimates of pesticide use for states producing a major amount of a specific commodity. For vegetable crops, estimates are available only for major producing states. National level estimates create problems in that states have different pest problems and use different pesticides leading to both over and under estimation for specific pesticides in an individual state. The state level information is only available for major producing states. Either way biases are incorporated into the analysis which are not consistent across site-types. In both cases pesticide use estimates (Table 3) are based on a single year of survey information and are not currently sensitive to yearly changes in weather and pest pressures.

In this analysis, state level estimates were used where available. National level estimates were used when state level estimates were not available.

Table 3. Spatial resolution and update frequency of information on pesticide use.[4]

Level of Spatial Resolution	Single Year	Annual Update
State	39%	0%
Federal	15%	0%

Among the 3,240 possible pesticide/site-type combinations, the registered or "valid" combinations have not been confirmed yet. Therefore, the percentage of the valid cells of pesticide use estimates available were not decided. The remaining unknown sites should be divided into two categories. On sites where a pesticide use survey has been conducted, the lack of a pesticide use estimate probably indicates the use of a specific pesticide is small enough to have not made the minimum reporting criteria of the pesticide use survey and are probably of little concern to the analysis. For the remaining unknown cells, we simply have no estimate of the magnitude of associated pesticide use. The remaining of this project will attempt to identify additional methods for providing these missing estimates.

[4]The frequency of information from the Appendix A Table 2:
For the single study - county is 28/72=39%, the federal is 11/72=15%
For the annual update - county is 0/72=0%, the federal is 0/72=0%

3.3 Two Types of Preliminary Matrices

Two types of preliminary matrices were developed describing: the magnitude of each site type in each county (MASS and CFADS, 1990) (Appendix B, Table 3) (Swartz, 1993) and the available pesticide use information associated with each site type (NASS-Agricultural Chemical Usage 1990 Field Crop, Vegetables and 1991 Fruits and Nuts Summaries) (Appendix B, Table 4). The columns in the appendix table 3 matrix consist of each site type in Michigan. The rows consist of the 83 counties in Michigan. The table cells or nodes contained the number of acres in a specific site for each county in 1989. The columns in the appendix table 4 matrix consist of each site type (pesticide use category). The rows consist of the types of pesticide use, percentage of acres treated and average application rate (groundwater impact factor).

The pesticides selected in appendix table 4 represent those pesticides listed in table 1 for which sufficient quantities were reported in the pesticide use surveys to warrant the publication of a use estimate that have actually been detected in the groundwater of Michigan or neighboring states. By the very fact of their occurrence in the groundwater these pesticides are identified as problem chemicals that are likely to leach. Obviously, with this selection criterion we cannot make any predictions about future groundwater pollution due to chemicals not yet on the list. The subsequent work of this project will attempt to get more information form different sources to make the table more complete.

For appendix table 4, part of data obtained in the rows is calculated from the following formula:

(a) Nitrogen Rate/crop year (lb/acre)

= Nitrogen rate per crop year

= Nitrogen pounds applied per treated acre during crop year

= Pounds applied per treated acre of crop per application * Number of application

For example, for corn grain:

Nitrogen Rate/crop year= 65*1.93 =125.45 (lb/ac)

(b) Nitrogen/acre (lb/acre)

= Nitrogen applied per acre

= Nitrogen area applied (%) * Nitrogen Rate/crop year

For example, for corn grain:

Nitrogen/acre = .97*125 = 121.25 (lb/ac)

(c) Total Nitrogen applied (lb)

= Nitrogen/acre * Area planted of a specific crop (site type)

For example, for corn grain:

Nitrogen total = 2,400,000 * 121.25 = 291,000,000 (lb)

(d) For pesticides:

Individual pesticide/acre (lb/acre)

= Individual pesticide area applied (%) * Individual pesticide rate per crop year

For example, for Atrazine used in corn grain:

Atrazine/acre = .643*1.22 = .7845 (lb/ac)

(e) Pesticide application (lb/acre)

= Total estimated available likely-to-leach ingredient applied per acre of a crop

For example, for corn grain:

Pesticide Application

= Alachlor/acre + Aldicarb/acre + Atrazine/acre + Bentazon/acre + DBCP/acre + Dacthal/acre + Dicamba/acre + EBDC/acre + Ethylene Dibromide/acre + Lindane/acre + Methomyl/acre + Metolachlor/acre + Prometon/acre + Propazine/acre + Simazine/acre

= .4846 + 0 +.7845 +.0071+ 0 +.0609 + 0 + 0 + 0 + 0 +. 4843 + 0 + 0 +.0264

= 1.848 (lb/ac)

3.4 Total Mass of Each Potential Leaching Pesticide at County Level in Michigan from the Prototype Matrix

Total mass of each potential leaching pesticide at county level in Michigan was calculated from combining the prototype matrices (Appendix C, Table 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16).

The calculation for appendix table 5 to table 14 is:

(a) Total of each specific pesticide applied in each county (lb)

= The sum of specific pesticide used in each activity (ie site type) in each county

= The sum of [each site type area (acres) relating to a specific individual pesticide treated activities in each county * individual pesticide/acre (lb/ac) of specific site type]

For example, for Alachlor used in Alcona county:

Total of Alachlor applied in Alcona county

= 2,150 (acres of grain corn and silage corn) * 0.485 (Alachlor/acre for corn) + 80 (acre of soybean) * 0.25 (Alachlor/acre for soybean)

= 1,063 (lb)

(b) Individual pesticide use per acre of cropland in each county (lb/acre)

= Total of each pesticide applied in each county/acres of total cropland in each county

For example, for Alachlor used in Alcona county:

Alachlor applied per acre of cropland in Alcona county

= 1,063/28,573 = 0.0372 (lb/ac) = 37.2 (lb/1,000 ac)

(c) Individual pesticide use per acre of total land in each county (lb/acre)

= Total of each pesticide applied in each county/acre of total land in each county

For example, for Alachlor used in Alcona county:

Alachlor applied per acre of total land in Alcona county

= 1,063/432,924 = 0.0025 (lb/ac) = 2.5 (lb/1,000 ac)

For appendix table 15, 16

(d) Total pesticides used in each county (lb)[5]

= Sum of total of each pesticide applied in each county

For example, for Alcona county:

Total pesticides (not include Nitrogen) used in Alcona county

= 1,063 (Alachlor) + 0.0 (Aldicarb) + 1,677 (Atrazine) + 24 (Bentazon) + 0.0 (Dacthal) + 77 (Dicamba) +9 (Methomyl) + 1,046 (Metolachlor)+56 (Simazine)

= 3,951 (lb)

(e) Aggregated pesticides used per acre of cropland in each county(lb/acre)

= Total pesticides used in each county/acre of total cropland in each county

For example, for Alcona county:

Aggregated pesticides used per acre of cropland in Alcona county

= 3,951/28,573 = 0.138 (lb/ac) = 138 (lb/1,000 ac)

(f) Aggregated pesticides used per acre of total land in each county (lb/acre)

= Total pesticides used in each county/acre of total land in each county

For example, for Alcona county:

Aggregated pesticides used per acre of total land in Alcona county

= 3,951/432,924 = 0.009 (lb/ac) = 9 (lb/1,000 ac)

---

[5] Due to the different characteristics and toxicological properties of pesticides, we should weight each active compound differently. However, each pesticide was roughly weighted equally in our calculation because of the incomplete set of characteristic and the toxicological data of some pesticides used. Different results will be obtained if we use different weighted scales.

3.5 Results of Literature Review

None of the books or articles retrieved from the query on the Magic or Agricola system were helpful in the estimation of the magnitude or distribution of pesticide use. Most of the materials retrieved from the Magic system dealt with pesticide properties, safety and risk of pesticide uses, how to reduce the use of pesticide, and residues in food. Materials retrieved from the Agricola database included pesticide applicator training guides, certification manuals, and articles discussing the restriction of pesticides, economic aspects of pesticide use and hearing articles.

Information more closely aligned with the task at hand was provided by the query on the ASI and SRI indexes. Nine articles obtained from ASI search and thirteen articles obtained from SRI search could be used as reference to help us to complete the prototype matrix (Appendix D, Table 17).

3.6 The Result of CAT ALERT Search

The frequencies of major pest, disease, or weed problems related different types of field crops were calculated from Michigan Agricultural Experiment Station/Extension Service CAT Alerts for the period of 1986-1993 (Appendix E, Table 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32). The times of specific pest, disease or weed problems mentioned related to specific site type in Michigan were counted for each volume.

The frequencies were calculated as following:

(a) Frequency of each specific pest, disease, or weed problems related to specific site type

= Times of specific pest, disease or weed problems mentioned related to specific site type/sum of times of each different problems mentioned related to specific site type

For example, for alfalfa blotch leafminer problem of alfalfa in Michigan from 1986 to 1993:

The frequency of alfalfa blotch leafminer problem of alfalfa

= 5/262 = 0.02

Chapter 4

Discussion

4.1 Summary of Results

Currently, the Michigan Department of Agriculture (MDA) is considering structuring its programs based on a combination of aquifer sensitivity and groundwater impact potential. MDA is attempting to estimate the sensitivity of heterogeneous unconfined aquifers based on soil type and sub-surface geology. The lack of comprehensive pesticide use information makes the measure of groundwater impact potential difficult, if not impossible. In order to develop state management plans, we try to estimate the pesticide mass use associated with agricultural and non-agricultural applications by using matrix approach.

Seventy-two site types were identified for this analysis. However, the available information that we can obtain to measure the site-type/county distribution, even the most consistent county level estimates from 1990 County Food and Agricultural Development Statistics, just provides 44 site types. There is no information currently available for measuring the magnitude of turf sites at the county level. And there is no information available for measuring the magnitude of non-agricultural sites at the county level. Because the pesticide contamination of groundwater is a non-point contamination problem, other site types which relate to the likely to leach pesticide uses are important for measuring the groundwater impact potential. To complete the analysis, it is important to get the information related to non-agricultural sites (for example, floriculture, turf site types, etc) in county level from other sources. Survey and expert team approaches can be conducted to obtain missing data and fulfill this need.

Pesticide use estimates were available for 30 of the 72 site types. There were no floriculture, turf, farm animals (ie cow, sheep, hog, horse, etc) pesticide use information. For field, fruit, and nut crops, the NASS pesticide surveys provide both national estimates of pesticide use and state estimates of pesticide use for states producing a major amount of a specific commodity. For vegetable crops, estimates are available only for major producing states. National level estimates create problems in that states have different pest problems and use different pesticide. The state level information is only available for major producing states. To avoid serious biases, we try to select the pesticides in matrix spreadsheet which have actually been detected in the groundwater of Michigan or neighboring states and omit those that have been banned in the meantime. Fifteen pesticides which are Alachlor, Aldicarb, Atrazine, Bentazon, DBCP, Dacthal, Dicamba, EBDC, Ethylene Dibromide, Lindane, Methomyl, Metolachlor, Prometon, Propazine, Simazine have been selected. With this selection criterion, the predictions about future groundwater contamination due to chemicals not yet on the list could not be made. Also, the figures of the spreadsheet almost certainly deviate from the historical level of application prior to the chemical's detection.

Since considerable time can pass until the existence of a chemical in the groundwater can be proven, its application rate is likely to have changed due to increased pest resistance or regulatory and market forces. However, these numbers listing the level of pesticide application presented in the spreadsheet are the best numbers we have at present stage. It is possible that the matrix spreadsheet could be made more forward-looking by integrating the type of chemicals that are likely to leach in the future and thus will be more helpful for management advice.

Two types of preliminary matrices were developed describing: the magnitude of each site type in a county and the available pesticide use information associated with each site type. Because of the lack of partial information to measure magnitude of site types in county level and pesticide use for some site types, these two matrix spreadsheets have not been completed yet. With available information, we have attempted to sum up the total mass of each potential leaching pesticide in county level. Aggregate mass of pesticide use has been also computed. The results will be then coupled with the aquifer sensitivity to rank for aquifer vulnerability for each county and to develop state management plans. Although results of total pesticide mass from combining two incomplete prototype matrices are not accurate enough to measure the groundwater impact potential, at the present stage, they can still provide us some degree of understanding the distribution of pesticide pollution of groundwater problem in county level in Michigan. More efforts will be made to fill the data gap.

None of the books or articles retrieved from the query on the Magic or Agricola systems could provide magnitude and distribution of pesticide uses. Information more useful was nine articles obtained from American Statistical Index (ASI) and thirteen articles from Statistical Reference Index (SRI) search respectively. Most of those articles provided information about pesticides use in specific site type (crop type) in different states. Some articles mentioned the pest problems in different states, and the share of acre treatments with specific pesticides directed at target pest. Although the geology deviation of different states and unlike pest problems due to weather condition made the information and data obtained from these sources could not be directly integrated into our matrix, they could be used as a reference to help us to complete the prototype matrix.

The information from Crop Advisory team (CAT) Alerts for the period from 1986 to 1993 has been summarized to get the major pest problem which are related to the different field crop types. The frequencies of major problems associated with different types of field crops were computed. The purpose for this search was to get the idea about the major pest problems related some major producing crops in Michigan. When developing the state management plans, we should take more consideration about these serious pest problems and their economic impacts. However, there was some limitation to use this information. The pest problems listed in CAT Alerts include the pest problems that farmers did not recognize and did the prevention action routinely. The pest problems widely recognized by farmers and they already did the prevention action routinely might be ignored by the CAT Alerts. Therefore, the frequency computed in our analysis did not typically rank the seriousness of the pest problems. In addition, the timing of preventive action to different pest problems could be varied (ie preventive action could be taken before or after the pests really showed up), the predictive information provided by CAT Alerts did not always demonstrate the upcoming pest problems and their seriousness. Because of the difficulties to get the information related pest problem and pesticide used in Michigan, the CAT Alerts information which could not precisely predict the pest problems still could provide some useful information to complete our prototype matrix. The following work will apply this information to define the registered pesticides and reported pesticides which are involved in elimination of pest problems. The pesticide use information compiled here can then be used to develop the survey questionnaire and get the data about the distribution of pesticide uses. This information also can be used as a reference for evaluating the opinions of expert team.

4.2 Discussion of Possible Methodology for Completing the Prototype Matrix

4.2.1 Expert Team Approach

Individuals and organizations associated with each site type that is covered in the prototype matrix will be identified to form potential expert teams. The expertise will be used as calibrating of original information, filling the missing data, evaluating the prototype matrix for uses, and developing the first draft of survey questionnaire. The expert teams are based on narrow field of their specialty. For example, the corn expert team will be chosen to serve as a calibration purpose for the prototype matrix. Other crops expert teams, such as dry bean, hay, forage, and turf, are also chosen to provide additional information sources about pesticide distribution or uses for these crops.

Recommendations for additional matrix rows and columns will also be requested. The objective of this working group will be to develop recommendations for additional work to be completed for full population of the matrix. The expert team results of pesticide use for site types with good information bases can be compared with the expert team projections. If the agreement is good, use of expert teams is warranted for site types which information availability is moderate to poor.

4.2.2 Survey Approach

The survey questionnaire can be designed. The results from CAT Alert analysis will be applied to design the questions about the pest problems and pesticide uses. The possible procedures such as mail, face-to-face grower surveys, and expert surveys will be conducted. Surveys must, if possible, assess why farmers are taking the observed pest control actions as well as finding out what actions they are taking. This permits us to better assess the impact of alternatives strategies that can be taken toward reducing the potential risks associated with agricultural chemicals. For example, does the farmer have a meaningful assessment of the pest problems that are present in term of incidence and magnitude? Does the farmer have a good assessment of alternative control mechanisms including both materials available and methods of application as well as mechanical methods. The expert opinion survey approach must define the distribution of pest problems and provide an assessment of farmer's knowledge of the appropriateness of the action they are taking relative to the problems faced.

4.2.3 Completion of Matrix

The additional information obtained from proposed different sources such as survey data and expert opinions will be used for development or fleshing out of the prototype matrix. These information also will help us to identify types of pesticide uses which were not included in the prototype matrix; determine pesticide use practices such as mixing and loading operations, and pesticide storage which may impact groundwater; and identify additional information sources not available during the development of the initial prototype matrix. The collected information and data from all these sources will be integrated into a single measure of groundwater impact potential for each type of pesticide use and each class of groundwater impact potential.

4.2.4 Involves "Expert" Review of the Previously Developed Matrix to Define Groundwater Protection Programs or Alternatives

The matrix developed in the proposed methods will be reviewed by expert teams again. The possible justification and adjustment of the matrix developed will be conducted. The matrix can be used to develop the state management plans, to measure the economic impact for reducing the current pesticide use, or to provide an economic analysis of alternatives to the current management state.

4.3 Potential Uses of Matrix

The anticipated uses of matrix by MDA include establishing well monitoring programs, developing state management plans by targeting areas of high pesticide use, measuring economic impact of reducing the current pesticide uses, and changes of the state regulation policies, or providing an economic analysis of alternates to current management. In the initial stage of developing state management plans in Michigan, one potential application of the matrix will be to design state monitoring programs.

Monitoring is an important element of developing state management plans to protect groundwater quality. The purpose of the monitoring program would be to collect, manage, and analyze groundwater samples to provide groundwater-quality data for each susceptibility region. Over time, monitoring data can be used for effective decision-making and regulating of agricultural pesticide use. The monitoring strategy could also be applied to evaluate the modeling programs which combine the aquifer sensitivity and groundwater impact potential.

Current MDA Monitoring Programs

At the present, the Michigan Department of Agriculture (MDA) has designed state monitoring program mainly based on the data that obtained form the EPA's National

Pesticide Survey of Drinking Water Wells (Swartz, 1993). The 4.2 percent average frequency nationally of private wells expected to contain pesticides was used. In this strategy, each county was treated the same. First, the total number of wells in each county was estimated. The expected pesticide contaminated wells were computed by multiplying the number of total wells to the expected frequency of pesticide contamination. The binomial distribution equation can be performed to get the confidence intervals of number of wells needed to monitor in order to get the expected contaminated wells. The budget constraint is also needed to be considered to distribute the number of monitoring wells. The cost of each sampling from each well was $380 (Swartz, 1993). And the budget only can provide 400 samples be conducted in Michigan annually (Swartz, 1993). Therefore, detection of possible pesticide contamination wells in each county is impossible. Because of the different susceptibility of each county, this monitoring program was not efficient. It is financially and administratively impractical to monitor all areas equally of the state on a continuing basis at a density that would be meaningful. If there was no any information related pesticide use and aquifer sensitivity available, this was the possible monitoring program we could design. The cost of the monitoring was the total budget, and the benefit of conducting this kind of program was not maximized. In order to develop cost effectiveness state monitoring program, the frequency of sampling and analysis should be depended upon the severity and the extent of contamination. A logical approach to this statement is to focus monitoring activities on areas that are believed to be most prone to groundwater contamination by pesticides. If this approach is followed, the first step in the implementation process is to develop a set of criteria by which to judge the relative susceptibility of any specified area.

Because of the high spatial variability in pesticide use and accompanying variability in groundwater contamination, a monitoring program is most effective if pesticide use data, aquifer conditions, and environmental fate information were considered to determine the sampling program. The aquifer vulnerability assessment model proposed by MDA that combines groundwater impact potential and aquifer sensitivity was very useful to identify susceptible areas. However, the research data that evaluate the relationship between aquifer sensitivity and soil structure affecting pesticides contamination of groundwater obtained from the current models and monitoring system conducted in Michigan did not match the expected results (ie there was little correlation between the prediction of current models and observed pesticide contamination), the MDA is still working to design more effective models to predict aquifer sensitivity and pesticide contamination of groundwater.

Due to the failure of current models, MDA has to depend more heavily upon the pesticide use mass information to develop a cost effectiveness state monitoring program. This pesticide use mass data was the only information available at the present stage. From the pesticide use mass matrix data, we can divide the counties into three different susceptibility areas according to the amount of total pesticides use per total land (the mean and percentile calculation can be used). The 83 counties are divided into low, medium, high susceptible areas. It is appropriate to monitor more wells in high susceptible areas and less wells in low susceptible areas. The objective of distribution of the different numbers of monitoring wells in different vulnerable areas is to uncover potential pollution problems as early as possible by relating contamination levels to the composition, quantity, and quality of a pollutant, and provides a basis for preventive or corrective action.

It is not an easy task to distribute exact numbers of monitoring wells in different susceptible areas. Some states, the numbers of wells monitored in different susceptible areas were just arbitrarily designed based on reasonable distribution. Wisconsin, for example, designated 5% of the funds to low susceptible areas, 25% to medium susceptible areas, and 70% to high susceptible areas. Because of the lack of available expected frequency in different susceptible areas, the different approach should be conducted. The economic benefit and cost analysis would be used. In order to assess the economic viability of a groundwater protection plan, benefits of the program are compared with the costs. If the net benefits (benefits minus costs) are positive, the program should be implemented. The numbers of monitored wells distributed are based on the principle of economic efficiency. When the marginal benefit (MB) of monitoring susceptible wells equals the marginal cost of conducting the program (MC), the efficiency will be achieved.

The benefits of conducting the monitoring program in three different susceptible areas (high, medium, low) are different. The high susceptible areas, where the pesticide use mass is large, the probability to detect the contaminated wells through monitoring program is high, and the preventive or corrective action can be conducted instantly to eliminate the externality due to contamination of groundwater. On the contrast, the low susceptible areas, where the pesticide use is rare or none, the benefits of conducting monitoring program in this area is low. The benefits of conducting monitoring program are to eliminate the costs of possible consequence of inferior quality of groundwater. However, the groundwater is a nonmarket good, it is hard to estimate the value of groundwater quality through the market valuation. There are a variety of techniques which can be used to value nonmarket good quality, for example, travel cost, hedonic price, and contingent valuation. Of these techniques, the most often utilized is contingent valuation (CV). Contingent valuation is a formal procedure for estimating, through opinion surveys, the value of nonmarket goods.

Willingness to pay for increases in groundwater quality, includes personal use values, existence values, bequest values, and the availability of the groundwater for future use or option values. For example, participants may be told the amount of pesticides in their drinking water will be reduced by X amount. The amount they are willing to pay for a monitoring program that would achieve these results is elicited using a variety of methods including open ended questioning, dichotomous choice (yes, no), and checklist. The survey participants should include the farm workers (or producers), the consumers. In order to include the ecological component that is easily ignored by the private sector (producers, consumers) in the surveys, the additional information presented focused of the positive benefits of the natural resource should be provided. The benefits of eliminating inferior groundwater due to pesticide contamination should include the categories of obvious service it provides to human being and the prevention of possible costs of contamination. The service of groundwater to human being includes drinking water value, municipal use value, industrial use value, irrigation use value, etc. The groundwater also may serve as a recharge source for a wetland. Because the wetland provides services, such as recreation, wildlife habitat, fish spawning grounds, and lower-level food chain function, it has other values as well as its value as drinking water. Therefore, the overall values mentioned above should include in the services sector. The possible costs of contamination of groundwater include contamination of surface water by groundwater recharge can affect biodiversity and other measures of ecosystem health, the effects on nontarget organisms (for example, aquatic organisms, birds, bee, beneficial arthropods, mammals, etc), and adverse human health effects (acute toxicity and chronic toxicity), containment and remediation costs, treatment costs and replacement costs. From the contingent valuation, we can transfer each category's estimation into dollar values. The summation equation includes the factors mentioned above could be obtained. The method (Higley and Wintersteen, 1992) to assess of pesticides as a basis for incorporation environmental costs into economic injury level can be adopted to our calculation. Then, we can acquire the marginal benefit that one more well monitored in different susceptible areas. Because one more well monitored in high susceptible areas can have high probabilities to get the benefits as mentioned previously, more funding and intensive monitoring programs should be involved in these areas. Less funding and monitoring programs would be conducted in the less potentially vulnerable areas.

The costs of the monitoring program mainly include sampling procedure fee and subsequent analysis of those samples taken from monitoring wells. Other costs such as administrative costs, program designing costs are also needed to be considered to estimate the costs. However, to consider the limited funding and available manpower, the more well monitored, the more costs are spent. The marginal costs of each additional well will be increased accordingly. In order to meet the increasing costs of additional well monitored, the high benefits should also be obtained from the additional well monitored to achieve the cost effectiveness objective. From economic view, the net benefits are maximized when the marginal benefits equal to marginal costs. The marginal benefits of well monitoring in high susceptible areas are higher due to the high probability to uncover the contamination problem and eliminate the possible consequence of contamination, therefore, it is worth to conduct more monitoring wells (ie spend more budget) in this area. In other words, when we consider the positive externality of monitoring program to detect the contamination of groundwater and to conduct possible preventive action, the actual marginal social costs of monitoring programs conducted in the high susceptible area will be lower than the private sector expenditures (the visible dollar value spent in monitoring program). The costs of each well monitored include the installation and maintenance of monitoring wells and the sampling and analysis of groundwater for pesticides. The capital expenditures that include casing, screens, drilling rig supplies, and any other material goods necessary for well installation. Maintenance costs are usually estimated as a percentage of initial drilling costs, which will vary depending on the total number of wells installed. The total costs of well monitored are computed by summation the factors included in well monitoring programs, the marginal costs of each additional well in different susceptible areas are also obtained.

The numbers of monitored wells in different susceptible areas are decided based on the marginal benefits and marginal costs of each additional well conducted in each area.

This strategy is to insure the efficiency and achieve most cost effectiveness well monitoring programs. The net benefit is maximized when the efficiency is accomplished. However, the budget constraint factor should also be taken into accounts to decide the final numbers of distribution of the monitored wells. Therefore, the actual numbers of monitored wells conducted are limited to the available budget constraint. The actual numbers of wells monitoring in each different susceptible areas are proportionally increased or decreased to the numbers that we obtained from the economic efficiency achievement equation (MB=MC) according to the available funding. After the numbers of monitored wells are decided, it is important to define the location of wells monitored. The first step in implementing monitoring plan would be to list all possible contaminant sources in the area under investigation. Sampling points should not be just based on a statistical prespecified random sampling process and should not be uniformly distributed with regard to the regional flow systems. We should adopt statistical stratified strategy to divided each county to different susceptible locations. The monitoring wells should be chosen and focused on the location highly susceptible to pesticide contamination such as bulk pesticide storage facilities, swine production facilities on sandy soils, pesticide mixing and loading areas, underground fuel tanks, animal feedlots, pesticide container disposal areas, pesticide container cleaning and rinsing areas, etc. In such a way, it is easy to find the contaminated spots and to recognize the possible sources of contamination. However, some consideration should be given to the location believed to be low susceptible to pesticide contamination. This will provide background groundwater quality data and help to verify and calibrate the system used to select the high susceptible locations that are likely to be the first monitoring targets. On the other side, areas with existing problems would be given immediate monitoring attention and to conduct the instant correction action.

After the discovery of actual contamination sites through monitoring programs, the immediate corrective action should be taken. Producers who are contaminants distributors should become more aware of the potential for groundwater contamination and take steps to change their chemical practices. Monitoring data are also critical to the regulatory agency as a planning and rule-making tool. Through awareness, it becomes possible to recognize trends in groundwater quality and take appropriate action to keep pesticide level in groundwater below enforcement standards. Through monitoring efforts, it becomes apparent that certain areas have increasing levels of pesticide, regulation and monitoring need to focus on these problem areas. The effective state management plans will also be developed by the aid of proposed monitoring programs.

The pesticide use mass database matrix provides the useful information to divide the counties in Michigan into different susceptible areas, and hence give the higher possibility to conduct more efficient well monitoring programs. The more information available can be more accurate to specify the different susceptible areas. The pesticide use mass data could be coupled with the aquifer sensitivity to rank for aquifer vulnerability for each county and to develop state management plans. The actual aquifer sensitivity data would be very helpful if combining the pesticide use data to identify the susceptibility of groundwater to pesticide contamination in each county. Hopefully, the developed matrix can be combined with more effective aquifer sensitivity models to precisely predict pesticide contamination of groundwater and to develop economic state management plans in the near future.

Bibliography

Abdalla, C. W., B. A. Roach, and D. J. Epp. 1992. "Valuing Environmental quality Changes Using Averting Expenditures: An Application to Groundwater Contamination." Land Econ. 68(2):163-169.

Adams, Tani and Jeffrey Tryens. 1988. "The Pesticides Crisis: Blueprint for States." The National Center for Policy Alternatives.

Alford, H.G., and Mary P. Ferguson. 1982. "Pesticides in Soil and Groundwater: Proceedings of A Conference Presented at The University of California, Davis, June 15-16, 1982." Berkeley, Calif.: Agricultural Sciences Publications, Division of Agricultural Science, University of California.

Backer, D.B. 1990. "Groundwater Quality Assessment through Cooperative Private Well Testing: An Ohio Example." Journal of Soil and Water Conservation. 45(2): 230-235.

Baker, Brian. 1990. "Groundwater Protection from Pesticides." Garland Publishing, Inc. New York & London.

Batie, S.S., W.E. Cox, and P.L. Diebel. 1989. "Managing Agricultural Contamination of Ground Water: State Strategies." National Governors' Association, Washington, D.C.

Batie, S.S., and P.L. Diebel. 1990. "Key Policy Choice in Groundwater Quality Management." Journal of Soil and Water Conservation 45(2):194-197.

Black, J.R., and E.P. Ditschman. "A Decision Making Framework for The Development of Agricultural Chemicals in Groundwater Management Plans." Proposal Submitted to The Water Resources Research Program, Michigan State University, E. Lansing, MI.

Bouwer, H. 1990. "Agricultural Chemicals and Groundwater Quality." Journal of Soil and Water Conservation 45(2):184-189.

Buchholz, R.A. 1992. "Principles of Environmental Management: The Greening of Business." Prentic-Hall, Inc., Englewood Cliffs, NJ.

Carlson, C.G., R. Dean, and G.Lemme. 1990. "Prescription Planning: An Approach to Nonpoint Pollution Problems." Journal of Soil and Water Conservation 45(2):239-241.

Carlson, G.A., D. Zilberman, and J.A. Miranowski, 1993. "Agricultural and Environmental Resource Economics." Oxford University Press, New York, NY.

Choffnes, Eileen Renee. 1982. "The Evolution of Federal Pesticide Regulatory Policy Involving Public Participation." Unpublished Master's Thesis. Michigan State University.

Committee on Ground Water Quality Protection, Water Science and Technology Board, Commission on Physical Science, Mathematics, and Resources, and National Research Council. 1986. "Ground Water Quality Protection." National Academy Press Washington, D.C.

Committee on Prototype, Explicit Analyses for Pesticides, Environmental Studies Board, Commission on Natural Resources, National Research Council. 1980. "Regulating Pesticides." National Academy of Science, Washington, D.C.

Committee on Long-Range Soil and Water Conservation, Board on Agriculture, National Research Council. 1993. "Soil and Water Quality: An Agenda for Agriculture." National Academy Press, Washington, D.C.

Conservation Foundation. 1985. "Groundwater Protection." The Conservation Foundation, Washington, D.C.

Council for Agricultural Science and Technology. May 1985. "Agriculture and Groundwater Quality." Council for Agricultural Science and Technology, Report No.103.

Crocker, T.D., and B.A. Forster. 1991. "Valuing Potential Groundwater Protection Benefits." Water Resources Res. 27(1):1-6.

Dean, L.F., M.A. Wyckoff, and Planning & Zoing Center, Inc. December 1990. "Community Planning & Zoning for Groundwater Protection in Michigan: A Guide Book for Local Officials." Michigan Department of Natural Resources, Lansing, MI.

Dee, N., and M. Mlay. 1990. "Informational Needs for Local Groundwater Management Decisions." Journal of Soil and Water Conservation 45(2):223-225.

Ditschman, E.P., J.R. Black, and J.P. Hoehn. October 1990. "A Decision Making Framework for The Development of Agricultural Chemical Management Plans." Staff Paper, Department of Agricultural Economics, Michigan State University, East Lansing, MI.

Fairchild, Deborah M. 1987. "Ground Water Quality and Agricultural Practices." Lewis Publishers, INC., Chelsea, MI.

Feitshans, T.A. 1990. "Liability Issues in Groundwater Quality Protection." Journal of Soil and Water Conservation 45(2):211-215.

Fort, D. D. 1991. "Federalism and the Prevention of Groundwater Contamination." Water Resources Res. 27(11):2811-2817.

Freshwater Foundation. 1987. "Pesticide and Groundwater: A Health Concern for the Midwest, Proceeding of A Conference Held October 16-17, 1986, Radission Hotel St. Paul, St. Paul, Minnesota." The Freshwater Foundation, Navarre, MN.

Fuhriman, K., and James R. Barton. 1971. "Ground Water Pollution in Arizona, California, Nevada & Utah." U.S. Environmental Protection Agency Washington D.C.

Garner, W.Y., R.C. Honeycutt, and H.N. Nigg. 1986. "Evaluation of Pesticides in Ground Water." American Chemical Society, Washington, DC.

Highley, L. G., and W.K. Wintersteen. 1992. "A Novel Approach to Environmental Risk Assessment of Pesticides as a Basis for Incorporating Environmental Costs into Economic Injury Levels." American Entomologist. 38(1):34-39.

Hoag, D.L., and A.G. Hornsby. 1992. "Coupling Groundwater Contamination with Economic Returns When Applying Farm Pesticides." Journal of Environmental Quality. 21:569-586.

Holden, Patrick W. 1986. "Pesticides and Groundwater Quality: Issues and Problems in Four States." National Academy Press, Washington, D.C.

Holden, L.R., J.A. Graham, R.W. Whitmore, W.J. Alexander, R.W. Pratt, S.K. Llddle, and L.L. Piper. 1992. "Results of The National Alachlor Well Water Survey." Environ. Sci. Technol. 26(5): 935-943.

Johnson, S. L., R. M. Adams, and G. M. Perry. 1991. "The On-Farm Costs of Reducing Groundwater Pollution." Amer. J. Agr. Econ. 73(4):1063-1073.

Just, R.E., and N. Bockstael. 1991. "Commodity and Resource Policies in Agricultural Systems." Berlin; New York; Springer-Verlag.

Kovach, J., C. Petzoldt, J. Degni, and J. Tette. 1992. "A Method to Measure the Environmental Impact of Pesticides." New York's Food and Life Sciences Bulletin. New York State Agricultural Experiment Station Bull. No. 139.

Kovan, Jessica Trumbull. 1986. "An Analysis of Selected Policy Alternatives to Alleviate Groundwater Contamination in Michigan." Unpublished Master's Thesis. Michigan State University.

Logan, T.J. 1990. "Agricultural Best Management Practices and Groundwater Protection." Journal of Soil and Water Conservation 45(2):201-206.

MacDonnell, L. J., and D. J. Guy. 1991. "Approaches to Groundwater Quality Protection in the Western United States." Water Resources Res. 27(3):259-265.

Michigan Agricultural Statistics Service. "1990 County Food and Agricultural Development Statistics." Michigan Department of Agriculture, Lansing, MI.

Michigan Agricultural Statistics Service. "Michigan Agricultural Statistics 1989." Michigan Department of Agriculture, Lansing, MI.

Michigan Agricultural Statistics Service. " Michigan Agricultural Statistics 1991." Michigan Department of Agriculture, Lansing, MI.

Michigan Department of Agriculture, Pesticide & Plant Pest Management Division. 1988. "Pesticide Control Act of 1976, Act No. 171, Public Acts of 1976, as Amended." Michigan Department of Agriculture, Lansing, MI.

Michigan Turfgrass Foundation. " 1988 Michigan Turfgrass Industry Report." Michigan Turfgrass Foundation, Lansing, MI.

Moody, D. W. 1990. "Groundwater Contamination in the United States." Journal of Soil and Water Conservation. 45(2):170-179.

MSU Cooperative Extension Service. "1992 North Central Weed Control Guide for Vegetable Crops." Michigan State University, E.Lansing, MI.

MSU Cooperative Extension Service. "1992 Fruit Spraying Calendar." Michigan State University, E.Lansing, MI.

MSU Cooperative Extension service. "1992 Weed Control Guide for Field Crops." Michigan State University, E.Lansing, MI.

MSU Cooperative Extension Service. "CAT Alerts: 1986 to 1993 Field Crops." Michigan State University, E.Lansing, MI.

Murphey, D. 1990. "Working toward Rural Groundwater Policies for The 1990s." Journal of Soil and Water Conservation 45(2):278-280.

National Agricultural Statistics Service. " Agricultural Chemical Usage 1990 Field Crop Summary." U.S. Department of Agriculture, Washington, D.C.

National Agricultural Statistics Service. " Agricultural Chemical Usage 1991 Fruits and Nuts Summary." U.S. Department of Agriculture, Washington, D.C.

National Agricultural Statistics Service. "Agricultural Chemical Usage 1990 Vegetables Summary." U.S. Department of Agriculture, Washington, D.C.

National Research Council: Committee on Ground Water Quality Protection, Water Science and Technology Board, Commission on Physical Science, Mathematics, and Resources. 1986. "Ground Water Quality Protection." National Academy Press Washington, D.C.

O'Neil, W. B., and R. S. Raucher. 1990. "The Costs of Groundwater Contamination." Journal of Soil and Water Conservation 45(2):180-183.

Office of Technology Assessment, U.S. Congress. November 1990. "Beneath the Bottom Line: Agricultural Approaches to Reduce Agrichemical Contamination of Groundwater." OTA-F-418, U.S. Government Printing Office, Washington, D.C.

Pimentel, D., L. McLaughlin, A. Zepp, B. Lakitan, T. Kraus, P. Kleinman, F. Vancini, W.J. Roach, E. Graap, W.S. Keeton, and G. Selig. 1991. "Environmental and Economic Effects of Reducing Pesticide Use." BioScience 41(6):402-409.

Research Triangle Institute. Draft, Appendix B, May 1991. "Prevention, Monitoring, and Response, Components of Pesticide State Management Plans: A Support Document to The Pesticides and Ground Water State Management Plan Guidance." Research Triangle Institute, Research Triangle Park, NC.

Roberts, R. S., and D. R. Lighthall. 1991. "The Political Economy of Agriculture, Groundwater Quality Management, and Agricultural Research." Water Resources Bulletin 27:437-446.

Saliba, B.C. 1985. "Irrigated Agriculture and Groundwater Quality- A Framework for Policy Development." Amer. J. Agr. Econ. 67:1231-1237.

Segerson, K. 1990. "Liability for Groundwater Contamination from Pesticides." J. Environ. Econ. Manage. 19:227-243.

Skelding, Patty Teresa. 1984. "Pesticide and Policy: Risk-Benefit Analysis at The Environmental Protection Agency." Unpublished Master's Thesis. Michigan State University.

Students in The Water Resources Management Program at The University of Wisconsin-Madison. 1988. "Managing Pesticides in Groundwater: A Decision-Making Framework." Institute for Environmental Studies, University of Wisconsin-Madison, Madison, WI.

Swartz, Mark., Manager - Groundwater, Michigan Departmant of Agriculture, Pesticide and Plant Management Division. 1993. Personal Communication through scheduled meeting.

U.S. Environmental Protection Agency, Environmental Fate and Effects Division. April 3, 1990. "Pesticides Which Have Been Confirmed in Groundwater." U.S. Environmental Protection Agency, Washington, D.C.

U.S. General Accounting Office. October 1991. "Groundwater Protection: Measurement of Relative Vulnerability to Pesticide Contamination." U.S. General Accounting Office, Washington, D.C.

U.S. General Accounting Office. December 1992. "Groundwater Protection: Validity and Feasibility of EPA's Differential Protection Strategy." U.S. General Accounting Office, Washington, D.C.

U.S. Environmental Protection Agency, Office of Pesticide Program. Review Draft, September 1991. "Pesticides State Management Plan Guidance for Ground-Water Protection." U.S. Environmental Protection Agency, Washington, D.C.

U.S. Environmental Protection Agency, Office of Ground-Water Protection. February 1988. "Protecting Ground Water: Pesticides and Agricultural Practices." U.S. Environmental Protection Agency, Washington, D.C.

U.S. General Accounting Office. October 1991. "Groundwater Protection: The Use of Drinking Water Standards by The States." U.S. General Accounting Office, Washington, D.C.

U.S. Environmental Protection Agency, Office of Prevention, Pesticides, and Toxic Substances. December 1993. "Guidance for Pesticides and Ground Water State Management Plans." U.S. Environmental Protection Agency, Washington, D.C.

Ware, G.W. 1991. "Fundamentals of Pesticides- A Self-Instruction Guide." Thomson Publications, Fresno, Ca.

West Publishing Co. 1993. "Selected Environmental Law Statutes: 1993-94 Educational Edition." West Publishing Co. St. Paul. MN.

Yanggen, D.A., and S.M. Born. 1990. "Protecting Groundwater Quality by Managing Local Land Use." Journal of Soil and Water Conservation 45(2):207-210.

APPENDIX A

SUMMARY OF INFORMATION AVAILABLE ON PESTICIDE USE

DISTRIBUTION & PESTICIDE USE INFORMATION

Table 1. Summary of information available on pesticide use distribution

Site Type	Distribution-County or State Estimate			
	Units	County	State	citation
Corn-grain & silage	Acre	Y	Y	MASS(annual)
Oats	Acre	Y	Y	MASS(annual)
Barley	Acre	Y	Y	MASS(annual)
Wheat	Acre	Y	Y	MASS(annual)
Rye	Acre	Y	Y	CFADS(1990),MASS(annual)
Soybeans	Acre	Y	Y	MASS(annual)
Hay	Acre	Y	Y	CFADS(1990),MASS(annual)
Dry Beans	Acre	Y	Y	MASS(annual)
Potatoes	Acre	Y	Y	MASS(annual)
Sugarbeets	Acre	Y	Y	MASS(annual)
Spearmint	Acre	Y	Y	CFADS(1990),MASS(annual)
Apples	Acre	Y	Y	CFADS(1990),MASS(annual)
Tart Cherries	Acre	Y	Y	CFADS(1990),MASS(annual)
Sweet Cherries	Acre	Y	Y	CFADS(1990),MASS(annual)
Peaches	Acre	Y	Y	CFADS(1990),MASS(annual)
Grapes	Acre	Y	Y	CFADS(1990),MASS(annual)
Pears	Acre	Y	Y	CFADS(1990),MASS(annual)
Prunes & Plums	Acre	Y	Y	CFADS(1990),MASS(annual)
Asparagus	Acre	Y	Y	CFADS(1990),MASS(annual)
Broccoli	Acre	Y	Y	CFADS(1990),MASS(annual)
Cabbage	Acre	Y	Y	CFADS(1990),MASS(annual)
Carrots	Acre	Y	Y	CFADS(1990),MASS(annual)
Cauliflower	Acre	Y	Y	CFADS(1990),MASS(annual)
Celery	Acre	Y	Y	CFADS(1990),MASS(annual)
Cucumber,Fresh	Acre	Y	.	CFADS(1990)
Cucumber,Proc	Acre	Y	Y	CFADS(1990),MASS(annual)
Greens	Acre	Y	.	CFADS(1990)
Lettuce	Acre	Y	Y	CFADS(1990),MASS(annual)
Muskmelon	Acre	Y	.	CFADS(1990)
Mushrooms	Ft^2	.	Y	MASS(annual)
Onions,Dry	Acre	Y	Y	CFADS(1990),MASS(annual)
Onions,Green	Acre	Y	.	CFADS(1990)
Peas	Acre	Y	.	CFADS(1990)
Peppers all	Acre	Y	.	CFADS(1990)
Pumpkins	Acre	Y	.	CFADS(1990)
Radishes	Acre	Y	.	CFADS(1990)
Snap Beans	Acre	Y	Y	CFADS(1990),MASS(annual)
Squash	Acre	Y	.	CFADS(1990)
Strawberries	Acre	Y	Y	CFADS(1990),MASS(annual)
Sweet Corn	Acre	Y	Y	CFADS(1990),MASS(annual)
Tomatoes	Acre	Y	Y	CFADS(1990),MASS(annul)

Table 1. Summary of information available on pesticide use distribution

Site Type	Distribution-County or State Estimate			
	Units	County	State	citation
Beef	Head	Y	Y	CFADS(1990),MASS(annul)
Dairy	Head	Y	Y	CFADS(1990),MASS(annul)
Poultry	Head	Y	Y	CFADS(1990),MASS(annual)
Hogs and Pigs	Head	Y	Y	CFADS(1990),MASS(annual)
Fur Bearing Animals	Head		Y	MASS(annual)
Trout	Head		Y	MASS(annual)
Honey	Colony		Y	MASS(annual)
Mink	Head		Y	MASS(annual)
Covered Greenhouse	Ft^2		Y	MASS(annual)
Shade & Cover	Ft^2		Y	MASS(annual)
Open Ground	Ft^2		Y	MASS(annual)
Airports	Acre		Y	MTIR(1988)
Cemeteries	Acre		Y	MTIR(1988)
Golf Courses	Acre		Y	MTIR(1988)
Health Institution	Acre		Y	MTIR(1988)
Highways	Acre		Y	MTIR(1988)
Landscape/LawnCare	Acre		Y	MTIR(1988)
Parks	Acre		Y	MTIR(1988)
Schools	Acre		Y	MTIR(1988)
Sod Growers	Acre		Y	MTIR(1988)
Restaurants	Acre			
Public Buildings	Acre			
Household	Acre			
Yard and Garden	Acre			
Forestry timber	Acre			
Forestry pulp	Acre			
Christmas Trees	Acre			
Cooling Towers	Acre			
Water Intakes	Acre			
Aquatic Species	Acre			
Marine antifouling	Acre			.

MASS - Michigan Agricultural Statistics Service
CFADS - Michigan County Food and Agricultural Development Statistics
"." - no information available
MTIR - Michigan Turfgrass Industry Report

Table 2. Summary of pesticide use information

Site Type	Pesticide Use-State or National Estimates			
	Use	State	National	Citation
Corn-grain & silage	Y	Y	Y	NASS-Field Crop(1990)
Oats	.	.		.
Barley	.	.		.
Wheat	Y	.	Y	NASS-Field Crop(1990)
Rye	.	.		.
Soybeans	Y	Y	Y	NASS-Field Crop(1990)
Hay	.	.		.
Dry Beans	.	.		.
Potatoes	Y	Y	Y	NASS-Field Crop(1990)
Sugarbeets	.	.		.
Spearmint	.	.		.
Apples	Y	Y	Y	NASS-Fruit & Nut(1991)
Tart Cherries	Y	Y	Y	NASS-Fruit & Nut(1991)
Sweet Cherries	Y	Y	Y	NASS-Fruit & Nut(1991)
Peaches	Y	Y	Y	NASS-Fruit & Nut(1991)
Grapes	Y	Y	Y	NASS-Fruit & Nut(1991)
Pears	Y	.	Y	NASS-Fruit & Nut(1991)
Prunes & Plums	Y	Y	Y	NASS-Fruit & Nut(1991)
Asparagus	Y	Y	.	NASS-Vegetables (1990)
Broccoli	Y	Y	.	NASS-Vegetables (1990)
Cabbage	Y	Y	.	NASS-Vegetables (1990)
Carrots	Y	Y	.	NASS-Vegetables (1990)
Cauliflower	Y	Y	.	NASS-Vegetables (1990)
Celery	Y	Y	.	NASS-Vegetables (1990)
Cucumber,Fresh	Y	Y	.	NASS-Vegetables (1990)
Cucumber,Proc	Y	Y	.	NASS-Vegetables (1990)
Greens	Y	Y	.	NASS-Vegetables (1990)
Lettuce	Y	Y	.	NASS-Vegetables (1990)
Muskmelon	Y	Y	.	NASS-Vegetables (1990)
Mushrooms	.	.	.	.
Onions,Dry	Y	Y	.	NASS-Vegetables (1990)
Onions,Green	Y	Y	.	NASS-Vegetables (1990)
Peas	.	.	.	.
Peppers all	.	.	.	.
Pumpkins	Y	Y	.	NASS-Vegetables (1990)
Radishes	Y	Y	.	NASS-Vegetables (1990)
Snap Beans	Y	Y	.	NASS-Vegetables (1990)
Squash	.	.	.	.
Strawberries	Y	Y	.	NASS-Vegetables (1990)
Sweet Corn	Y	Y	.	NASS-Vegetables (1990)
Tomatoes	Y	Y	.	NASS-Vegetables (1990)

Table 2. Summary of pesticide use information

Site Type	Pesticide Use-State or National Estimates			
	Use	State	National	Citation
Beef	.	.	.	.
Dairy	.	.	.	.
Poultry	.	.	.	.
Hogs and Pigs	.	.	.	.
Fur Bearing Animals	.	.	.	.
Trout	.	.	.	.
Honey	.	.	.	.
Mink	.	.	.	.
Covered Greenhouse	.	.	.	.
Shade & Cover	.	.	.	.
Open Ground	.	.	.	.
Airports	.	.	.	.
Cemeteries	.	.	.	.
Golf Courses	.	.	.	.
Health Institution	.	.	.	.
Highways	.	.	.	.
Landscape/LawnCare	.	.	.	.
Parks	.	.	.	.
Schools	.	.	.	.
Sod Growers	.	.	.	.
Restaurants	.	.	.	.
Public Buildings	.	.	.	.
Household	.	.	.	.
Yard and Garden	.	.	.	.
Forestry timber	.	.	.	.
Forestry pulp	.	.	.	.
Christmas Trees	.	.	.	.
Cooling Towers	.	.	.	.
Water Intakes	.	.	.	.
Aquatic Species	.	.	.	.
Marine antifouling	.	.	.	.

NASS - National Agricultural Statistics Service
"." - no information available

APPENDIX B

TWO TYPES OF PRELIMINARY MATRICES:

THE MAGNITUDE OF EACH SITE TYPE IN EACH COUNTY

AND THE AVAILABLE PESTICIDE USE INFORMATION

ASSOCIATED WITH EACH SITE TYPE

Table 3
The magnitude of each site type in each county

CC	RE	County	Percent Cropland	Acres of Total Cropland	Total Acres of Land	Acres of Corn (Grain)	Acres of Corn (Silage)	Acres of Corn (Sweet)	Acres of All Corn Crops	Acres of Wheat	Acres of Soybeans	Acres of Oats
01	2	Alcona	6.6	28,573	432,924	1,200	950		2,150	850	80	1,100
02	1	Alger	1.9	9,426	496,105	D	D	D	0	70		90
03	5	Allegan	38.6	205,385	532,085	62,000	9,500	150	71,650	9,300	11,300	4,400
04	2	Alpena	15.1	54,767	362,695	4,400	1,900	20	6,320	2,000	510	7,400
05	2	Antrim	11.2	34,493	307,973	2,900	1,300	20	4,220	750		1,000
06	4	Arenac	29.6	69,511	234,834	12,500	3,000	50	15,550	5,300	7,400	3,400
07	1	Baraga	1.5	7,447	496,467	D	D		0			450
08	5	Barry	35.9	128,641	358,331	29,500	4,000	50	33,550	12,300	11,800	3,600
09	4	Bay	56.3	161,157	286,247	36,500	1,000	500	38,000	6,000	29,000	1,300
10	2	Benzie	6.1	12,665	207,623	200	1,000	D	1,200	80		90
11	5	Berrien	40.7	150,082	368,752	39,500	3,000	550	43,050	6,800	26,300	1,700
12	5	Branch	55.1	179,034	324,926	83,000	3,500	100	86,600	10,300	34,400	2,700
13	5	Calhoun	42.6	193,816	454,967	66,000	5,500	200	71,700	21,000	23,700	5,400
14	5	Cass	47.8	151,655	317,270	64,500	1,300	1,100	66,900	8,300	25,800	2,100
15	2	Charlevoix	9.1	24,558	269,868	1,900	1,600	D	3,500	80	D	600
16	2	Cheboygan	5.6	25,803	460,768	600	750		1,350	250		550
17	1	Chippewa	6.4	65,394	1,021,781	D	D		0	450	D	3,300
18	4	Clare	13.2	47,994	363,591	2,000	2,700		4,700	2,250	200	900
19	6	Clinton	59.9	219,621	366,646	50,500	13,000	100	63,600	27,000	48,500	9,700
20	2	Crawford	0.2	715	357,652			D	0			
21	1	Delta	6.3	37,828	600,444	1,300	1,250	D	2,550	280	70	1,700
22	1	Dickinson	3.0	14,927	497,567	550	900		1,450			850
23	6	Eaton	50.7	188,024	370,856	54,500	3,000	120	57,620	25,600	32,400	4,500
24	2	Emmet	8.6	25,649	298,244	2,000	600	D	2,600	80	80	1,200
25	4	Genesee	30.8	126,584	410,987	35,000	4,000	550	39,550	12,800	21,400	5,300
26	4	Gladwin	15.3	49,499	323,523	5,300	2,000	70	7,370	3,400	1,700	2,400
27	1	Gogebic	0.6	3,454	575,667		D		0			90
28	2	Grand Traverse	16.8	50,180	298,690	5,100	1,700	50	6,850	1,750	120	1,100
29	6	Gratiot	68.4	249,668	365,012	64,500	11,000	50	75,550	19,600	68,500	5,000
30	6	Hillsdale	50.8	196,210	386,240	71,000	6,000	50	77,050	15,000	33,400	3,200
31	1	Houghton	2.5	16,168	646,720	D	D	10	10			1,000
32	4	Huron	72.2	383,583	531,278	111,000	32,000		143,000	41,000	13,700	26,500
33	6	Ingham	48.1	172,277	358,164	53,000	6,500	120	59,620	18,700	24,800	3,800
34	3	Ionia	56.2	207,677	369,532	59,500	8,000	170	67,670	27,300	26,500	10,500
35	4	Iosco	7.7	26,892	349,247	4,400	2,900	D	7,300	1,850	290	1,900
36	1	Iron	2.2	16,376	744,371	D	D		0	90		1,050
37	4	Isabella	43.1	158,954	368,803	27,500	14,000	60	41,560	14,600	14,000	7,000
38	6	Jackson	35.7	160,981	450,927	48,500	10,000	200	58,700	12,800	6,900	5,700
39	5	Kalamazoo	36.8	132,533	360,144	47,000	1,700	200	48,900	12,300	21,300	3,300
40	2	Kalkaska	3.0	10,741	358,033	1,150	600		1,750	750	D	120
41	3	Kent	29.6	163,275	551,605	36,500	7,000	700	44,200	8,100	3,850	6,200
42	1	Keweenaw	0.0	0	347,827				0			
43	3	Lake	3.0	11,004	366,800	250	200	50	500	150	D	300
44	4	Lapeer	41.6	175,050	420,793	51,000	5,500	500	57,000	13,300	8,900	9,500
45	2	Leelanau	17.9	39,218	219,095	2,500	1,000	D	3,500	270	D	470
46	6	Lenawee	64.4	310,342	481,898	100,000	6,000	100	106,100	34,900	95,000	4,800
47	6	Livingston	27.2	99,835	367,040	27,000	3,500	50	30,550	8,300	5,300	2,300
48	1	Luce	1.4	5,787	413,357	D	D	D	0	50		270
49	1	Mackinac	2.2	14,635	665,227	D	D	D	0	140		650
50	7	Macomb	22.1	68,255	308,846	14,000	1,500	1,300	16,800	4,900	14,700	2,600
51	2	Manistee	8.4	29,246	348,167	1,450	400	50	1,900	450	D	220
52	1	Marquette	0.9	10,527	1,169,667	D	D	D	0			350
53	3	Mason	17.9	56,687	316,687	6,500	3,400	130	10,030	3,500	420	2,500
54	3	Mecosta	25.0	89,564	358,256	10,500	2,300	50	12,850	2,900	150	3,300
55	1	Menominee	9.5	63,542	668,863	5,800	7,000		12,800	70	D	2,100
56	4	Midland	22.3	74,957	336,130	19,000	1,000		20,000	3,700	19,000	1,400
57	2	Missaukee	17.1	61,912	362,058	4,600	7,000		11,600	640	50	2,400
58	7	Monroe	57.2	203,774	356,248	53,000	1,500	600	55,100	20,000	82,700	4,600

Table 3
The magnitude of each site type in each county

CC	RE	County	Percent Cropland	Acres of Total Cropland	Total Acres of Land	Acres of Corn (Grain)	Acres of Corn (Silage)	Acres of Corn (Sweet)	Acres of All Corn Crops	Acres of Wheat	Acres of Soybeans	Acres of Oats
59	3	Montcalm	40.9	186,322	455,555	37,000	7,500	20	44,520	20,500	10,300	6,500
60	2	Montmorency	4.3	15,004	348,930	800	1,500		2,300	650	240	1,900
61	3	Muskegon	17.5	56,910	325,200	15,500	1,600	80	17,180	2,350	2,440	1,800
62	3	Newaygo	15.6	84,764	543,359	15,000	6,700	70	21,770	2,200	170	2,100
63	7	Oakland	8.5	47,708	561,271	10,500	300	400	11,200	2,650	600	1,150
64	3	Oceana	24.8	85,922	346,460	7,250	2,100	70	9,420	2,100	50	800
65	4	Ogemaw	14.7	53,732	365,524	6,200	3,500	D	9,700	1,900	170	3,100
66	1	Ontonagon	2.0	16,776	838,800	D	D		0	90		1,050
67	3	Osceola	20.6	75,019	364,170	3,200	5,500		8,700	1,050	150	1,500
68	2	Oscoda	2.9	10,679	368,241	350	550		900		D	110
69	2	Otsego	5.5	18,017	327,582	630	830		1,460	550	D	900
70	3	Ottawa	40.3	146,152	362,660	31,500	9,000	500	41,000	4,900	1,450	3,500
71	2	Presque Isle	12.3	51,610	419,593	900	2,100		3,000	1,450		5,000
72	4	Roscommon	1.0	2,362	236,200	D	D		0			40
73	4	Saginaw	53.1	277,062	521,774	66,500	2,000	250	68,750	26,500	114,400	5,800
76	4	Sanilac	63.3	390,529	616,949	83,000	28,000	100	111,100	49,000	46,700	36,000
77	1	Schoolcraft	1.7	9,323	548,412	D	D	D	0	60		550
78	6	Shiawassee	58.7	203,050	345,911	40,500	5,000	70	45,570	27,600	64,000	14,500
74	7	St. Clair	31.7	148,961	469,909	25,000	2,500	200	27,700	15,900	23,500	8,400
75	5	St. Joseph	55.9	179,703	321,472	91,000	1,500	120	92,620	7,400	33,400	1,400
79	4	Tuscola	56.6	294,089	519,592	76,500	4,000	100	80,600	28,200	38,800	12,000
80	5	Van Buren	37.8	147,853	391,146	28,000	1,500	800	30,300	3,300	9,700	1,800
81	6	Washtenaw	37.6	170,968	454,702	45,000	4,000	1,000	50,000	17,100	16,500	9,000
82	7	Wayne	4.8	19,024	396,333	2,500	200	1,300	4,000	1,150	2,900	350
83	2	Wexford	5.1	18,547	363,667	1,700	800		2,500	1,050	170	800
		Total Michigan	23.0	8,186,638	35,557,933	1,969,130	298,130	13,100	2,280,360	640,000	1,079,860	300,000

D-too few to report

Table 3
The magnitude of each site type in each county

CC	RE	County	Acres of Dry Beans	Acres of Barley	Acres of Potatoes	Acres of Sugar Beets	Acres of Apples (Dwarf)	Acres of Apples (Stand)	Acres of Cherries (Tart)	Acres of Cherries (Sweet)	Acres of Peaches	Acres of Blueberries	Acres of Grapes
01	2	Alcona	D	200									
02	1	Alger		350	D								
03	5	Allegan	D	200	650		1,110	960	620	30	790	1,770	90
04	2	Alpena	2,900	430	510								
05	2	Antrim	D	50	1,200		D	D	2,730	1,010	70	D	D
06	4	Arenac	9,500	90	1,400	4,800		D					
07	1	Baraga		350									
08	5	Barry	400	400	D		D	D	D	D	D	D	D
09	4	Bay	24,000	90	5,100	21,300	D						
10	2	Benzie					640	590	1,840	620	50	D	D
11	5	Berrien	D	40	D		4,740	3,550	3,960	210	3,640	960	5,770
12	5	Branch	D	130	D		D	D	D				
13	5	Calhoun	D	90	D		D	D	D	D	D	D	
14	5	Cass	D	350	D		790	580	540	D	D	D	540
15	2	Charleviox	240	200	D		D	D	D	D	D		
16	2	Cheboygan	230	500	D								
17	1	Chippewa		450									
18	4	Clare	150	250				D					
19	6	Clinton	3,800	600	D		250	110	D	D	D		D
20	2	Crawford											
21	1	Delta	1,650	2,200	1,100		D	D	D				
22	1	Dickinson		180	1,200								
23	6	Eaton	9,400	220	650		D	D	D	D	D	D	
24	2	Emmet	D	90	630								
25	4	Genesee	450	280	270		16	16	4			4	3
26	4	Gladwin	1,000	250		800							
27	1	Gogebic											
28	2	Grand Traverse	D	D			980	280	6,200	2,540	80	D	D
29	6	Gratiot	24,000	110	350	15,600	D	D				D	
30	6	Hillsdale	D	90			160	65	D				
31	1	Houghton		350	D		D					D	
32	4	Huron	82,000	10,000	490	30,700	D				D		D
33	6	Ingham	800	350	D		D	D	D	D	D	D	D
34	3	Ionia	4,900	600	D		1,230	990	D	D	110		D
35	4	Iosco	D	200				D				D	
36	1	Iron		90	590								
37	4	Isabella	7,700	1,150	D	800	D	D	D	D	D		
38	6	Jackson	270	300	D		110	140	D	D	D	D	
39	5	Kalamazoo	D	220			420	230	140	D	D	D	550
40	2	Kalkaska	D	D	430								
41	3	Kent	1,850	700	430		7,800	5,080	990	100	600	D	D
42	1	Keweenaw											
43	3	Lake	D	D	D								
44	4	Lapeer	5,600	850	600	D	380	160	D	D	D	130	D
45	2	Leelanau	D	D			1,750	250	8,740	4,360	140		80
46	6	Lenawee	300	160	950	2,600	D	D	D	D	D		D
47	6	Livingston	180	40			D	D	D	D	D	D	
48	1	Luce	D	350	450								
49	1	Mackinac		140									
50	7	Macomb	300	80	450		500	430	D	D	D		D
51	2	Manistee	950	100	290		850	970	1,930	320	160		
52	1	Marquette		250	270								
53	3	Mason	D	220	D		950	670	2,290	580	320	D	
54	3	Mecosta	1,150	350	870		D	D	D	D	D	D	D
55	1	Menominee	D	2,400	D								
56	4	Midland	13,000	40	350	3,000	D				D		
57	2	Missaukee	D	120	330								
58	7	Monroe	350	130	1,500	2,050	D	D			D		

Table 3
The magnitude of each site type in each county

CC	RE	County	Acres of Dry Beans	Acres of Barley	Acres of Potatoes	Acres of Sugar Beets	Acres of Apples (Dwarf)	Acres of Apples (Stand)	Acres of Cherries (Tart)	Acres of Cherries (Sweet)	Acres of Peaches	Acres of Blueberries	Acres of Grapes
59	3	Montcalm	18,000	900	9.550	D	D	D	D	D	D	D	
60	2	Montmorency	950	200									
61	3	Muskegon	D	120	D		1.470	690	770	D	170	930	
62	3	Newaygo	D	200	D		1.170	730	520	D	270	D	
63	7	Oakland	D	D			D	D	D	D	D	D	D
64	3	Oceana	D	50	D		1.970	1.540	8,520	610	790	D	D
65	4	Ogemaw	D	500	D	D		D					
66	1	Ontonagon		40									
67	3	Osceola		350	D								
68	2	Oscoda		40									
69	2	Otsego	350	80	790								
70	3	Ottawa	D	220	D		2.560	1.570	270	60	170	4,540	D
71	2	Presque Isle	4.500	550	2.950								
72	4	Roscommon					D	D	D		D		D
73	4	Saginaw	17,000	90	380	18.200	50	120				110	D
76	4	Sanilac	18,500	4.700	480	13,600	120	170	D	D	D	D	D
77	1	Schoolcraft	D	450	D								
78	6	Shiawassee	2,200	680	150 ·	D	D	D	D	D	D		
74	7	St. Clair	1,650	550	D	1.200	70	160	D	D		D	D
75	5	St. Joseph	D	40	D		D	D	D	D	D	D	
79	4	Tuscola	37,000	1,530	2.150	34.600	D	D	D	D	D	D	D
80	5	Van Buren		370	D		4.040	2.380	3,340	110	900	5,110	4,390
81	6	Washtenaw	D	900	340		230	100	D ·		D	D	
82	7	Wayne					D	D	D	D	D	D	
83	2	Wexford	D	D				D	D	D			
		Total Michigan	297.220	39.940	37,850	149.250	34,356	22,531	43,404	10,550	8,260	13,554	11,423

D-too few to report

Table 3
The magnitude of each site type in each county

CC	RE	County	Acres of Prunes & Plums	Acres of Pears	Acres of Apricots	Acres of Nectarines	Acres of Special Grains	Acres of Forages	Acres of Field Seed	Acres of Nursery Open	1000 sq. ft. Nursery Protection	Acres of Asparagus
01	2	Alcona					58	11,086				
02	1	Alger						5,390				
03	5	Allegan	130	290	D	D	D	39,554	244	587	3,066,304	400
04	2	Alpena					D	18,720	D	D	D	
05	2	Antrim	D	40	D	D	261	9,803		21	36,180	
06	4	Arenac		D				10,804		D	D	
07	1	Baraga						3,938				
08	5	Barry	D	D	D		106	29,299	136	D	D	
09	4	Bay		D			259	5,220		120	336,637	
10	2	Benzie	140	40	D	D	73	1,974				
11	5	Berrien	400	270	D	D	601	8,306	67	997	417,166	900
12	5	Branch	D	D			D	11,353	136	684	50,872	
13	5	Calhoun	D	D			696	23,846	161	D	D	
14	5	Cass	D	D	D	D	219	14,151	D	26	99,662	600
15	2	Charlevoix	D	D	D		43	9,958		D	D	
16	2	Cheboygan					D	12,356		8	98,400	
17	1	Chippewa						32,250	D			
18	4	Clare					84	19,817		D	D	
19	6	Clinton	D	D			337	34,150	D	D	38,346	
20	2	Crawford										
21	1	Delta	D	D			34	16,346		D	D	
22	1	Dickinson						7,308		D	D	
23	6	Eaton		D	D	D	D	22,030	397	D	D	
24	2	Emmet					20	10,732		22	30,804	
25	4	Genesee	7	5			D	13,305	D	533	111,030	
26	4	Gladwin					71	15,098				
27	1	Gogebic						2,185				
28	2	Grand Traverse	360	100	D	D	D	11,542		24	46,276	150
29	6	Gratiot		D			1,034	17,590		D	D	
30	6	Hillsdale	D	D			513	24,072	D	27	227,020	
31	1	Houghton	D	D				8,288		D	D	
32	4	Huron					89	40,595	D	D	D	
33	6	Ingham	D	D	D	D	D	26,258	134	1,078	260,672	
34	3	Ionia	D	D	D	D	D	35,178	199	D	D	
35	4	Iosco						11,379		D	D	
36	1	Iron						5,925				
37	4	Isabella	D	D			233	40,998	D	D	D	100
38	6	Jackson	D	D			D	32,310	215	98	180,384	
39	5	Kalamazoo	D	D	D		198	11,642		217	5,247,981	100
40	2	Kalkaska					111	3,041		D	D	
41	3	Kent	260	60	D	D	D	39,950	193	353	2,346,598	
42	1	Keweenaw										
43	3	Lake						5,148	39			
44	4	Lapeer	D	D			D	41,934	111	669	491,884	
45	2	Leelanau	600	40	D	D	261	6,349		D	D	100
46	6	Lenawee	D	D		D	D	20,294	54	40	40,890	
47	6	Livingston	D	D	D		121	24,075	323	351	141,611	
48	1	Luce						2,305		D	D	
49	1	Mackinac						7,931				
50	7	Macomb	D	D	D	D	78	7,669		1,678	2,058,869	
51	2	Manistee	40	D	D	D	187	6,117		183	24,500	950
52	1	Marquette						4,679		D	D	
53	3	Mason	230	100	D	D	175	14,814	D	267	42,550	2,200
54	3	Mecosta	D	D			D	35,219		D	D	450
55	1	Menominee					67	35,316				
56	4	Midland		D				5,041		D	D	
57	2	Missaukee					26	36,102		D	D	
58	7	Monroe	D	D		D	148	4,727		586	1,497,987	

Table 3
The magnitude of each
site type in each county

CC	RE	County	Acres of Prunes & Plums	Acres of Pears	Acres of Apricots	Acres of Nectarines	Acres of Special Grains	Acres of Forages	Acres of Field Seed	Acres of Nursery Open	1000 sq. ft. Nursery Protection	Acres of Asparagus
59	3	Montcalm	D		D		D	30,551	692	D	D	
60	2	Montmorency						5,313				
61	3	Muskegon	D	D	D	D	D	14,400	46	76	894,425	700
62	3	Newaygo	70	D	D	D	142	29.716	56	94	9,700	300
63	7	Oakland	D	D			23	11.915		465	1,272,310	
64	3	Oceana	610	270	D	D	564	15,118	D	D	D	13,300
65	4	Ogemaw					78	24,921				
66	1	Ontonagon						9,534	2.671			
67	3	Osceola					58	40,655	40	D	D	
68	2	Oscoda						5,097				
69	2	Otsego					54	9.380				
70	3	Ottawa	70	40	D	D	399	33,541	39	5,007	8,520,338	600
71	2	Presque Isle					548	16,359				
72	4	Roscommon	D	D				1.289				
73	4	Saginaw		D			169	11,247		156	310,076	
76	4	Sanilac	D	D	D		D	77,622	253	817	36,400	
77	1	Schoolcraft						4,584				
78	6	Shiawassee		D			104	24,254	190	302	D	
74	7	St. Clair	D	D			17	26,696	87	D	399,812	
75	5	St. Joseph	D	D			D	12,888	46	741	16,060	400
79	4	Tuscola	D	D	D		148	22,714	D	D	D	
80	5	Van Buren	610	200	D	D	D	13,784	149	457	798,252	3,100
81	6	Washtenaw	D	D	D		D	30.126	230	396	691,241	
82	7	Wayne	D	D				1,119		600	2,500,471	
83	2	Wexford	D	D			22	7.962		D	D	
		Total Michigan	3,527	1.455	0	0	8.429	1.436.252	6.908	17,680	32,341.708	24,350

D-too few to report

Table 3
The magnitude of each site type in each county

CC	RE	County	Acres of Beans (Green)	Acres of Broccoli	Acres of Cabbage	Acres of Carrots	Acres of Cauliflower	Acres of Celery	Acres of Cucumbers	Acres of Greens	Acres of Lettuce (Head)	Acres of Lettuce (Leaf)	Acres of Muskmelo
01	2	Alcona											
02	1	Alger											
03	5	Allegan	420			350	520	430	500				
04	2	Alpena	D										
05	2	Antrim			D		D						
06	4	Arenac		60		D	D						10
07	1	Baraga			D				D				
08	5	Barry	630		D	D							
09	4	Bay			320		190		300				320
10	2	Benzie											
11	5	Berrien							1,400				200
12	5	Branch	D		D								10
13	5	Calhoun	D		10	100		D	D				
14	5	Cass	6,850			D		D					10
15	2	Charleviox	D			D							
16	2	Cheboygan											
17	1	Chippewa											
18	4	Clare											
19	6	Clinton	D			D							D
20	2	Crawford											
21	1	Delta											
22	1	Dickinson			D								
23	6	Eaton	160			160							10
24	2	Emmet											
25	4	Genesee	80		30				30				70
26	4	Gladwin		D				D					
27	1	Gogebic											
28	2	Grand Traverse	2,600						D				
29	6	Gratiot			70		230		D				
30	6	Hillsdale		D	D								D
31	1	Houghton	D						D				
32	4	Huron											
33	6	Ingham			210	400					800		
34	3	Ionia	2,000		D	D		D					10
35	4	Iosco											D
36	1	Iron											
37	4	Isabella	D	D	D		D	D		D			
38	6	Jackson		10	60				10				20
39	5	Kalamazoo			30	D		D					10
40	2	Kalkaska	D										
41	3	Kent	120	90	200			340					
42	1	Keweenaw											
43	3	Lake											
44	4	Lapeer				1,350	20			30	390		10
45	2	Leelanau											
46	6	Lenawee			60	200							50
47	6	Livingston				D	D			D		D	70
48	1	Luce		D	D	D	D				D		
49	1	Mackinac	D	D	D				D				
50	7	Macomb	650		480		150			330		120	
51	2	Manistee		D	D		20						
52	1	Marquette											
53	3	Mason	3,200	D	D				D				
54	3	Mecosta											D
55	1	Menominee			D								
56	4	Midland											D
57	2	Missaukee											
58	7	Monroe	90		260				230				120

Table 3
The magnitude of each site type in each county

CC	RE	County	Acres of Beans (Green)	Acres of Broccoli	Acres of Cabbage	Acres of Carrots	Acres of Cauliflower	Acres of Celery	Acres of Cucumbers	Acres of Greens	Acres of Lettuce (Head)	Acres of Lettuce (Leaf)	Acres of Muskmelo
59	3	Montcalm	400			150	D						
60	2	Montmorency											
61	3	Muskegon	850			450		430	D				
62	3	Newaygo				1,900		220					
63	7	Oakland	D		10				20				10
64	3	Oceana	1,150			250	130		500				
65	4	Ogemaw	D						D				
66	1	Ontonagon											
67	3	Osceola											
68	2	Oscoda											
69	2	Otsego											
70	3	Ottawa			180			750					
71	2	Presque Isle											
72	4	Roscommon											
73	4	Saginaw		70	30				50				20
76	4	Sanilac	D			D			D				
77	1	Schoolcraft											
78	6	Shiawassee	10		10	D							
74	7	St. Clair	210	10	90		50		30				
75	5	St. Joseph	20		D								D
79	4	Tuscola		D	D		D		D				
80	5	Van Buren	1,970			850		320	450				180
81	6	Washtenaw		110									30
82	7	Wayne	60		40		10						50
83	2	Wexford	1,900				D						
		Total Michigan	23,370	350	2,090	6,160	1,320	2,490	3,520	360	1,190	120	1,210

D-too few to report

Table 3
The magnitude of each site type in each county

CC	RE	County	Acres of Onions (Dry)	Acres of Onions (Green)	Acres of Peas	Acres of Peppers (Bell)	Acres of Peppers (Other)	Acres of Pickles	Acres of Pumpkins	Acres of Radishes	Acres of Rutabagas	Acres of Squash (Summer)	Acres of Squash (Winter)
01	2	Alcona											
02	1	Alger											
03	5	Allegan	1,000			60		2,000					
04	2	Alpena							D				D
05	2	Antrim				D			D				D
06	4	Arenac						1,900		D			D
07	1	Baraga											
08	5	Barry	D						10	D			
09	4	Bay	140			200	290	1,100					
10	2	Benzie											
11	5	Berrien				560		600				210	420
12	5	Branch				D			20	D			10
13	5	Calhoun	370						D				D
14	5	Cass	D					500					
15	2	Charlevoix							D				
16	2	Cheboygan											D
17	1	Chippewa											
18	4	Clare											
19	6	Clinton	D					D	30				10
20	2	Crawford							D				
21	1	Delta											
22	1	Dickinson											
23	6	Eaton	330					D	20	800			
24	2	Emmet											
25	4	Genesee				20			70				20
26	4	Gladwin											
27	1	Gogebic											
28	2	Grand Traverse				D							
29	6	Gratiot	30			460	400	3,600	30				90
30	6	Hillsdale							D			D	D
31	1	Houghton							D		D		D
32	4	Huron											
33	6	Ingham	730			100		500	30				
34	3	Ionia	310							D			
35	4	Iosco						D					D
36	1	Iron											
37	4	Isabella								D			D
38	6	Jackson	270						20	D			
39	5	Kalamazoo							40				40
40	2	Kalkaska											
41	3	Kent	400			160		1,100	110				250
42	1	Keweenaw											
43	3	Lake											
44	4	Lapeer	600						20	100			
45	2	Leelanau							D				D
46	6	Lenawee				30	D	D					60
47	6	Livingston							10	D			
48	1	Luce								D			
49	1	Mackinac			D				D			D	
50	7	Macomb							180			120	240
51	2	Manistee						600	D				D
52	1	Marquette											
53	3	Mason				D		100	D				
54	3	Mecosta				D			D				
55	1	Menominee											
56	4	Midland				D							
57	2	Missaukee											
58	7	Monroe				160		190					90

Table 3
The magnitude of each
site type in each county

CC	RE	County	Acres of Onions (Dry)	Acres of Onions (Green)	Acres of Peas	Acres of Peppers (Bell)	Acres of Peppers (Other)	Acres of Pickles	Acres of Pumpkins	Acres of Radishes	Acres of Rutabagas	Acres of Squash (Summer)	Acres of Squash (Winter)
59	3	Montcalm	310		1,200	D		500					D
60	2	Montmorency											
61	3	Muskegon	500			D		D					
62	3	Newaygo	1,700			20		D				60	80
63	7	Oakland				20			100				30
64	3	Oceana				70		1,200				350	320
65	4	Ogemaw				D		D	D			D	D
66	1	Ontonagon											
67	3	Osceola											
68	2	Oscoda											
69	2	Otsego											
70	3	Ottawa	650			120		400	90	100			220
71	2	Presque Isle											
72	4	Roscommon											
73	4	Saginaw				120		2,000	20				20
76	4	Sanilac	D					200	D				D
77	1	Schoolcraft											
78	6	Shiawassee	D					D	10			D	
74	7	St. Clair				10						10	40
75	5	St. Joseph							10	D			10
79	4	Tuscola	140			20		800					
80	5	Van Buren										100	
81	6	Washtenaw	60	D		20			190				20
82	7	Wayne				30			130				30
83	2	Wexford											
		Total Michigan	7,540	0	1,200	2,180	690	17,290	1,140	1,000	0	850	2,000

D-too few to report

Table 3
The magnitude of each site type in each county

CC	RE	County	Acres of Strawberries	Acres of Tomatoes	Acres of Turnips	Acres of Watermelon
01	2	Alcona				
02	1	Alger	10			
03	5	Allegan				
04	2	Alpena	70	D		
05	2	Antrim	D			
06	4	Arenac	10	20		
07	1	Baraga				
08	5	Barry	10	10		
09	4	Bay		220		
10	2	Benzie	D			
11	5	Berrien	460	2,800		
12	5	Branch	20	270		
13	5	Calhoun		D		
14	5	Cass	30	360		
15	2	Charleviox	D			
16	2	Cheboygan	20			
17	1	Chippewa	D			
18	4	Clare				
19	6	Clinton	10	10		
20	2	Crawford				
21	1	Delta	D			
22	1	Dickinson	D			
23	6	Eaton	20	30		
24	2	Emmet	10			
25	4	Genesee	120	60		
26	4	Gladwin	D	D		
27	1	Gogebic				
28	2	Grand Traverse	D	10		
29	6	Gratiot				
30	6	Hillsdale	20	120		
31	1	Houghton	40			
32	4	Huron	D			
33	6	Ingham	50	40		
34	3	Ionia	30	10		
35	4	Iosco	10	10		D
36	1	Iron	D			
37	4	Isabella	10			
38	6	Jackson	20	80		
39	5	Kalamazoo	40	10		
40	2	Kalkaska				
41	3	Kent				
42	1	Keweenaw				
43	3	Lake				
44	4	Lapeer	40			
45	2	Leelanau	210			
46	6	Lenawee	20	2,250		
47	6	Livingston	20	D		
48	1	Luce				
49	1	Mackinac	D	D		
50	7	Macomb		140		
51	2	Manistee	160	10		
52	1	Marquette	D			
53	3	Mason	D			
54	3	Mecosta	10	D		
55	1	Menominee	D			
56	4	Midland	D			
57	2	Missaukee	D			
58	7	Monroe	70	1,900		

Table 3
The magnitude of each
site type in each county

CC	RE	County	Acres of Strawberries	Acres of Tomatoes	Acres of Turnips	Acres of Watermelon
59	3	Montcalm		D		
60	2	Montmorency	D			
61	3	Muskegon	20			
62	3	Newaygo			D	
63	7	Oakland	90	10		
64	3	Oceana				
65	4	Ogemaw	D	D		
66	1	Ontonagon				
67	3	Osceola	D			
68	2	Oscoda				
69	2	Otsego				
70	3	Ottawa				
71	2	Presque Isle				
72	4	Roscommon				
73	4	Saginaw		30		
76	4	Sanilac	20	10		
77	1	Schoolcraft	D			
78	6	Shiawassee	20	10		
74	7	St. Clair		20		
75	5	St. Joseph	50	D		
79	4	Tuscola	20	10		
80	5	Van Buren	220	140		
81	6	Washtenaw	120	40		
82	7	Wayne	70	60		
83	2	Wexford				
		Total Michigan	2,170	8,690	0	0

D-too few to report

Table 4
The available pesticide use information associated with each site type

State of Michigan	Corn (Grain)	Corn (Sweet)	Wheat	Soybeans	Oats	Dry Beans	Barley	Rye	Potatoes	Sugar Beets
Area Planted('000 acre)	2,400	14	770	1,150	250	350	45	135	34	160
Nitrogen Area Applied(%)	97	93	99	67	97		96		96	
Nitrogen Rate/Application(lb/ac)	65	64	45	19					70	
Nitrogen Rate/crop year(lb/ac)	125	103	80	20	31		29		156	
Nitrogen/acre(lb/ac)	121	96	79	13	30		28		150	
Nitrogen Total('000,000 lb)	291.0	1.3	62.0	15.0	7.5		1.3		5.0	
Average Yield(bu/ac)										
Average Nitrogen Required(lb/ac)										
Alachlor Area Applied(%)	24.6	25.0	*	13.3	*		*		*	
Alachlor Rate/crop year(lb/ac)	2.0	1.9	*	1.9	*		*		*	
Alachlor/acre(lb/ac)	0.4846	0.4625	0.0000	0.2540	0.0000		0.0000		0.0000	
Aldicarb Area Applied(%)	*	*	*	*	*		*		1.6	
Aldicarb Rate/crop year(lb/ac)	*	*	*	*	*		*		2.4	
Aldicarb/acre(lb/ac)	0.0000	0.0000	0.0000	0.0000	0.0000		0.0000		0.0390	
Atrazine Area Applied(%)	64.3	51.0	*	*	*		*		*	
Atrazine Rate/crop year(lb/ac)	1.2	1.3	*	*	*		*		*	
Atrazine/acre(lb/ac)	0.7845	0.6375	0.0000	0.0000	0.0000		0.0000		0.0000	
Bentazon Area Applied(%)	1.2	2.0	*	15.8	*		*		*	
Bentazon Rate/crop year(lb/ac)	0.6	0.5	*	0.7	*		*		*	
Bentazon/acre(lb/ac)	0.0071	0.0106	0.0000	0.1059	0.0000		0.0000		0.0000	
DBCP Area Applied(%)	*	*	*	*	*		*		*	
DBCP Rate/crop year(lb/ac)	*	*	*	*	*		*		*	
DBCP/acre(lb/ac)	0.0000	0.0000	0.0000	0.0000	0.0000		0.0000		0.0000	
Dacthal Area Applied(%)	*	*	*	*	*		*		*	
Dacthal Rate/crop year(lb/ac)	*	*	*	*	*		*		*	
Dacthal/acre(lb/ac)	0.0000	0.0000	0.0000	0.0000	0.0000		0.0000		0.0000	
Dicamba Area Applied(%)	17.9	*	3.7	*	0.0		*		*	
Dicamba Rate/crop year(lb/ac)	0.3	*	0.1	*	1.1		*		*	
Dicamba/acre(lb/ac)	0.0609	0.0000	0.0044	0.0000	0.0001		0.0000		0.0000	
EBDC Area Applied(%)	*	*	*	*	*		*		*	
EBDC Rate/crop year(lb/ac)	*	*	*	*	*		*		*	
EBDC/acre(lb/ac)	0.0000	0.0000	0.0000	0.0000	0.0000		0.0000		0.0000	
Ethylene Dibromide Area Appl.(%)	*	*	*	*	*		*		*	
Ethylene D. Rate/crop year(lb/ac)	*	*	*	*	*		*		*	
Ethylene D./acre(lb/ac)	0.0000	0.0000	0.0000	0.0000	0.0000		0.0000		0.0000	
Lindane Area Applied(%)	*	*	*	*	*		*		*	
Lindane Rate/crop year(lb/ac)	*	*	*	*	*		*		*	
Lindane/acre(lb/ac)	0.0000	0.0000	0.0000	0.0000	0.0000		0.0000		0.0000	
Methomyl Area Applied(%)	*	12.0	2.5	*	*		*		*	
Methomyl Ratae/crop year(lb/ac)	*	0.8	0.4	*	*		*		*	
Methomyl/acre(lb/ac)	0.0000	0.0984	0.0100	0.0000	0.0000		0.0000		0.0000	
Metolachlor Area Applied(%)	25.9	21.0	*	9.7	*		*		7.9	
Metolachlor Rate/crop year(lb/ac)	1.9	1.8	*	1.8	*		*		1.8	
Metolachlor/acre(lb/ac)	0.4843	0.3801	0.0000	0.1707	0.0000		0.0000		0.1446	
Prometon Area Applied(%)	*	*	*	*	*		*		*	
Prometon Rate/crop year(lb/ac)	*	*	*	*	*		*		*	
Prometon/acre(lb/ac)	0.0000	0.0000	0.0000	0.0000	0.0000		0.0000		0.0000	
Propazine Area Applied(%)	*	*	*	*	*		*		*	
Propazine Rate/crop year(lb/ac)	*	*	*	*	*		*		*	
Propazine/acre(lb/ac)	0.0000	0.0000	0.0000	0.0000	0.0000		0.0000		0.0000	
Simazine Area Applied(%)	1.7	2.0	*	*	*		*		*	
Simazine Rate/crop year(lb/ac)	1.6	1.4	*	*	*		*		*	
Simazine/acre(lb/ac)	0.0264	0.0272	0.0000	0.0000	0.0000		0.0000		0.0000	
Pesticide Application(lb/ac)	1.85	1.62	0.01	0.53					0.18	
Pesticide Mix & Load(# appl/yr)										
Fertilizer Mix & Load(# appl/yr)	1.93	1.60	1.80	1.06					2.23	

Table 4
The available pesticide use information associated with each site type

State of Michigan	Apples	Cherries (Tart)	Cherries (Sweet)	Peaches	Blueberries	Grapes	Prunes & Plums	Pears	Raspber	Asparagus
Area Planted('000 acre)	52	33	10	8	15	11	4	1	1	24
Nitrogen Area Applied(%)	80	85	85	92	92	82	85	82	89	85
Nitrogen Rate/Application(lb/ac)	43	72	59	38	34	67	57	58	42	54
Nitrogen Rate/crop year(lb/ac)	71	2	85	66	78	80	83	93	55	77
Nitrogen/acre(lb/ac)	57	1	72	61	72	66	71	76	49	65
Nitrogen Total('000,000 lb)	2.9	2.8	0.7	0.5	1.0	0.7	0.3	0.1	0.0	1.6
Average Yield(bu/ac)										
Average Nitrogen Required(lb/ac)										
Alachlor Area Applied(%)	*	*	*	*	*	*	*	*	*	6.0
Alachlor Rate/crop year(lb/ac)	*	*	*	*	*	*	*	*	*	0.6
Alachlor/acre(lb/ac)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0384
Aldicarb Area Applied(%)	*	*	*	*	*	*	*	*	*	*
Aldicarb Rate/crop year(lb/ac)	*	*	*	*	*	*	*	*	*	*
Aldicarb/acre(lb/ac)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Atrazine Area Applied(%)	*	*	*	*	*	*	*	*	*	*
Atrazine Rate/crop year(lb/ac)	*	*	*	*	*	*	*	*	*	*
Atrazine/acre(lb/ac)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Bentazon Area Applied(%)	*	*	*	*	*	*	*	*	*	*
Bentazon Rate/crop year(lb/ac)	*	*	A	*	*	*	*	*	*	*
Bentazon/acre(lb/ac)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DBCP Area Applied(%)	*	*	*	*	*	*	*	*	*	*
DBCP Rate/crop year(lb/ac)	*	*	*	*	*	*	*	*	*	*
DBCP/acre(lb/ac)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Dacthal Area Applied(%)	*	*	*	*	*	*	*	*	*	*
Dacthal Rate/crop year(lb/ac)	*	*	*	*	*	*	*	*	*	*
Dacthal/acre(lb/ac)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Dicamba Area Applied(%)	*	*	*	*	*	*	*	*	*	*
Dicamba Rate/crop year(lb/ac)	*	*	*	*	*	*	*	*	*	*
Dicamba/acre(lb/ac)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
EBDC Area Applied(%)	*	*	*	*	*	*	*	*	*	*
EBDC Rate/crop year(lb/ac)	*	*	*	*	*	*	*	*	*	*
EBDC/acre(lb/ac)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ethylene Dibromide Area Appl.(%)	*	*	*	*	*	*	*	*	*	*
Ethylene D. Rate/crop year(lb/ac)	*	*	*	*	*	*	*	*	*	*
Ethylene D./acre(lb/ac)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Lindane Area Applied(%)	*	*	*	*	*	*	*	*	*	*
Lindane Rate/crop year(lb/ac)	*	*	*	*	*	*	*	*	*	*
Lindane/acre(lb/ac)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Methomyl Area Applied(%)	60.0	*	*	12.0	58.0	17.0	*	2.0	*	*
Methomyl Ratac/crop year(lb/ac)	0.9	*	*	0.7	0.7	0.6	*	0.8	*	*
Methomyl/acre(lb/ac)	0.5520	0.0000	0.0000	0.0828	0.4234	0.0952	0.0000	0.0162	0.0000	0.0000
Metolachlor Area Applied(%)	*	*	*	*	*	*	*	*	*	*
Metolachlor Rate/crop year(lb/ac)	*	*	*	*	*	*	*	*	*	*
Metolachlor/acre(lb/ac)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Prometon Area Applied(%)	*	*	*	*	*	*	*	*	*	*
Prometon Rate/crop year(lb/ac)	*	*	*	*	*	*	*	*	*	*
Prometon/acre(lb/ac)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propazine Area Applied(%)	*	*	*	*	*	*	*	*	*	*
Propazine Rate/crop year(lb/ac)	*	*	*	*	*	*	*	*	*	*
Propazine/acre(lb/ac)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Simazine Area Applied(%)	15.0	13.0	9.0	15.0	27.0	39.0	14.0	20.0	42	59.0
Simazine Rate/crop year(lb/ac)	1.0	1.5	2.2	0.6	0.8	0.7	0.8	1.3	2	1.4
Simazine/acre(lb/ac)	0.1515	0.1898	0.2007	0.0945	0.2079	0.2847	0.1176	0.2540	0.9198	0.8496
Pesticide Application(lb/ac)	0.70	0.19	0.20	0.18	0.63	0.38	0.12	0.27	0.92	0.89
Pesticide Mix & Load(# appl/yr)										
Fertilizer Mix & Load(# appl/yr)	1.70	1.50	1.40	1.70	2.30	1.20	1.40	1.60	1.30	1.40

Table 4
The available pesticide use information associated with each site type

State of Michigan	Snap Beans (fresh)	Beans (proc)	Broccoli	Cabbage	Carrots	Cauliflower	Celery	Cucumb fresh	Cucumbers proc	Greens
Area Planted('000 acre)	3	30	1	3	7	1	3	4	25	1
Nitrogen Area Applied(%)	97	98	90	95	97	99	96	93	100	78
Nitrogen Rate/Application(lb/ac)	56	24	47	60	31	60	68	41	34	56
Nitrogen Rate/crop year(lb/ac)	72	34	96	91	84	151	195	94	65	71
Nitrogen/acre(lb/ac)	70	33	86	86	81	149	187	87	65	55
Nitrogen Total('000,000 lb)	0.2	1.0	0.0	0.2	0.6	0.2	0.6	0.4	1.6	0.0
Average Yield(bu/ac)										
Average Nitrogen Required(lb/ac)										
Alachlor Area Applied(%)	*	*	*	*	*	*	*	*	*	*
Alachlor Rate/crop year(lb/ac)	*	*	*	*	*	*	*	*	*	*
Alachlor/acre(lb/ac)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Aldicarb Area Applied(%)	*	*	*	*	*	*	*	*	*	*
Aldicarb Rate/crop year(lb/ac)	*	*	*	*	*	*	*	*	*	*
Aldicarb/acre(lb/ac)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Atrazine Area Applied(%)	*	*	*	*	*	*	*	*	*	*
Atrazine Rate/crop year(lb/ac)	*	*	*	*	*	*	*	*	*	*
Atrazine/acre(lb/ac)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Bentazon Area Applied(%)	25	*	*	*	*	*	*	*	*	*
Bentazon Rate/crop year(lb/ac)	1	*	*	*	*	*	*	*	*	*
Bentazon/acre(lb/ac)	0.2475	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DBCP Area Applied(%)	*	*	*	*	*	*	*	*	*	*
DBCP Rate/crop year(lb/ac)	*	*	*	*	*	*	*	*	*	*
DBCP/acre(lb/ac)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Dacthal Area Applied(%)	*	*	9.0	1.0	*	*	*	*	*	*
Dacthal Rate/crop year(lb/ac)	*	*	6.1	6.9	*	*	*	*	*	*
Dacthal/acre(lb/ac)	0.0000	0.0000	0.5481	0.0694	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Dicamba Area Applied(%)	*	*	*	*	*	*	*	*	*	*
Dicamba Rate/crop year(lb/ac)	*	*	*	*	*	*	*	*	*	*
Dicamba/acre(lb/ac)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
EBDC Area Applied(%)	*	*	*	*	*	*	*	*	*	*
EBDC Rate/crop year(lb/ac)	*	*	*	*	*	*	*	*	*	*
EBDC/acre(lb/ac)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ethylene Dibromide Area Appl.(%)	*	*	*	*	*	*	*	*	*	*
Ethylene D. Rate/crop year(lb/ac)	*	*	*	*	*	*	*	*	*	*
Ethylene D./acre(lb/ac)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Lindane Area Applied(%)	*	*	*	*	*	*	*	*	*	*
Lindane Rate/crop year(lb/ac)	*	*	*	*	*	*	*	*	*	*
Lindane/acre(lb/ac)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Methomyl Area Applied(%)	*	*	*	*	*	*	65.0	*	*	*
Methomyl Ratae/crop year(lb/ac)	*	*	*	*	*	*	2.1	*	*	*
Methomyl/acre(lb/ac)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.3910	0.0000	0.0000	0.0000
Metolachlor Area Applied(%)	*	51.0	*	*	*	*	*	*	*	*
Metolachlor Rate/crop year(lb/ac)	*	1.0	*	*	*	*	*	*	*	*
Metolachlor/acre(lb/ac)	0.0000	0.5304	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Prometon Area Applied(%)	*	*	*	*	*	*	*	*	*	*
Prometon Rate/crop year(lb/ac)	*	*	*	*	*	*	*	*	*	*
Prometon/acre(lb/ac)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propazine Area Applied(%)	*	*	*	*	*	*	*	*	*	*
Propazine Rate/crop year(lb/ac)	*	*	*	*	*	*	*	*	*	*
Propazine/acre(lb/ac)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Simazine Area Applied(%)	*	*	*	*	*	*	*	*	*	*
Simazine Rate/crop year(lb/ac)	*	*	*	*	*	*	*	*	*	*
Simazine/acre(lb/ac)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Pesticide Application(lb/ac)	0.25	0.53	0.55	0.07	0.00	0.00	1.39	0.00	0.00	0.00
Pesticide Mix & Load(# appl/yr)										
Fertilizer Mix & Load(# appl/yr)	1.30	1.40	2.00	1.50	2.70	2.50	2.90	2.30	1.90	1.30

Table 4
The available pesticide use information associated with each site type

State of Michigan	Lettuce (Head)	Lettuce (Leaf)	Onions (Dry)	Onions (Green)	Pumpkins	Radishes	Strawberries	Tomatoe (fresh)	Tomatoes (Proc)
Area Planted('000 acre)	1	1	0	0	2	6	2	3	6
Nitrogen Area Applied(%)	100	92	100	100	80	100	93	82	99
Nitrogen Rate/Application(lb/ac)	51	126	50	51	53	20	58	55	55
Nitrogen Rate/crop year(lb/ac)	92	253	120	53	73	37	105	87	94
Nitrogen/acre(lb/ac)	92	233	120	53	58	37	98	71	93
Nitrogen Total('000,000 lb)	0.1	0.2	0.9	0.0	0.1	0.2	0.2	0.2	0.6
Average Yield(bu/ac)									
Average Nitrogen Required(lb/ac)									
Alachlor Area Applied(%)	*	*	*	*	*	*	*	*	*
Alachlor Rate/crop year(lb/ac)	*	*	*	*	*	*	*	*	*
Alachlor/acre(lb/ac)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Aldicarb Area Applied(%)	*	*	*	*	*	*	*	*	*
Aldicarb Rate/crop year(lb/ac)	*	*	*	*	*	*	*	*	*
Aldicarb/acre(lb/ac)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Atrazine Area Applied(%)	*	*	*	*	*	*	*	*	*
Atrazine Rate/crop year(lb/ac)	*	*	*	*	*	*	*	*	*
Atrazine/acre(lb/ac)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Bentazon Area Applied(%)	*	*	*	*	*	*	*	*	*
Bentazon Rate/crop year(lb/ac)	*	*	*	*	*	*	*	*	*
Bentazon/acre(lb/ac)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DBCP Area Applied(%)	*	*	*	*	*	*	*	*	*
DBCP Rate/crop year(lb/ac)	*	*	*	*	*	*	*	*	*
DBCP/acre(lb/ac)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Dacthal Area Applied(%)	*	*	*	*	*	*	*	*	*
Dacthal Rate/crop year(lb/ac)	*	*	*	*	*	*	*	*	*
Dacthal/acre(lb/ac)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Dicamba Area Applied(%)	*	*	*	*	*	*	*	*	*
Dicamba Rate/crop year(lb/ac)	*	*	*	*	*	*	*	*	*
Dicamba/acre(lb/ac)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
EBDC Area Applied(%)	*	*	*	*	*	*	*	*	*
EBDC Rate/crop year(lb/ac)	*	*	*	*	*	*	*	*	*
EBDC/acre(lb/ac)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ethylene Dibromide Area Appl.(%)	*	*	*	*	*	*	*	*	*
Ethylene D. Rate/crop year(lb/ac)	*	*	*	*	*	*	*	*	*
Ethylene D./acre(lb/ac)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Lindane Area Applied(%)	*	*	*	*	*	*	*	*	*
Lindane Rate/crop year(lb/ac)	*	*	*	*	*	*	*	*	*
Lindane/acre(lb/ac)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Methomyl Area Applied(%)	*	*	16.0	*	*	*	*	*	*
Methomyl Ratae/crop year(lb/ac)	*	*	0.6	*	*	*	*	*	*
Methomyl/acre(lb/ac)	0.0000	0.0000	0.0976	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Metolachlor Area Applied(%)	*	*	5.0	*	*	*	*	*	*
Metolachlor Rate/crop year(lb/ac)	*	*	1.5	*	*	*	*	*	*
Metolachlor/acre(lb/ac)	0.0000	0.0000	0.0740	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Prometon Area Applied(%)	*	*	*	*	*	*	*	*	*
Prometon Rate/crop year(lb/ac)	*	*	*	*	*	*	*	*	*
Prometon/acre(lb/ac)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propazine Area Applied(%)	*	*	*	*	*	*	*	*	*
Propazine Rate/crop year(lb/ac)	*	*	*	*	*	*	*	*	*
Propazine/acre(lb/ac)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Simazine Area Applied(%)	*	*	*	*	*	*	*	*	*
Simazine Rate/crop year(lb/ac)	*	*	*	*	*	*	*	*	*
Simazine/acre(lb/ac)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Pesticide Application(lb/ac)	0.00	0.00	0.17	0.00	0.00	0.00	0.00	0.00	0.00
Pesticide Mix & Load(# appl/yr)									
Fertilizer Mix & Load(# appl/yr)	1.80	1.90	2.40	1.00	1.40	1.90	1.80	1.60	1.70

APPENDIX C

TOTAL MASS OF EACH POTENTIAL LEACHING PESTICIDE IN COUNTY LEVEL IN MICHIGAN AND AGGREGATE PESTICIDE USE MASS IN COUNTY LEVEL IN MICHIGAN

Table 5
Pesticide(Alachlor)
Used
in Michigan

CC	RE	County	Percent Cropland	Acres of Total Cropland	Total Acres of Land	Total Alachlor applied (lb)	Alachlor per Cropland (lb/ 1000acre)	Alachlor per Totalland (lb/ 1000acre)
01	2	Alcona	6.6	28,573	432,924	1,063	37.2	2.5
02	1	Alger	1.9	9,426	496,105	0	0.0	0.0
03	5	Allegan	38.6	205,385	532,085	37,590	183.0	70.6
04	2	Alpena	15.1	54,767	362,695	3,193	58.3	8.8
05	2	Antrim	11.2	34,493	307,973	2,047	59.3	6.6
06	4	Arenac	29.6	69,511	234,834	9,392	135.1	40.0
07	1	Baraga	1.5	7,447	496,467	0	0.0	0.0
08	5	Barry	35.9	128,641	358,331	19,222	149.4	53.6
09	4	Bay	56.3	161,157	286,247	25,680	159.3	89.7
10	2	Benzie	6.1	12,665	207,623	582	46.0	2.8
11	5	Berrien	40.7	150,082	368,752	27,488	183.2	74.5
12	5	Branch	55.1	179,034	324,926	50,601	282.6	155.7
13	5	Calhoun	42.6	193,816	454,967	40,700	210.0	89.5
14	5	Cass	47.8	151,655	317,270	38,919	256.6	122.7
15	2	Charleviox	9.1	24,558	269,868	1,698	69.1	6.3
16	2	Cheboygan	5.6	25,803	460,768	655	25.4	1.4
17	1	Chippewa	6.4	65,394	1,021,781	0	0.0	0.0
18	4	Clare	13.2	47,994	363,591	2,330	48.5	6.4
19	6	Clinton	59.9	219,621	366,646	42,971	195.7	117.2
20	2	Crawford	0.2	715	357,652	0	0.0	0.0
21	1	Delta	6.3	37,828	600,444	1,254	33.2	2.1
22	1	Dickinson	3.0	14,927	497,567	703	47.1	1.4
23	6	Eaton	50.7	188,024	370,856	36,046	191.7	97.2
24	2	Emmet	8.6	25,649	298,244	1,281	49.9	4.3
25	4	Genesee	30.8	126,584	410,987	24,532	193.8	59.7
26	4	Gladwin	15.3	49,499	323,523	3,999	80.8	12.4
27	1	Gogebic	0.6	3,454	575,667	0	0.0	0.0
28	2	Grand Traverse	16.8	50,180	298,690	3,358	66.9	11.2
29	6	Gratiot	68.4	249,668	365,012	53,767	215.4	147.3
30	6	Hillsdale	50.8	196,210	386,240	45,719	233.0	118.4
31	1	Houghton	2.5	16,168	646,720	5	0.3	0.0
32	4	Huron	72.2	383,583	531,278	72,780	189.7	137.0
33	6	Ingham	48.1	172,277	358,164	35,116	203.8	98.0
34	3	Ionia	56.2	207,677	369,532	39,445	189.9	106.7
35	4	Iosco	7.7	26,892	349,247	3,613	134.4	10.3
36	1	Iron	2.2	16,376	744,371	0	0.0	0.0
37	4	Isabella	43.1	158,954	368,803	23,660	148.9	64.2
38	6	Jackson	35.7	160,981	450,927	30,195	187.6	67.0
39	5	Kalamazoo	36.8	132,533	360,144	29,045	219.2	80.6
40	2	Kalkaska	3.0	10,741	358,033	849	79.0	2.4
41	3	Kent	29.6	163,275	551,605	22,400	137.2	40.6
42	1	Keweenaw	0.0	0	347,827	0	0.0	0.0
43	3	Lake	3.0	11,004	366,800	243	22.0	0.7
44	4	Lapeer	41.6	175,050	420,793	29,870	170.6	71.0
45	2	Leelanau	17.9	39,218	219,095	1,701	43.4	7.8
46	6	Lenawee	64.4	310,342	481,898	75,209	242.3	156.1
47	6	Livingston	27.2	99,835	367,040	16,142	161.7	44.0
48	1	Luce	1.4	5,787	413,357	0	0.0	0.0
49	1	Mackinac	2.2	14,635	665,227	0	0.0	0.0
50	7	Macomb	22.1	68,255	308,846	11,823	173.2	38.3
51	2	Manistee	8.4	29,246	348,167	958	32.7	2.8
52	1	Marquette	0.9	10,527	1,169,667	0	0.0	0.0
53	3	Mason	17.9	56,687	316,687	5,053	89.1	16.0
54	3	Mecosta	25.0	89,564	358,256	6,287	70.2	17.5

Table 5
Pesticide(Alachlor)
Used
in Michigan

CC	RE	County	Percent Cropland	Acres of Total Cropland	Total Acres of Land	Total Alachlor applied (lb)	Alachlor per Cropland (lb/ 1000acre)	Alachlor per Totalland (lb/ 1000acre)
55	1	Menominee	9.5	63,542	668,863	6,208	97.7	9.3
56	4	Midland	22.3	74,957	336,130	14,450	192.8	43.0
57	2	Missaukee	17.1	61,912	362,058	5,639	91.1	15.6
58	7	Monroe	57.2	203,774	356,248	47,399	232.6	133.0
59	3	Montcalm	40.9	186,322	455,555	24,167	129.7	53.1
60	2	Montmorency	4.3	15,004	348,930	1,176	78.3	3.4
61	3	Muskegon	17.5	56,910	325,200	8,969	157.6	27.6
62	3	Newaygo	15.6	84,764	543,359	10,612	125.2	19.5
63	7	Oakland	8.5	47,708	561,271	5,582	117.0	9.9
64	3	Oceana	24.8	85,922	346,460	5,087	59.2	14.7
65	4	Ogemaw	14.7	53,732	365,524	4,747	88.3	13.0
66	1	Ontonagon	2.0	16,776	838,800	0	0.0	0.0
67	3	Osceola	20.6	75,019	364,170	4,257	56.7	11.7
68	2	Oscoda	2.9	10,679	368,241	437	40.9	1.2
69	2	Otsego	5.5	18,017	327,582	708	39.3	2.2
70	3	Ottawa	40.3	146,152	362,660	20,270	138.7	55.9
71	2	Presque Isle	12.3	51,610	419,593	1,455	28.2	3.5
72	4	Roscommon	1.0	2,362	236,200	0	0.0	0.0
73	4	Saginaw	53.1	277,062	521,774	61,944	223.6	118.7
76	4	Sanilac	63.3	390,529	616,949	65,559	167.9	106.3
77	1	Schoolcraft	1.7	9,323	548,412	0	0.0	0.0
78	6	Shiawassee	58.7	203,050	345,911	38,101	187.6	110.1
74	7	St. Clair	31.7	148,961	469,909	19,310	129.6	41.1
75	5	St. Joseph	55.9	179,703	321,472	53,286	296.5	165.8
79	4	Tuscola	56.6	294,089	519,592	48,791	165.9	93.9
80	5	Van Buren	37.8	147,853	391,146	17,238	116.6	44.1
81	6	Washtenaw	37.6	170,968	454,702	28,375	166.0	62.4
82	7	Wayne	4.8	19,024	396,333	2,665	140.1	6.7
83	2	Wexford	5.1	18,547	363,667	1,255	67.7	3.5
Total		Michigan	23.0	8,186,638	35,557,933	1,376,865	168.2	38.7

Table 6
Pesticides(Aldicarb)
Used
in Michigan

CC	RE	County	Percent Cropland	Acres of Total Cropland	Total Acres of Land	Total Aldicarb Applied (lb)	Aldicarb per Cropland (lb/ 1000acres)	Aldicarb per Totalland (lb/ 1000acres)
01	2	Alcona	6.6	28,573	432,924	0	0.0	0.0
02	1	Alger	1.9	9,426	496,105	0	0.0	0.0
03	5	Allegan	38.6	205,385	532,085	25	0.1	0.0
04	2	Alpena	15.1	54,767	362,695	20	0.4	0.1
05	2	Antrim	11.2	34,493	307,973	47	1.4	0.2
06	4	Arenac	29.6	69,511	234,834	55	0.8	0.2
07	1	Baraga	1.5	7,447	496,467	0	0.0	0.0
08	5	Barry	35.9	128,641	358,331	0	0.0	0.0
09	4	Bay	56.3	161,157	286,247	199	1.2	0.7
10	2	Benzie	6.1	12,665	207,623	0	0.0	0.0
11	5	Berrien	40.7	150,082	368,752	0	0.0	0.0
12	5	Branch	55.1	179,034	324,926	0	0.0	0.0
13	5	Calhoun	42.6	193,816	454,967	0	0.0	0.0
14	5	Cass	47.8	151,655	317,270	0	0.0	0.0
15	2	Charleviox	9.1	24,558	269,868	0	0.0	0.0
16	2	Cheboygan	5.6	25,803	460,768	0	0.0	0.0
17	1	Chippewa	6.4	65,394	1,021,781	0	0.0	0.0
18	4	Clare	13.2	47,994	363,591	0	0.0	0.0
19	6	Clinton	59.9	219,621	366,646	0	0.0	0.0
20	2	Crawford	0.2	715	357,652	0	0.0	0.0
21	1	Delta	6.3	37,828	600,444	43	1.1	0.1
22	1	Dickinson	3.0	14,927	497,567	47	3.1	0.1
23	6	Eaton	50.7	188,024	370,856	25	0.1	0.1
24	2	Emmet	8.6	25,649	298,244	25	1.0	0.1
25	4	Genesee	30.8	126,584	410,987	11	0.1	0.0
26	4	Gladwin	15.3	49,499	323,523	0	0.0	0.0
27	1	Gogebic	0.6	3,454	575,667	0	0.0	0.0
28	2	Grand Traverse	16.8	50,180	298,690	0	0.0	0.0
29	6	Gratiot	68.4	249,668	365,012	14	0.1	0.0
30	6	Hillsdale	50.8	196,210	386,240	0	0.0	0.0
31	1	Houghton	2.5	16,168	646,720	0	0.0	0.0
32	4	Huron	72.2	383,583	531,278	19	0.0	0.0
33	6	Ingham	48.1	172,277	358,164	0	0.0	0.0
34	3	Ionia	56.2	207,677	369,532	0	0.0	0.0
35	4	Iosco	7.7	26,892	349,247	0	0.0	0.0
36	1	Iron	2.2	16,376	744,371	23	1.4	0.0
37	4	Isabella	43.1	158,954	368,803	0	0.0	0.0
38	6	Jackson	35.7	160,981	450,927	0	0.0	0.0
39	5	Kalamazoo	36.8	132,533	360,144	0	0.0	0.0
40	2	Kalkaska	3.0	10,741	358,033	17	1.6	0.0
41	3	Kent	29.6	163,275	551,605	17	0.1	0.0
42	1	Keweenaw	0.0	0	347,827	0	0.0	0.0
43	3	Lake	3.0	11,004	366,800	0	0.0	0.0
44	4	Lapeer	41.6	175,050	420,793	23	0.1	0.1
45	2	Leelanau	17.9	39,218	219,095	0	0.0	0.0
46	6	Lenawee	64.4	310,342	481,898	37	0.1	0.1
47	6	Livingston	27.2	99,835	367,040	0	0.0	0.0
48	1	Luce	1.4	5,787	413,357	18	3.0	0.0
49	1	Mackinac	2.2	14,635	665,227	0	0.0	0.0
50	7	Macomb	22.1	68,255	308,846	18	0.3	0.1
51	2	Manistee	8.4	29,246	348,167	11	0.4	0.0
52	1	Marquette	0.9	10,527	1,169,667	11	1.0	0.0
53	3	Mason	17.9	56,687	316,687	0	0.0	0.0
54	3	Mecosta	25.0	89,564	358,256	34	0.4	0.1

Table 6
Pesticides(Aldicarb)
Used
in Michigan

CC	RE	County	Percent Cropland	Acres of Total Cropland	Total Acres of Land	Total Aldicarb Applied (lb)	Aldicarb per Cropland (lb/ 1000acres)	Aldicarb per Totalland (lb/ 1000acres)
55	1	Menominee	9.5	63,542	668,863	0	0.0	0.0
56	4	Midland	22.3	74,957	336,130	14	0.2	0.0
57	2	Missaukee	17.1	61,912	362,058	13	0.2	0.0
58	7	Monroe	57.2	203,774	356,248	59	0.3	0.2
59	3	Montcalm	40.9	186,322	455,555	372	2.0	0.8
60	2	Montmorency	4.3	15,004	348,930	0	0.0	0.0
61	3	Muskegon	17.5	56,910	325,200	0	0.0	0.0
62	3	Newaygo	15.6	84,764	543,359	0	0.0	0.0
63	7	Oakland	8.5	47,708	561,271	0	0.0	0.0
64	3	Oceana	24.8	85,922	346,460	0	0.0	0.0
65	4	Ogemaw	14.7	53,732	365,524	0	0.0	0.0
66	1	Ontonagon	2.0	16,776	838,800	0	0.0	0.0
67	3	Osceola	20.6	75,019	364,170	0	0.0	0.0
68	2	Oscoda	2.9	10,679	368,241	0	0.0	0.0
69	2	Otsego	5.5	18,017	327,582	31	1.7	0.1
70	3	Ottawa	40.3	146,152	362,660	0	0.0	0.0
71	2	Presque Isle	12.3	51,610	419,593	115	2.2	0.3
72	4	Roscommon	1.0	2,362	236,200	0	0.0	0.0
73	4	Saginaw	53.1	277,062	521,774	15	0.1	0.0
76	4	Sanilac	63.3	390,529	616,949	19	0.0	0.0
77	1	Schoolcraft	1.7	9,323	548,412	0	0.0	0.0
78	6	Shiawassee	58.7	203,050	345,911	6	0.0	0.0
74	7	St. Clair	31.7	148,961	469,909	0	0.0	0.0
75	5	St. Joseph	55.9	179,703	321,472	0	0.0	0.0
79	4	Tuscola	56.6	294,089	519,592	84	0.3	0.2
80	5	Van Buren	37.8	147,853	391,146	0	0.0	0.0
81	6	Washtenaw	37.6	170,968	454,702	13	0.1	0.0
82	7	Wayne	4.8	19,024	396,333	0	0.0	0.0
83	2	Wexford	5.1	18,547	363,667	0	0.0	0.0
Total		Michigan	23.0	8,186,638	35,557,933	1,476	0.2	0.0

Table 7
Pesticide(Atrazine)
Used
in Michigan

CC	RE	County	Percent Cropland	Acres of Total Cropland	Total Acres of Land	Total Atrazine Applied (lb)	Atrazine per Cropland (lb/ 1000acre)	Atrazine per Totalland (lb/ 1000acre)
01	2	Alcona	6.6	28,573	432,924	1,677	58.7	3.9
02	1	Alger	1.9	9,426	496,105	0	0.0	0.0
03	5	Allegan	38.6	205,385	532,085	55,887	272.1	105.0
04	2	Alpena	15.1	54,767	362,695	4,930	90.0	13.6
05	2	Antrim	11.2	34,493	307,973	3,292	95.4	10.7
06	4	Arenac	29.6	69,511	234,834	12,129	174.5	51.6
07	1	Baraga	1.5	7,447	496,467	0	0.0	0.0
08	5	Barry	35.9	128,641	358,331	26,169	203.4	73.0
09	4	Bay	56.3	161,157	286,247	29,640	183.9	103.5
10	2	Benzie	6.1	12,665	207,623	936	73.9	4.5
11	5	Berrien	40.7	150,082	368,752	33,579	223.7	91.1
12	5	Branch	55.1	179,034	324,926	67,548	377.3	207.9
13	5	Calhoun	42.6	193,816	454,967	55,926	288.6	122.9
14	5	Cass	47.8	151,655	317,270	52,182	344.1	164.5
15	2	Charleviox	9.1	24,558	269,868	2,730	111.2	10.1
16	2	Cheboygan	5.6	25,803	460,768	1,053	40.8	2.3
17	1	Chippewa	6.4	65,394	1,021,781	0	0.0	0.0
18	4	Clare	13.2	47,994	363,591	3,666	76.4	10.1
19	6	Clinton	59.9	219,621	366,646	49,608	225.9	135.3
20	2	Crawford	0.2	715	357,625	0	0.0	0.0
21	1	Delta	6.3	37,828	600,444	1,989	52.6	3.3
22	1	Dickinson	3.0	14,927	497,567	1,131	75.8	2.3
23	6	Eaton	50.7	188,024	370,856	44,944	239.0	121.2
24	2	Emmet	8.6	25,649	298,244	2,028	79.1	6.8
25	4	Genesee	30.8	126,584	410,987	30,849	243.7	75.1
26	4	Gladwin	15.3	49,499	323,523	5,749	116.1	17.8
27	1	Gogebic	0.6	3,454	575,667	0	0.0	0.0
28	2	Grand Traverse	16.8	50,180	298,690	5,343	106.5	17.9
29	6	Gratiot	68.4	249,668	365,012	58,929	236.0	161.4
30	6	Hillsdale	50.8	196,210	386,240	60,099	306.3	155.6
31	1	Houghton	2.5	16,168	646,720	8	0.5	0.0
32	4	Huron	72.2	383,583	531,278	111,540	290.8	209.9
33	6	Ingham	48.1	172,277	358,164	46,504	269.9	129.8
34	3	Ionia	56.2	207,677	369,532	52,783	254.2	142.8
35	4	Iosco	7.7	26,892	349,247	5,694	211.7	16.3
36	1	Iron	2.2	16,376	744,371	0	0.0	0.0
37	4	Isabella	43.1	158,954	368,803	32,417	203.9	87.9
38	6	Jackson	35.7	160,981	450,927	45,786	284.4	101.5
39	5	Kalamazoo	36.8	132,533	360,144	38,142	287.8	105.9
40	2	Kalkaska	3.0	10,741	358,033	1,365	127.1	3.8
41	3	Kent	29.6	163,275	551,605	34,476	211.2	62.5
42	1	Keweenaw	0.0	0	347,827	0	0.0	0.0
43	3	Lake	3.0	11,004	366,800	390	35.4	1.1
44	4	Lapeer	41.6	175,050	420,793	44,460	254.0	105.7
45	2	Leelanau	17.9	39,218	219,095	2,730	69.6	12.5
46	6	Lenawee	64.4	310,342	481,898	82,758	266.7	171.7
47	6	Livingston	27.2	99,835	367,040	23,829	238.7	64.9
48	1	Luce	1.4	5,787	413,357	0	0.0	0.0
49	1	Mackinac	2.2	14,635	665,227	0	0.0	0.0
50	7	Macomb	22.1	68,255	308,846	13,104	192.0	42.4
51	2	Manistee	8.4	29,246	348,167	1,482	50.7	4.3
52	1	Marquette	0.9	10,527	1,169,667	0	0.0	0.0
53	3	Mason	17.9	56,687	316,687	7,823	138.0	24.7
54	3	Mecosta	25.0	89,564	358,256	10,023	111.9	28.0

Table 7
Pesticide(Atrazine)
Used
in Michigan

CC	RE	County	Percent Cropland	Acres of Total Cropland	Total Acres of Land	Total Atrazine Applied (lb)	Atrazine per Cropland (lb/ 1000acre)	Atrazine per Totalland (lb/ 1000acre)
55	1	Menominee	9.5	63,542	668,863	9,984	157.1	14.9
56	4	Midland	22.3	74,957	336,130	15,600	208.1	46.4
57	2	Missaukee	17.1	61,912	362,058	9,048	146.1	25.0
58	7	Monroe	57.2	203,774	356,248	42,978	210.9	120.6
59	3	Montcalm	40.9	186,322	455,555	34,726	186.4	76.2
60	2	Montmorency	4.3	15,004	348,930	1,794	119.6	5.1
61	3	Muskegon	17.5	56,910	325,200	13,400	235.5	41.2
62	3	Newaygo	15.6	84,764	543,359	16,981	200.3	31.3
63	7	Oakland	8.5	47,708	561,271	8,736	183.1	15.6
64	3	Oceana	24.8	85,922	346,460	7,348	85.5	21.2
65	4	Ogemaw	14.7	53,732	365,524	7,566	140.8	20.7
66	1	Ontonagon	2.0	16,776	838,800	0	0.0	0.0
67	3	Osceola	20.6	75,019	364,170	6,786	90.5	18.6
68	2	Oscoda	2.9	10,679	368,241	702	65.7	1.9
69	2	Otsego	5.5	18,017	327,582	1,139	63.2	3.5
70	3	Ottawa	40.3	146,152	362,660	31,980	218.8	88.2
71	2	Presque Isle	12.3	51,610	419,593	2,340	45.3	5.6
72	4	Roscommon	1.0	2,362	236,200	0	0.0	0.0
73	4	Saginaw	53.1	277,062	521,774	53,625	193.5	102.8
76	4	Sanilac	63.3	390,529	616,949	86,658	221.9	140.5
77	1	Schoolcraft	1.7	9,323	548,412	0	0.0	0.0
78	6	Shiawassee	58.7	203,050	345,911	35,545	175.1	102.8
74	7	St. Clair	31.7	148,961	469,909	21,606	145.0	46.0
75	5	St. Joseph	55.9	179,703	321,472	72,244	402.0	224.7
79	4	Tuscola	56.6	294,089	519,592	62,868	213.8	121.0
80	5	Van Buren	37.8	147,853	391,146	23,634	159.8	60.4
81	6	Washtenaw	37.6	170,968	454,702	39,000	228.1	85.8
82	7	Wayne	4.8	19,024	396,333	3,120	164.0	7.9
83	2	Wexford	5.1	18,547	363,667	1,950	105.1	5.4
Total Michigan			23.0	8,186,638	35,557,906	1,778,681	217.3	50.0

Table 8
Pesticide(Bentazon)
Used
in Michigan

CC	RE	County	Percent Cropland	Acres of Total Cropland	Total Acres of Land	Total Bentazon Applied (lb)	Bentazon per Cropland (lb/ 1000acre)	Bentazon per Totalland (lb/ 1000acre)
01	2	Alcona	6.6	28,573	432,924	24	0.8	0.1
02	1	Alger	1.9	9,426	496,105	0	0.0	0.0
03	5	Allegan	38.6	205,385	532,085	1,857	9.0	3.5
04	2	Alpena	15.1	54,767	362,695	101	1.8	0.3
05	2	Antrim	11.2	34,493	307,973	30	0.9	0.1
06	4	Arenac	29.6	69,511	234,834	924	13.3	3.9
07	1	Baraga	1.5	7,447	496,467	0	0.0	0.0
08	5	Barry	35.9	128,641	358,331	1,694	13.2	4.7
09	4	Bay	56.3	161,157	286,247	3,460	21.5	12.1
10	2	Benzie	6.1	12,665	207,623	9	0.7	0.0
11	5	Berrien	40.7	150,082	368,752	3,199	21.3	8.7
12	5	Branch	55.1	179,034	324,926	4,399	24.6	13.5
13	5	Calhoun	42.6	193,816	454,967	3,116	16.1	6.8
14	5	Cass	47.8	151,655	317,270	5,025	33.1	15.8
15	2	Charleviox	9.1	24,558	269,868	25	1.0	0.1
16	2	Cheboygan	5.6	25,803	460,768	10	0.4	0.0
17	1	Chippewa	6.4	65,394	1,021,781	0	0.0	0.0
18	4	Clare	13.2	47,994	363,591	55	1.2	0.2
19	6	Clinton	59.9	219,621	366,646	5,787	26.3	15.8
20	2	Crawford	0.2	715	357,652	0	0.0	0.0
21	1	Delta	6.3	37,828	600,444	26	0.7	0.0
22	1	Dickinson	3.0	14,927	497,567	10	0.7	0.0
23	6	Eaton	50.7	188,024	370,856	4,013	21.3	10.8
24	2	Emmet	8.6	25,649	298,244	27	1.1	0.1
25	4	Genesee	30.8	126,584	410,987	2,655	21.0	6.5
26	4	Gladwin	15.3	49,499	323,523	239	4.8	0.7
27	1	Gogebic	0.6	3,454	575,667	0	0.0	0.0
28	2	Grand Traverse	16.8	50,180	298,690	712	14.2	2.4
29	6	Gratiot	68.4	249,668	365,012	8,071	32.3	22.1
30	6	Hillsdale	50.8	196,210	386,240	4,221	21.5	10.9
31	1	Houghton	2.5	16,168	646,720	0	0.0	0.0
32	4	Huron	72.2	383,583	531,278	2,522	6.6	4.7
33	6	Ingham	48.1	172,277	358,164	3,151	18.3	8.8
34	3	Ionia	56.2	207,677	369,532	3,895	18.8	10.5
35	4	Iosco	7.7	26,892	349,247	84	3.1	0.2
36	1	Iron	2.2	16,376	744,371	0	0.0	0.0
37	4	Isabella	43.1	158,954	368,803	1,835	11.5	5.0
38	6	Jackson	35.7	160,981	450,927	1,176	7.3	2.6
39	5	Kalamazoo	36.8	132,533	360,144	2,690	20.3	7.5
40	2	Kalkaska	3.0	10,741	358,033	12	1.2	0.0
41	3	Kent	29.6	163,275	551,605	767	4.7	1.4
42	1	Keweenaw	0.0	0	347,827	0	0.0	0.0
43	3	Lake	3.0	11,004	366,800	4	0.3	0.0
44	4	Lapeer	41.6	175,050	420,793	1,384	7.9	3.3
45	2	Leelanau	17.9	39,218	219,095	25	0.6	0.1
46	6	Lenawee	64.4	310,342	481,898	11,203	36.1	23.2
47	6	Livingston	27.2	99,835	367,040	800	8.0	2.2
48	1	Luce	1.4	5,787	413,357	0	0.0	0.0
49	1	Mackinac	2.2	14,635	665,227	0	0.0	0.0
50	7	Macomb	22.1	68,255	308,846	1,899	27.8	6.1
51	2	Manistee	8.4	29,246	348,167	13	0.5	0.0
52	1	Marquette	0.9	10,527	1,169,667	0	0.0	0.0
53	3	Mason	17.9	56,687	316,687	917	16.2	2.9
54	3	Mecosta	25.0	89,564	358,256	108	1.2	0.3

Table 8
Pesticide(Bentazon)
Used
in Michigan

CC	RE	County	Percent Cropland	Acres of Total Cropland	Total Acres of Land	Total Bentazon Applied (lb)	Bentazon per Cropland (lb/ 1000acre)	Bentazon per Totalland (lb/ 1000acre)
55	1	Menominee	9.5	63,542	668,863	91	1.4	0.1
56	4	Midland	22.3	74,957	336,130	2,232	29.8	6.6
57	2	Missaukee	17.1	61,912	362,058	88	1.4	0.2
58	7	Monroe	57.2	203,774	356,248	9,511	46.7	26.7
59	3	Montcalm	40.9	186,322	455,555	1,549	8.3	3.4
60	2	Montmorency	4.3	15,004	348,930	43	2.8	0.1
61	3	Muskegon	17.5	56,910	325,200	603	10.6	1.9
62	3	Newaygo	15.6	84,764	543,359	173	2.0	0.3
63	7	Oakland	8.5	47,708	561,271	146	3.1	0.3
64	3	Oceana	24.8	85,922	346,460	360	4.2	1.0
65	4	Ogemaw	14.7	53,732	365,524	88	1.6	0.2
66	1	Ontonagon	2.0	16,776	838,800	0	0.0	0.0
67	3	Osceola	20.6	75,019	364,170	78	1.0	0.2
68	2	Oscoda	2.9	10,679	368,241	6	0.6	0.0
69	2	Otsego	5.5	18,017	327,582	10	0.6	0.0
70	3	Ottawa	40.3	146,152	362,660	451	3.1	1.2
71	2	Presque Isle	12.3	51,610	419,593	21	0.4	0.1
72	4	Roscommon	1.0	2,362	236,200	0	0.0	0.0
73	4	Saginaw	53.1	277,062	521,774	13,072	47.2	25.1
76	4	Sanilac	63.3	390,529	616,949	5,926	15.2	9.6
77	1	Schoolcraft	1.7	9,323	548,412	0	0.0	0.0
78	6	Shiawassee	58.7	203,050	345,911	7,366	36.3	21.3
74	7	St. Clair	31.7	148,961	469,909	2,834	19.0	6.0
75	5	St. Joseph	55.9	179,703	321,472	4,337	24.1	13.5
79	4	Tuscola	56.6	294,089	519,592	4,840	16.5	9.3
80	5	Van Buren	37.8	147,853	391,146	1,775	12.0	4.5
81	6	Washtenaw	37.6	170,968	454,702	2,170	12.7	4.8
82	7	Wayne	4.8	19,024	396,333	362	19.0	0.9
83	2	Wexford	5.1	18,547	363,667	511	27.6	1.4
Total Michigan			23.0	8,186,638	35,557,933	140,818	17.2	4.0

Table 9
Pesticide(Dacthal)
Used
in Michigan

CC	RE	County	Percent Cropland	Acres of Total Cropland	Total Acres of Land	Total Dacthal Applied (lb)	Dacthal per Cropland (lb/ 1000acre)	Dacthal per Totalland (lb/ 1000acre)
01	2	Alcona	6.6	28,573	432,924	0	0.0	0.0
02	1	Alger	1.9	9,426	496,105	0	0.0	0.0
03	5	Allegan	38.6	205,385	532,085	0	0.0	0.0
04	2	Alpena	15.1	54,767	362,695	0	0.0	0.0
05	2	Antrim	11.2	34,493	307,973	0	0.0	0.0
06	4	Arenac	29.6	69,511	234,834	33	0.5	0.1
07	1	Baraga	1.5	7,447	496,467	0	0.0	0.0
08	5	Barry	35.9	128,641	358,331	0	0.0	0.0
09	4	Bay	56.3	161.157	286,247	22	0.1	0.1
10	2	Benzie	6.1	12,665	207,623	0	0.0	0.0
11	5	Berrien	40.7	150,082	368,752	0	0.0	0.0
12	5	Branch	55.1	179,034	324,926	0	0.0	0.0
13	5	Calhoun	42.6	193.816	454.967	1	0.0	0.0
14	5	Cass	47.8	151,655	317,270	0	0.0	0.0
15	2	Charleviox	9.1	24,558	269,868	0	0.0	0.0
16	2	Cheboygan	5.6	25,803	460,768	0	0.0	0.0
17	1	Chippewa	6.4	65.394	1,021,781	0	0.0	0.0
18	4	Clare	13.2	47,994	363,591	0	0.0	0.0
19	6	Clinton	59.9	219,621	366,646	0	0.0	0.0
20	2	Crawford	0.2	715	357,652	0	0.0	0.0
21	1	Delta	6.3	37,828	600,444	0	0.0	0.0
22	1	Dickinson	3.0	14,927	497,567	0	0.0	0.0
23	6	Eaton	50.7	188,024	370,856	0	0.0	0.0
24	2	Emmet	8.6	25,649	298,244	0	0.0	0.0
25	4	Genesee	30.8	126.584	410,987	2	0.0	0.0
26	4	Gladwin	15.3	49,499	323,523	0	0.0	0.0
27	1	Gogebic	0.6	3.454	575.667	0	0.0	0.0
28	2	Grand Traverse	16.8	50,180	298,690	0	0.0	0.0
29	6	Gratiot	68.4	249.668	365,012	5	0.0	0.0
30	6	Hillsdale	50.8	196.210	386,240	0	0.0	0.0
31	1	Houghton	2.5	16,168	646,720	0	0.0	0.0
32	4	Huron	72.2	383,583	531,278	0	0.0	0.0
33	6	Ingham	48.1	172,277	358.164	14	0.1	0.0
34	3	Ionia	56.2	207,677	369,532	0	0.0	0.0
35	4	Iosco	7.7	26,892	349.247	0	0.0	0.0
36	1	Iron	2.2	16.376	744,371	0	0.0	0.0
37	4	Isabella	43.1	158.954	368.803	0	0.0	0.0
38	6	Jackson	35.7	160,981	450,927	10	0.1	0.0
39	5	Kalamazoo	36.8	132.533	360.144	2	0.0	0.0
40	2	Kalkaska	3.0	10.741	358,033	0	0.0	0.0
41	3	Kent	29.6	163.275	551,605	63	0.4	0.1
42	1	Keweenaw	0.0	0	347,827	0	0.0	0.0
43	3	Lake	3.0	11,004	366.800	0	0.0	0.0
44	4	Lapeer	41.6	175,050	420.793	0	0.0	0.0
45	2	Leelanau	17.9	39.218	219.095	0	0.0	0.0
46	6	Lenawee	64.4	310.342	481.898	4	0.0	0.0
47	6	Livingston	27.2	99,835	367.040	0	0.0	0.0
48	1	Luce	1.4	5.787	413.357	0	0.0	0.0
49	1	Mackinac	2.2	14.635	665.227	0	0.0	0.0
50	7	Macomb	22.1	68.255	308.846	33	0.5	0.1
51	2	Manistee	8.4	29.246	348.167	0	0.0	0.0
52	1	Marquette	0.9	10.527	1.169.667	0	0.0	0.0
53	3	Mason	17.9	56.687	316.687	0	0.0	0.0
54	3	Mecosta	25.0	89.564	358.256	0	0.0	0.0

Table 9
Pesticide(Dacthal)
Used
in Michigan

CC	RE	County	Percent Cropland	Acres of Total Cropland	Total Acres of Land	Total Dacthal Applied (lb)	Dacthal per Cropland (lb/ 1000acre)	Dacthal per Totalland (lb/ 1000acre)
55	1	Menominee	9.5	63,542	668,863	0	0.0	0.0
56	4	Midland	22.3	74,957	336,130	0	0.0	0.0
57	2	Missaukee	17.1	61,912	362,058	0	0.0	0.0
58	7	Monroe	57.2	203,774	356,248	18	0.1	0.1
59	3	Montcalm	40.9	186,322	455,555	0	0.0	0.0
60	2	Montmorency	4.3	15,004	348,930	0	0.0	0.0
61	3	Muskegon	17.5	56,910	325,200	0	0.0	0.0
62	3	Newaygo	15.6	84,764	543,359	0	0.0	0.0
63	7	Oakland	8.5	47,708	561,271	1	0.0	0.0
64	3	Oceana	24.8	85,922	346,460	0	0.0	0.0
65	4	Ogemaw	14.7	53,732	365,524	0	0.0	0.0
66	1	Ontonagon	2.0	16,776	838,800	0	0.0	0.0
67	3	Osceola	20.6	75,019	364,170	0	0.0	0.0
68	2	Oscoda	2.9	10,679	368,241	0	0.0	0.0
69	2	Otsego	5.5	18,017	327,582	0	0.0	0.0
70	3	Ottawa	40.3	146,152	362,660	12	0.1	0.0
71	2	Presque Isle	12.3	51,610	419,593	0	0.0	0.0
72	4	Roscommon	1.0	2,362	236,200	0	0.0	0.0
73	4	Saginaw	53.1	277,062	521,774	41	0.1	0.1
76	4	Sanilac	63.3	390,529	616,949	0	0.0	0.0
77	1	Schoolcraft	1.7	9,323	548,412	0	0.0	0.0
78	6	Shiawassee	58.7	203,050	345,911	1	0.0	0.0
74	7	St. Clair	31.7	148,961	469,909	12	0.1	0.0
75	5	St. Joseph	55.9	179,703	321,472	0	0.0	0.0
79	4	Tuscola	56.6	294,089	519,592	0	0.0	0.0
80	5	Van Buren	37.8	147,853	391,146	0	0.0	0.0
81	6	Washtenaw	37.6	170,968	454,702	61	0.4	0.1
82	7	Wayne	4.8	19,024	396,333	3	0.1	0.0
83	2	Wexford	5.1	18,547	363,667	0	0.0	0.0
Total Michigan			23.0	8,186,638	35,557,933	337	0.0	0.0

Table 10
Pesticide(Dicamba)
Used
in Michigan

CC	RE	County	Percent Cropland	Acres of Total Cropland	Total Acres of Land	Total Dicamba Applied (lb)	Dicamba per Cropland (lb/ 1000acre)	Dicamba per Totalland (lb/ 1000acre)
01	2	Alcona	6.6	28,573	432,924	77	2.7	0.2
02	1	Alger	1.9	9,426	496,105	0	0.0	0.0
03	5	Allegan	38.6	205,385	532,085	3,823	18.6	7.2
04	2	Alpena	15.1	54,767	362,695	277	5.1	0.8
05	2	Antrim	11.2	34,493	307,973	180	5.2	0.6
06	4	Arenac	29.6	69,511	234,834	786	11.3	3.3
07	1	Baraga	1.5	7,447	496,467	0	0.0	0.0
08	5	Barry	35.9	128,641	358,331	1,854	14.4	5.2
09	4	Bay	56.3	161,157	286,247	2,253	14.0	7.9
10	2	Benzie	6.1	12,665	207,623	13	1.0	0.1
11	5	Berrien	40.7	150,082	368,752	2,439	16.3	6.6
12	5	Branch	55.1	179,034	324,926	5,108	28.5	15.7
13	5	Calhoun	42.6	193,816	454,967	4,118	21.2	9.1
14	5	Cass	47.8	151,655	317,270	3,971	26.2	12.5
15	2	Charlevoix	9.1	24,558	269,868	116	4.7	0.4
16	2	Cheboygan	5.6	25,803	460,768	38	1.5	0.1
17	1	Chippewa	6.4	65,394	1,021,781	2	0.0	0.0
18	4	Clare	13.2	47,994	363,591	132	2.7	0.4
19	6	Clinton	59.9	219,621	366,646	3,199	14.6	8.7
20	2	Crawford	0.2	715	357,652	0	0.0	0.0
21	1	Delta	6.3	37,828	600,444	81	2.1	0.1
22	1	Dickinson	3.0	14,927	497,567	34	2.2	0.1
23	6	Eaton	50.7	188,024	370,856	3,437	18.3	9.3
24	2	Emmet	8.6	25,649	298,244	122	4.8	0.4
25	4	Genesee	30.8	126,584	410,987	2,191	17.3	5.3
26	4	Gladwin	15.3	49,499	323,523	338	6.8	1.0
27	1	Gogebic	0.6	3,454	575,667	0	0.0	0.0
28	2	Grand Traverse	16.8	50,180	298,690	319	6.4	1.1
29	6	Gratiot	68.4	249,668	365,012	4,021	16.1	11.0
30	6	Hillsdale	50.8	196,210	386,240	4,397	22.4	11.4
31	1	Houghton	2.5	16,168	646,720	0	0.0	0.0
32	4	Huron	72.2	383,583	531,278	6,951	18.1	13.1
33	6	Ingham	48.1	172,277	358,164	3,315	19.2	9.3
34	3	Ionia	56.2	207,677	369,532	3,750	18.1	10.1
35	4	Iosco	7.7	26,892	349,247	277	10.3	0.8
36	1	Iron	2.2	16,376	744,371	0	0.0	0.0
37	4	Isabella	43.1	158,954	368,803	1,742	11.0	4.7
38	6	Jackson	35.7	160,981	450,927	3,015	18.7	6.7
39	5	Kalamazoo	36.8	132,533	360,144	2,921	22.0	8.1
40	2	Kalkaska	3.0	10,741	358,033	73	6.8	0.2
41	3	Kent	29.6	163,275	551,605	2,262	13.9	4.1
42	1	Keweenaw	0.0	0	347,827	0	0.0	0.0
43	3	Lake	3.0	11,004	366,800	16	1.4	0.0
44	4	Lapeer	41.6	175,050	420,793	3,170	18.1	7.5
45	2	Leelanau	17.9	39,218	219,095	154	3.9	0.7
46	6	Lenawee	64.4	310,342	481,898	6,254	20.2	13.0
47	6	Livingston	27.2	99,835	367,040	1,684	16.9	4.6
48	1	Luce	1.4	5,787	413,357	0	0.0	0.0
49	1	Mackinac	2.2	14,635	665,227	1	0.0	0.0
50	7	Macomb	22.1	68,255	308,846	876	12.8	2.8
51	2	Manistee	8.4	29,246	348,167	90	3.1	0.3
52	1	Marquette	0.9	10,527	1,169,667	0	0.0	0.0
53	3	Mason	17.9	56,687	316,687	412	7.3	1.3
54	3	Mecosta	25.0	89,564	358,256	653	7.3	1.8

Table 10
Pesticide(Dicamba)
Used
in Michigan

CC	RE	County	Percent Cropland	Acres of Total Cropland	Total Acres of Land	Total Dicamba Applied (lb)	Dicamba per Cropland (lb/ 1000acre)	Dicamba per Totalland (lb/ 1000acre)
55	1	Menominee	9.5	63,542	668,863	354	5.6	0.5
56	4	Midland	22.3	74,957	336,130	1,175	15.7	3.5
57	2	Missaukee	17.1	61,912	362,058	283	4.6	0.8
58	7	Monroe	57.2	203,774	356,248	3,321	16.3	9.3
59	3	Montcalm	40.9	186,322	455,555	2,347	12.6	5.2
60	2	Montmorency	4.3	15,004	348,930	52	3.4	0.1
61	3	Muskegon	17.5	56,910	325,200	956	16.8	2.9
62	3	Newaygo	15.6	84,764	543,359	925	10.9	1.7
63	7	Oakland	8.5	47,708	561,271	652	13.7	1.2
64	3	Oceana	24.8	85,922	346,460	451	5.3	1.3
65	4	Ogemaw	14.7	53,732	365,524	387	7.2	1.1
66	1	Ontonagon	2.0	16,776	838,800	0	0.0	0.0
67	3	Osceola	20.6	75,019	364,170	200	2.7	0.5
68	2	Oscoda	2.9	10,679	368,241	21	2.0	0.1
69	2	Otsego	5.5	18,017	327,582	41	2.3	0.1
70	3	Ottawa	40.3	146,152	362,660	1,943	13.3	5.4
71	2	Presque Isle	12.3	51,610	419,593	61	1.2	0.1
72	4	Roscommon	1.0	2,362	236,200	0	0.0	0.0
73	4	Saginaw	53.1	277,062	521,774	4,173	15.1	8.0
76	4	Sanilac	63.3	390,529	616,949	5,279	13.5	8.6
77	1	Schoolcraft	1.7	9,323	548,412	0	0.0	0.0
78	6	Shiawassee	58.7	203,050	345,911	2,592	12.8	7.5
74	7	St. Clair	31.7	148,961	469,909	1,595	10.7	3.4
75	5	St. Joseph	55.9	179,703	321,472	5,584	31.1	17.4
79	4	Tuscola	56.6	294,089	519,592	4,791	16.3	9.2
80	5	Van Buren	37.8	147,853	391,146	1,723	11.7	4.4
81	6	Washtenaw	37.6	170,968	454,702	2,820	16.5	6.2
82	7	Wayne	4.8	19,024	396,333	158	8.3	0.4
83	2	Wexford	5.1	18,547	363,667	108	5.8	0.3
Total Michigan			23.0	8,186,638	35,557,933	122,933	15.0	3.5

Table 11
Pesticide(Methomyl)
Used
in Michigan

CC	RE	County	Percent Cropland	Acres of Total Cropland	Total Acres of Land	Total Methomyl Applied (lb)	Methomyl per Cropland (lb/ 1000acre)	Methomyl per Totalland (lb/ 1000acre)
01	2	Alcona	6.6	28,573	432,924	9	0.3	0.0
02	1	Alger	1.9	9,426	496,105	1	0.1	0.0
03	5	Allegan	38.6	205,385	532,085	2,764	13.5	5.2
04	2	Alpena	15.1	54,767	362,695	22	0.4	0.1
05	2	Antrim	11.2	34,493	307,973	16	0.5	0.1
06	4	Arenac	29.6	69,511	234,834	58	0.8	0.2
07	1	Baraga	1.5	7,447	496,467	0	0.0	0.0
08	5	Barry	35.9	128,641	358,331	128	1.0	0.4
09	4	Bay	56.3	161,157	286,247	123	0.8	0.4
10	2	Benzie	6.1	12,665	207,623	682	53.9	3.3
11	5	Berrien	40.7	150,082	368,752	5,939	39.6	16.1
12	5	Branch	55.1	179,034	324,926	113	0.6	0.3
13	5	Calhoun	42.6	193,816	454,967	266	1.4	0.6
14	5	Cass	47.8	151,655	317,270	996	6.6	3.1
15	2	Charleviox	9.1	24,558	269,868	1	0.0	0.0
16	2	Cheboygan	5.6	25,803	460,768	3	0.1	0.0
17	1	Chippewa	6.4	65,394	1,021,781	5	0.1	0.0
18	4	Clare	13.2	47,994	363,591	23	0.5	0.1
19	6	Clinton	59.9	219,621	366,646	478	2.2	1.3
20	2	Crawford	0.2	715	357,652	0	0.0	0.0
21	1	Delta	6.3	37,828	600,444	3	0.1	0.0
22	1	Dickinson	3.0	14,927	497,567	0	0.0	0.0
23	6	Eaton	50.7	188,024	370,856	300	1.6	0.8
24	2	Emmet	8.6	25,649	298,244	1	0.0	0.0
25	4	Genesee	30.8	126,584	410,987	202	1.6	0.5
26	4	Gladwin	15.3	49,499	323,523	41	0.8	0.1
27	1	Gogebic	0.6	3,454	575,667	0	0.0	0.0
28	2	Grand Traverse	16.8	50,180	298,690	724	14.4	2.4
29	6	Gratiot	68.4	249,668	365,012	204	0.8	0.6
30	6	Hillsdale	50.8	196,210	386,240	279	1.4	0.7
31	1	Houghton	2.5	16,168	646,720	1	0.1	0.0
32	4	Huron	72.2	383,583	531,278	410	1.1	0.8
33	6	Ingham	48.1	172,277	358,164	270	1.6	0.8
34	3	Ionia	56.2	207,677	369,532	1,550	7.5	4.2
35	4	Iosco	7.7	26,892	349,247	19	0.7	0.1
36	1	Iron	2.2	16,376	744,371	1	0.1	0.0
37	4	Isabella	43.1	158,954	368,803	152	1.0	0.4
38	6	Jackson	35.7	160,981	450,927	312	1.9	0.7
39	5	Kalamazoo	36.8	132,533	360,144	552	4.2	1.5
40	2	Kalkaska	3.0	10,741	358,033	8	0.7	0.0
41	3	Kent	29.6	163,275	551,605	7,796	47.7	14.1
42	1	Keweenaw	0.0	0	347,827	0	0.0	0.0
43	3	Lake	3.0	11,004	366,800	6	0.6	0.0
44	4	Lapeer	41.6	175,050	420,793	592	3.4	1.4
45	2	Leelanau	17.9	39,218	219,095	1,123	28.6	5.1
46	6	Lenawee	64.4	310,342	481,898	359	1.2	0.7
47	6	Livingston	27.2	99,835	367,040	88	0.9	0.2
48	1	Luce	1.4	5,787	413,357	1	0.1	0.0
49	1	Mackinac	2.2	14,635	665,227	1	0.1	0.0
50	7	Macomb	22.1	68,255	308,846	688	10.1	2.2
51	2	Manistee	8.4	29,246	348,167	1,024	35.0	2.9
52	1	Marquette	0.9	10,527	1,169,667	0	0.0	0.0
53	3	Mason	17.9	56,687	316,687	967	17.1	3.1
54	3	Mecosta	25.0	89,564	358,256	34	0.4	0.1

Table 11
Pesticide(Methomyl)
Used
in Michigan

CC	RE	County	Percent Cropland	Acres of Total Cropland	Total Acres of Land	Total Methomyl Applied (lb)	Methomyl per Cropland (lb/ 1000acre)	Methomyl per Totalland (lb/ 1000acre)
55	1	Menominee	9.5	63,542	668,863	1	0.0	0.0
56	4	Midland	22.3	74,957	336,130	37	0.5	0.1
57	2	Missaukee	17.1	61,912	362,058	6	0.1	0.0
58	7	Monroe	57.2	203,774	356,248	259	1.3	0.7
59	3	Montcalm	40.9	186,322	455,555	237	1.3	0.5
60	2	Montmorency	4.3	15,004	348,930	7	0.4	0.0
61	3	Muskegon	17.5	56,910	325,200	2,271	39.9	7.0
62	3	Newaygo	15.6	84,764	543,359	1,569	18.5	2.9
63	7	Oakland	8.5	47,708	561,271	66	1.4	0.1
64	3	Oceana	24.8	85,922	346,460	2,028	23.6	5.9
65	4	Ogemaw	14.7	53,732	365,524	19	0.4	0.1
66	1	Ontonagon	2.0	16,776	838,800	1	0.1	0.0
67	3	Osceola	20.6	75,019	364,170	11	0.1	0.0
68	2	Oscoda	2.9	10,679	368,241	0	0.0	0.0
69	2	Otsego	5.5	18,017	327,582	6	0.3	0.0
70	3	Ottawa	40.3	146,152	362,660	5,397	36.9	14.9
71	2	Presque Isle	12.3	51,610	419,593	15	0.3	0.0
72	4	Roscommon	1.0	2,362	236,200	0	0.0	0.0
73	4	Saginaw	53.1	277,062	521,774	429	1.5	0.8
76	4	Sanilac	63.3	390,529	616,949	659	1.7	1.1
77	1	Schoolcraft	1.7	9,323	548,412	1	0.1	0.0
78	6	Shiawassee	58.7	203,050	345,911	283	1.4	0.8
74	7	St. Clair	31.7	148,961	469,909	305	2.0	0.6
75	5	St. Joseph	55.9	179,703	321,472	86	0.5	0.3
79	4	Tuscola	56.6	294,089	519,592	306	1.0	0.6
80	5	Van Buren	37.8	147,853	391,146	6,728	45.5	17.2
81	6	Washtenaw	37.6	170,968	454,702	456	2.7	1.0
82	7	Wayne	4.8	19,024	396,333	139	7.3	0.4
83	2	Wexford	5.1	18,547	363,667	11	0.6	0.0
Total Michigan			23.0	8,186,638	35,557,933	50,658	6.2	1.4

Table 12
Pesticide(Metolachlor)
Used
in Michigan

CC	RE	County	Percent Cropland	Acres of Total Cropland	Total Acres of Land	Total Metolachlo Applied (lb)	Metolachlo per Cropland (lb/ 1000acre)	Metolachlo per Totalland (lb/ 1000acre)
01	2	Alcona	6.6	28,573	432,924	1,046	36.6	2.4
02	1	Alger	1.9	9,426	496,105	0	0.0	0.0
03	5	Allegan	38.6	205,385	532,085	36,478	177.6	68.6
04	2	Alpena	15.1	54,767	362,695	4,729	86.3	13.0
05	2	Antrim	11.2	34,493	307,973	2,194	63.6	7.1
06	4	Arenac	29.6	69,511	234,834	13,953	200.7	59.4
07	1	Baraga	1.5	7,447	496,467	0	0.0	0.0
08	5	Barry	35.9	128,641	358,331	18,322	142.4	51.1
09	4	Bay	56.3	161,157	286,247	36,614	227.2	127.9
10	2	Benzie	6.1	12,665	207,623	576	45.5	2.8
11	5	Berrien	40.7	150,082	368,752	25,135	167.5	68.2
12	5	Branch	55.1	179,034	324,926	47,416	264.8	145.9
13	5	Calhoun	42.6	193,816	454,967	38,472	198.5	84.6
14	5	Cass	47.8	151,655	317,270	36,498	240.7	115.0
15	2	Charleviox	9.1	24,558	269,868	1,807	73.6	6.7
16	2	Cheboygan	5.6	25,803	460,768	770	29.8	1.7
17	1	Chippewa	6.4	65,394	1,021,781	0	0.0	0.0
18	4	Clare	13.2	47,994	363,591	2,370	49.4	6.5
19	6	Clinton	59.9	219,621	366,646	40,787	185.7	111.2
20	2	Crawford	0.2	715	357,652	0	0.0	0.0
21	1	Delta	6.3	37,828	600,444	2,264	59.9	3.8
22	1	Dickinson	3.0	14,927	497,567	864	57.9	1.7
23	6	Eaton	50.7	188,024	370,856	38,263	203.5	103.2
24	2	Emmet	8.6	25,649	298,244	1,350	52.6	4.5
25	4	Genesee	30.8	126,584	410,987	22,898	180.9	55.7
26	4	Gladwin	15.3	49,499	323,523	4,357	88.0	13.5
27	1	Gogebic	0.6	3,454	575,667	0	0.0	0.0
28	2	Grand Traverse	16.8	50,180	298,690	3,308	65.9	11.1
29	6	Gratiot	68.4	249,668	365,012	60,680	243.0	166.2
30	6	Hillsdale	50.8	196,210	386,240	42,662	217.4	110.5
31	1	Houghton	2.5	16,168	646,720	5	0.3	0.0
32	4	Huron	72.2	383,583	531,278	114,498	298.5	215.5
33	6	Ingham	48.1	172,277	358,164	33,312	193.4	93.0
34	3	Ionia	56.2	207,677	369,532	39,607	190.7	107.2
35	4	Iosco	7.7	26,892	349,247	3,553	132.1	10.2
36	1	Iron	2.2	16,376	744,371	83	5.0	0.1
37	4	Isabella	43.1	158,954	368,803	26,410	166.1	71.6
38	6	Jackson	35.7	160,981	450,927	29,512	183.3	65.4
39	5	Kalamazoo	36.8	132,533	360,144	27,093	204.4	75.2
40	2	Kalkaska	3.0	10,741	358,033	900	83.8	2.5
41	3	Kent	29.6	163,275	551,605	22,941	140.5	41.6
42	1	Keweenaw	0.0	0	347,827	0	0.0	0.0
43	3	Lake	3.0	11,004	366,800	240	21.8	0.7
44	4	Lapeer	41.6	175,050	420,793	31,969	182.6	76.0
45	2	Leelanau	17.9	39,218	219,095	1,680	42.8	7.7
46	6	Lenawee	64.4	310,342	481,898	67,370	217.1	139.8
47	6	Livingston	27.2	99,835	367,040	15,660	156.9	42.7
48	1	Luce	1.4	5,787	413,357	63	10.9	0.2
49	1	Mackinac	2.2	14,635	665,227	0	0.0	0.0
50	7	Macomb	22.1	68,255	308,846	10,785	158.0	34.9
51	2	Manistee	8.4	29,246	348,167	1,456	49.8	4.2
52	1	Marquette	0.9	10,527	1,169,667	38	3.6	0.0
53	3	Mason	17.9	56,687	316,687	4,886	86.2	15.4
54	3	Mecosta	25.0	89,564	358,256	6,925	77.3	19.3

Table 12
Pesticide(Metolachlor)
Used
in Michigan

CC	RE	County	Percent Cropland	Acres of Total Cropland	Total Acres of Land	Total Metolachlo Applied (lb)	Metolachlo per Cropland (lb/ 1000acre)	Metolachlo per Totalland (lb/ 1000acre)
55	1	Menominee	9.5	63,542	668,863	6,144	96.7	9.2
56	4	Midland	22.3	74,957	336,130	19,769	263.7	58.8
57	2	Missaukee	17.1	61,912	362,058	5,623	90.8	15.5
58	7	Monroe	57.2	203,774	356,248	40,903	200.7	114.8
59	3	Montcalm	40.9	186,322	455,555	34,021	182.6	74.7
60	2	Montmorency	4.3	15,004	348,930	1,648	109.9	4.7
61	3	Muskegon	17.5	56,910	325,200	8,698	152.8	26.7
62	3	Newaygo	15.6	84,764	543,359	10,604	125.1	19.5
63	7	Oakland	8.5	47,708	561,271	5,478	114.8	9.8
64	3	Oceana	24.8	85,922	346,460	4,530	52.7	13.1
65	4	Ogemaw	14.7	53,732	365,524	4,685	87.2	12.8
66	1	Ontonagon	2.0	16,776	838,800	0	0.0	0.0
67	3	Osceola	20.6	75,019	364,170	4,202	56.0	11.5
68	2	Oscoda	2.9	10,679	368,241	432	40.5	1.2
69	2	Otsego	5.5	18,017	327,582	997	55.3	3.0
70	3	Ottawa	40.3	146,152	362,660	19,975	136.7	55.1
71	2	Presque Isle	12.3	51,610	419,593	4,238	82.1	10.1
72	4	Roscommon	1.0	2,362	236,200	0	0.0	0.0
73	4	Saginaw	53.1	277,062	521,774	61,511	222.0	117.9
76	4	Sanilac	63.3	390,529	616,949	71,139	182.2	115.3
77	1	Schoolcraft	1.7	9,323	548,412	0	0.0	0.0
78	6	Shiawassee	58.7	203,050	345,911	33,941	167.2	98.1
74	7	St. Clair	31.7	148,961	469,909	18,166	121.9	38.7
75	5	St. Joseph	55.9	179,703	321,472	50,136	279.0	156.0
79	4	Tuscola	56.6	294,089	519,592	65,205	221.7	125.5
80	5	Van Buren	37.8	147,853	391,146	16,193	109.5	41.4
81	6	Washtenaw	37.6	170,968	454,702	26,857	157.1	59.1
82	7	Wayne	4.8	19,024	396,333	2,413	126.8	6.1
83	2	Wexford	5.1	18,547	363,667	1,229	66.3	3.4
Total Michigan			23.0	8,186,638	35,557,933	1,441,533	176.1	40.5

Table 13
Fertilizer(Nitrogen)
Used
in Michigan

CC	RE	County	Percent Cropland	Acres of Total Cropland (Acres)	Total Acres of Land (Acres)	Total Nitrogen Applied (lb)	Nitrogen per Cropland (lb/acre)	Nitrogen per Totalland (lb/acre)
01	2	Alcona	6.6	28,573	432,924	366,940	12.8	0.8
02	1	Alger	1.9	9,426	496,105	19,010	2.0	0.0
03	5	Allegan	38.6	205,385	532,085	10,501,320	51.1	19.7
04	2	Alpena	15.1	54,767	362,695	1,246,750	22.8	3.4
05	2	Antrim	11.2	34,493	307,973	864,030	25.0	2.8
06	4	Arenac	29.6	69,511	234,834	2,718,830	39.1	11.6
07	1	Baraga	1.5	7,447	496,467	23,300	3.1	0.0
08	5	Barry	35.9	128.641	358,331	5.328.950	41.4	14.9
09	4	Bay	56.3	161,157	286,247	6,367,470	39.5	22.2
10	2	Benzie	6.1	12,665	207,623	286,840	22.6	1.4
11	5	Berrien	40.7	150,082	368,752	7,792,360	51.9	21.1
12	5	Branch	55.1	179,034	324,926	11,850,480	66.2	36.5
13	5	Calhoun	42.6	193,816	454,967	10,860,680	56.0	23.9
14	5	Cass	47.8	151,655	317,270	9,592,570	63.3	30.2
15	2	Charlevoix	9.1	24,558	269,868	453,420	18.5	1.7
16	2	Cheboygan	5.6	25,803	460,768	215,560	8.4	0.5
17	1	Chippewa	6.4	65,394	1,021,781	147,150	2.3	0.1
18	4	Clare	13.2	47,994	363,591	783,050	16.3	2.2
19	6	Clinton	59.9	219,621	366,646	10,791,000	49.1	29.4
20	2	Crawford	0.2	715	357,652	0	0.0	0.0
21	1	Delta	6.3	37,828	600,444	609,180	16.1	1.0
22	1	Dickinson	3.0	14,927	497,567	385,990	25.9	0.8
23	6	Eaton	50.7	188,024	370,856	9,747,900	51.8	26.3
24	2	Emmet	8.6	25,649	298,244	455,960	17.8	1.5
25	4	Genesee	30.8	126,584	410,987	6,313,961	49.9	15.4
26	4	Gladwin	15.3	49,499	323,523	1,261,470	25.5	3.9
27	1	Gogebic	0.6	3,454	575,667	2,700	0.8	0.0
28	2	Grand Traverse	16.8	50,180	298,690	1,404,810	28.0	4.7
29	6	Gratiot	68.4	249,668	365,012	11,831,660	47.4	32.4
30	6	Hillsdale	50.8	196,210	386,240	11,065,875	56.4	28.7
31	1	Houghton	2.5	16,168	646,720	44,930	2.8	0.1
32	4	Huron	72.2	383,583	531,278	21,868,600	57.0	41.2
33	6	Ingham	48.1	172,277	358,164	9,359,260	54.3	26.1
34	3	Ionia	56.2	207,677	369,532	11,267,320	54.3	30.5
35	4	Iosco	7.7	26,892	349,247	1,097,660	40.8	3.1
36	1	Iron	2.2	16,376	744,371	129,630	7.9	0.2
37	4	Isabella	43.1	158,954	368,803	6,613,840	41.6	17.9
38	6	Jackson	35.7	160,981	450,927	8,446,350	52.5	18.7
39	5	Kalamazoo	36.8	132,533	360,144	7,360,330	55.5	20.4
40	2	Kalkaska	3.0	10,741	358,033	339,100	31.6	0.9
41	3	Kent	29.6	163,275	551,605	7,257,440	44.4	13.2
42	1	Keweenaw	0.0	0	347,827	0	0.0	0.0
43	3	Lake	3.0	11,004	366,800	81,350	7.4	0.2
44	4	Lapeer	41.6	175,050	420,793	8,732,980	49.9	20.8
45	2	Leelanau	17.9	39,218	219,095	982,130	25.0	4.5
46	6	Lenawee	64.4	310,342	481,898	17,338,000	55.9	36.0
47	6	Livingston	27.2	99,835	367,040	4,493,810	45.0	12.2
48	1	Luce	1.4	5,787	413,357	89,350	15.4	0.2
49	1	Mackinac	2.2	14,635	665,227	34,480	2.4	0.1
50	7	Macomb	22.1	68,255	308,846	2,967,370	43.5	9.6
51	2	Manistee	8.4	29,246	348,167	540,930	18.5	1.6
52	1	Marquette	0.9	10,527	1,169,667	58,000	5.5	0.0
53	3	Mason	17.9	56,687	316,687	2,014,790	35.5	6.4
54	3	Mecosta	25.0	89,564	358,256	2,055,430	22.9	5.7
55	1	Menominee	9.5	63,542	668,863	1,684,530	26.5	2.5

Table 13
Fertilizer(Nitrogen)
Used
in Michigan

CC	RE	County	Percent Cropland	Acres of Total Cropland (Acres)	Total Acres of Land (Acres)	Total Nitrogen Applied (lb)	Nitrogen per Cropland (lb/acre)	Nitrogen per Totalland (lb/acre)
01	2	Alcona	6.6	28,573	432,924	366,940	12.8	0.8
56	4	Midland	22.3	74,957	336,130	3,054,920	40.8	9.1
57	2	Missaukee	17.1	61,912	362,058	1,579,670	25.5	4.4
58	7	Monroe	57.2	203,774	356,248	9,900,340	48.6	27.8
59	3	Montcalm	40.9	186,322	455,555	8,856,770	47.5	19.4
60	2	Montmorency	4.3	15,004	348,930	395,370	26.4	1.1
61	3	Muskegon	17.5	56,910	325,200	2,809,650	49.4	8.6
62	3	Newaygo	15.6	84,764	543,359	3,427,580	40.4	6.3
63	7	Oakland	8.5	47,708	561,271	1,624,550	34.1	2.9
64	3	Oceana	24.8	85,922	346,460	2,675,820	31.1	7.7
65	4	Ogemaw	14.7	53,732	365,524	1,433,010	26.7	3.9
66	1	Ontonagon	2.0	16,776	838,800	39,730	2.4	0.0
67	3	Osceola	20.6	75,019	364,170	1,192,400	15.9	3.3
68	2	Oscoda	2.9	10,679	368,241	113,320	10.6	0.3
69	2	Otsego	5.5	18,017	327,582	367,850	20.4	1.1
70	3	Ottawa	40.3	146,152	362,660	6,345,020	43.4	17.5
71	2	Presque Isle	12.3	51,610	419,593	1,085,450	21.0	2.6
72	4	Roscommon	1.0	2,362	236,200	1,200	0.5	0.0
73	4	Saginaw	53.1	277,062	521,774	12,166,320	43.9	23.3
76	4	Sanilac	63.3	390,529	616,949	19,224,150	49.2	31.2
77	1	Schoolcraft	1.7	9,323	548,412	33,840	3.6	0.1
78	6	Shiawassee	58.7	203,050	345,911	9,007,530	44.4	26.0
74	7	St. Clair	31.7	148,961	469,909	5,221,180	35.1	11.1
75	5	St. Joseph	55.9	179,703	321,472	12,301,140	68.5	38.3
79	4	Tuscola	56.6	294,089	519,592	13,229,760	45.0	25.5
80	5	Van Buren	37.8	147,853	391,146	5,731,040	38.8	14.7
81	6	Washtenaw	37.6	170,968	454,702	8,023,290	46.9	17.6
82	7	Wayne	4.8	19,024	396,333	649,700	34.2	1.6
83	2	Wexford	5.1	18,547	363,667	480,060	25.9	1.3
Total Michigan			23.0	8,186,638	35,557,933	369,117,486	45.1	10.4

Table 14
Pesticide(Simazine)
Used
in Michigan

CC	RE	County	Percent Cropland	Acres of Total Cropland	Total Acres of Land	Total Simazine Applied (lb)	Simazine per Cropland (lb/ 1000acre)	Simazine per Totalland (lb/ 1000acre)
01	2	Alcona	6.6	28,573	432,924	56	2.0	0.1
02	1	Alger	1.9	9.426	496.105	0	0.0	0.0
03	5	Allegan	38.6	205,385	532,085	3.197	15.6	6.0
04	2	Alpena	15.1	54,767	362.695	164	3.0	0.5
05	2	Antrim	11.2	34,493	307,973	847	24.6	2.8
06	4	Arenac	29.6	69.511	234.834	404	5.8	1.7
07	1	Baraga	1.5	7.447	496,467	0	0.0	0.0
08	5	Barry	35.9	128,641	358.331	872	6.8	2.4
09	4	Bay	56.3	161,157	286.247	988	6.1	3.5
10	2	Benzie	6.1	12,665	207.623	721	56.9	3.5
11	5	Berrien	40.7	150,082	368.752	6.201	41.3	16.8
12	5	Branch	55.1	179,034	324,926	2,252	12.6	6.9
13	5	Calhoun	42.6	193.816	454.967	1,864	9.6	4.1
14	5	Cass	47.8	151,655	317.270	2,709	17.9	8.5
15	2	Charleviox	9.1	24.558	269,868	91	3.7	0.3
16	2	Cheboygan	5.6	25.803	460,768	35	1.4	0.1
17	1	Chippewa	6.4	65.394	1.021.781	0	0.0	0.0
18	4	Clare	13.2	47,994	363.591	122	2.5	0.3
19	6	Clinton	59.9	219,621	366.646	1,708	7.8	4.7
20	2	Crawford	0.2	715	357.652	0	0.0	0.0
21	1	Delta	6.3	37,828	600.444	66	1.8	0.1
22	1	Dickinson	3.0	14.927	497.567	38	2.5	0.1
23	6	Eaton	50.7	188.024	370.856	1,498	8.0	4.0
24	2	Emmet	8.6	25.649	298.244	68	2.6	0.2
25	4	Genesee	30.8	126.584	410.987	1.038	8.2	2.5
26	4	Gladwin	15.3	49,499	323.523	192	3.9	0.6
27	1	Gogebic	0.6	3.454	575,667	0	0.0	0.0
28	2	Grand Traverse	16.8	50.180	298.690	2,256	45.0	7.6
29	6	Gratiot	68.4	249.668	365.012	1,964	7.9	5.4
30	6	Hillsdale	50.8	196.210	386.240	2,037	10.4	5.3
31	1	Houghton	2.5	16.168	646.720	0	0.0	0.0
32	4	Huron	72.2	383,583	531,278	3.718	9.7	7.0
33	6	Ingham	48.1	172,277	358,164	1,550	9.0	4.3
34	3	Ionia	56.2	207.677	369,532	2.103	10.1	5.7
35	4	Iosco	7.7	26,892	349.247	190	7.1	0.5
36	1	Iron	2.2	16.376	744.371	0.	0.0	0.0
37	4	Isabella	43.1	158.954	368.803	1.166	7.3	3.2
38	6	Jackson	35.7	160.981	450.927	1.564	9.7	3.5
39	5	Kalamazoo	36.8	132.533	360.144	1,635	12.3	4.5
40	2	Kalkaska	3.0	10.741	358.033	46	4.2	0.1
41	3	Kent	29.6	163.275	551.605	3.393	20.8	6.2
42	1	Keweenaw	0.0	0	347,827	0	0.0	0.0
43	3	Lake	3.0	11.004	366.800	13	1.2	0.0
44	4	Lapeer	41.6	175.050	420.793	1.590	9.1	3.8
45	2	Leelanau	17.9	39.218	219.095	3.126	79.7	14.3
46	6	Lenawee	64.4	310.342	481.898	2.759	8.9	5.7
47	6	Livingston	27.2	99.835	367.040	794	8.0	2.2
48	1	Luce	1.4	5.787	413.357	0	0.0	0.0
49	1	Mackinac	2.2	14.635	665.227	0	0.0	0.0
50	7	Macomb	22.1	68.255	308.846	576	8.4	1.9
51	2	Manistee	8.4	29.246	348.167	1.581	54.0	4.5
52	1	Marquette	0.9	10.527	1.169.667	0	0.0	0.0
53	3	Mason	17.9	56.687	316.687	3.008	53.1	9.5
54	3	Mecosta	25.0	89.564	358.256	717	8.0	2.0

Table 14
Pesticide(Simazine)
Used
in Michigan

CC	RE	County	Percent Cropland	Acres of Total Cropland	Total Acres of Land	Total Simazine Applied (lb)	Simazine per Cropland (lb/ 1000acre)	Simazine per Totalland (lb/ 1000acre)
55	1	Menominee	9.5	63,542	668,863	333	5.2	0.5
56	4	Midland	22.3	74,957	336,130	520	6.9	1.5
57	2	Missaukee	17.1	61,912	362,058	302	4.9	0.8
58	7	Monroe	57.2	203,774	356,248	1,433	7.0	4.0
59	3	Montcalm	40.9	186,322	455,555	1,158	6.2	2.5
60	2	Montmorency	4.3	15,004	348,930	60	4.0	0.2
61	3	Muskegon	17.5	56,910	325,200	1,723	30.3	5.3
62	3	Newaygo	15.6	84,764	543,359	1,239	14.6	2.3
63	7	Oakland	8.5	47,708	561,271	291	6.1	0.5
64	3	Oceana	24.8	85,922	346,460	14,033	163.3	40.5
65	4	Ogemaw	14.7	53,732	365,524	252	4.7	0.7
66	1	Ontonagon	2.0	16,776	838,800	0	0.0	0.0
67	3	Osceola	20.6	75,019	364,170	226	3.0	0.6
68	2	Oscoda	2.9	10,679	368,241	23	2.2	0.1
69	2	Otsego	5.5	18,017	327,582	38	2.1	0.1
70	3	Ottawa	40.3	146,152	362,660	3,247	22.2	9.0
71	2	Presque Isle	12.3	51,610	419,593	78	1.5	0.2
72	4	Roscommon	1.0	2,362	236,200	0	0.0	0.0
73	4	Saginaw	53.1	277,062	521,774	1,836	6.6	3.5
76	4	Sanilac	63.3	390,529	616,949	2,932	7.5	4.8
77	1	Schoolcraft	1.7	9,323	548,412	0	0.0	0.0
78	6	Shiawassee	58.7	203,050	345,911	1,185	5.8	3.4
74	7	St. Clair	31.7	148,961	469,909	755	5.1	1.6
75	5	St. Joseph	55.9	179,703	321,472	2,748	15.3	8.5
79	4	Tuscola	56.6	294,089	519,592	2,096	7.1	4.0
80	5	Van Buren	37.8	147,853	391,146	7,553	51.1	19.3
81	6	Washtenaw	37.6	170,968	454,702	1,350	7.9	3.0
82	7	Wayne	4.8	19,024	396,333	104	5.5	0.3
83	2	Wexford	5.1	18,547	363,667	65	3.5	0.2
Total Michigan			23.0	8,186,638	35,557,933	106,493	13.0	3.0

Table 15
Pesticides(not include Nitrogen)
Used
in Michigan(Summary)

CC	RE	County	Percent Cropland	Acres of Total Cropland	Total Acres of Land	Total Pesticides Applied (lb)	Pesticides per cropland (lb/ 1000acre)	Pesticides per Totalland (lb 1000acre)
01	2	Alcona	6.6	28,573	432,924	3,951	138	9
02	1	Alger	1.9	9,426	496,105	1	0	0
03	5	Allegan	38.6	205,385	532,085	141,622	690	266
04	2	Alpena	15.1	54,767	362,695	13,435	245	37
05	2	Antrim	11.2	34,493	307,973	8,652	251	28
06	4	Arenac	29.6	69,511	234,834	37,734	543	161
07	1	Baraga	1.5	7,447	496,467	0	0	0
08	5	Barry	35.9	128,641	358,331	68,260	531	190
09	4	Bay	56.3	161,157	286,247	98,979	614	346
10	2	Benzie	6.1	12,665	207,623	3,518	278	17
11	5	Berrien	40.7	150,082	368,752	103,980	693	282
12	5	Branch	55.1	179,034	324,926	177,437	991	546
13	5	Calhoun	42.6	193,816	454,967	144,463	745	318
14	5	Cass	47.8	151,655	317,270	140,300	925	442
15	2	Charleviox	9.1	24,558	269,868	6,468	263	24
16	2	Cheboygan	5.6	25,803	460,768	2,563	99	6
17	1	Chippewa	6.4	65,394	1,021,781	6	0	0
18	4	Clare	13.2	47,994	363,591	8,697	181	24
19	6	Clinton	59.9	219,621	366,646	144,537	658	394
20	2	Crawford	0.2	715	357,652	0	0	0
21	1	Delta	6.3	37,828	600,444	5,726	151	10
22	1	Dickinson	3.0	14,927	497,567	2,827	189	6
23	6	Eaton	50.7	188,024	370,856	128,526	684	347
24	2	Emmet	8.6	25,649	298,244	4,901	191	16
25	4	Genesee	30.8	126,584	410,987	84,377	667	205
26	4	Gladwin	15.3	49,499	323,523	14,915	301	46
27	1	Gogebic	0.6	3,454	575,667	0	0	0
28	2	Grand Traverse	16.8	50,180	298,690	16,020	319	54
29	6	Gratiot	68.4	249,668	365,012	187,655	752	514
30	6	Hillsdale	50.8	196,210	386,240	159,414	812	413
31	1	Houghton	2.5	16,168	646,720	19	1	0
32	4	Huron	72.2	383,583	531,278	312,438	815	588
33	6	Ingham	48.1	172,277	358,164	123,232	715	344
34	3	Ionia	56.2	207,677	369,532	143,132	689	387
35	4	Iosco	7.7	26,892	349,247	13,429	499	38
36	1	Iron	2.2	16,376	744,371	107	7	0
37	4	Isabella	43.1	158,954	368,803	87,381	550	237
38	6	Jackson	35.7	160,981	450,927	111,568	693	247
39	5	Kalamazoo	36.8	132,533	360,144	102,081	770	283
40	2	Kalkaska	3.0	10,741	358,033	3,270	304	9
41	3	Kent	29.6	163,275	551,605	94,114	576	171
42	1	Keweenaw	0.0	0	347,827	0	0	0
43	3	Lake	3.0	11,004	366,800	911	83	2
44	4	Lapeer	41.6	175,050	420,793	113,059	646	269
45	2	Leelanau	17.9	39,218	219,095	10,539	269	48
46	6	Lenawee	64.4	310,342	481,898	245,952	793	510
47	6	Livingston	27.2	99,835	367,040	58,997	591	161
48	1	Luce	1.4	5,787	413,357	81	14	0
49	1	Mackinac	2.2	14,635	665,227	2	0	0
50	7	Macomb	22.1	68,255	308,846	39,801	583	129
51	2	Manistee	8.4	29,246	348,167	6,615	226	19
52	1	Marquette	0.9	10,527	1,169,667	48	5	0
53	3	Mason	17.9	56,687	316,687	23,066	407	73
54	3	Mecosta	25.0	89,564	358,256	24,780	277	69

Table 15
Pesticides(not include Nitrogen)
Used
in Michigan(Summary)

CC	RE	County	Percent Cropland	Acres of Total Cropland	Total Acres of Land	Total Pesticides Applied (lb)	Pesticides per cropland (lb/ 1000acre)	Pesticides per Totalland (lb 1000acre)
55	1	Menominee	9.5	63.542	668.863	23.114	364	35
56	4	Midland	22.3	74.957	336,130	53,797	718	160
57	2	Missaukee	17.1	61,912	362.058	21,001	339	58
58	7	Monroe	57.2	203,774	356.248	145,879	716	409
59	3	Montcalm	40.9	186,322	455,555	98,577	529	216
60	2	Montmorency	4.3	15.004	348,930	4,778	318	14
61	3	Muskegon	17.5	56.910	325,200	36,620	643	113
62	3	Newaygo	15.6	84,764	543.359	42,103	497	77
63	7	Oakland	8.5	47,708	561.271	20,951	439	37
64	3	Oceana	24.8	85,922	346.460	33,837	394	98
65	4	Ogemaw	14.7	53.732	365.524	17,743	330	49
66	1	Ontonagon	2.0	16.776	838.800	1	0	0
67	3	Osceola	20.6	75.019	364.170	15.759	210	43
68	2	Oscoda	2.9	10,679	368.241	1.622	152	4
69	2	Otsego	5.5	18,017	327.582	2.969	165	9
70	3	Ottawa	40.3	146,152	362.660	83.275	570	230
71	2	Presque Isle	12.3	51.610	419.593	8.323	161	20
72	4	Roscommon	1.0	2.362	236.200	0	0	0
73	4	Saginaw	53.1	277.062	521.774	196.646	710	377
76	4	Sanilac	63.3	390.529	616,949	238.170	610	386
77	1	Schoolcraft	1.7	9.323	548.412	1	0	0
78	6	Shiawassee	58.7	203.050	345.911	119.019	586	344
74	7	St. Clair	31.7	148.961	469.909	64.582	434	137
75	5	St. Joseph	55.9	179.703	321.472	188,419	1.049	586
79	4	Tuscola	56.6	294.089	519.592	188.980	643	364
80	5	Van Buren	37.8	147.853	391.146	74.844	506	191
81	6	Washtenaw	37.6	170.968	454.702	101,102	591	222
82	7	Wayne	4.8	19.024	396,333	8,964	471	23
83	2	Wexford	5.1	18.547	363.667	5.129	277	14
Total		Michigan	23.0	8,186.638	35.557.933	5.019.793	613	141

Table 16
Pesticides and Nitrogen
Used
in Michigan(Summary)

CC	RE	County	Percent Cropland	Acres of Total Cropland	Total Acres of Land	Total Pesticides Applied (lb)	Pesticides per corpland (lb/acre)	Pesticides per Totalland (lb/acre)
01	2	Alcona	6.6	28,573	432,924	370,891	13.0	0.9
02	1	Alger	1.9	9,426	496,105	19,011	2.0	0.0
03	5	Allegan	38.6	205,385	532,085	10,642,942	51.8	20.0
04	2	Alpena	15.1	54,767	362,695	1,260,185	23.0	3.5
05	2	Antrim	11.2	34,493	307,973	872,682	25.3	2.8
06	4	Arenac	29.6	69,511	234,834	2,756,564	39.7	11.7
07	1	Baraga	1.5	7,447	496,467	23,300	3.1	0.0
08	5	Barry	35.9	128,641	358,331	5,397,210	42.0	15.1
09	4	Bay	56.3	161,157	286,247	6,466,449	40.1	22.6
10	2	Benzie	6.1	12,665	207,623	290,358	22.9	1.4
11	5	Berrien	40.7	150,082	368,752	7,896,340	52.6	21.4
12	5	Branch	55.1	179,034	324,926	12,027,917	67.2	37.0
13	5	Calhoun	42.6	193,816	454,967	11,005,143	56.8	24.2
14	5	Cass	47.8	151,655	317,270	9,732,870	64.2	30.7
15	2	Charlevìox	9.1	24,558	269,868	459,888	18.7	1.7
16	2	Cheboygan	5.6	25,803	460,768	218,123	8.5	0.5
17	1	Chippewa	6.4	65,394	1,021,781	147,156	2.3	0.1
18	4	Clare	13.2	47,994	363,591	791,747	16.5	2.2
19	6	Clinton	59.9	219,621	366,646	10,935,537	49.8	29.8
20	2	Crawford	0.2	715	357,652	0	0.0	0.0
21	1	Delta	6.3	37,828	600,444	614,906	16.3	1.0
22	1	Dickinson	3.0	14,927	497,567	388,817	26.0	0.8
23	6	Eaton	50.7	188,024	370,856	9,876,426	52.5	26.6
24	2	Emmet	8.6	25,649	298,244	460,861	18.0	1.5
25	4	Genesee	30.8	126,584	410,987	6,398,338	50.5	15.6
26	4	Gladwin	15.3	49,499	323,523	1,276,385	25.8	3.9
27	1	Gogebic	0.6	3,454	575,667	2,700	0.8	0.0
28	2	Grand Traverse	16.8	50,180	298,690	1,420,830	28.3	4.8
29	6	Gratiot	68.4	249,668	365,012	12,019,315	48.1	32.9
30	6	Hillsdale	50.8	196,210	386,240	11,225,289	57.2	29.1
31	1	Houghton	2.5	16,168	646,720	44,949	2.8	0.1
32	4	Huron	72.2	383,583	531,278	22,181,038	57.8	41.8
33	6	Ingham	48.1	172,277	358,164	9,482,492	55.0	26.5
34	3	Ionia	56.2	207,677	369,532	11,410,452	54.9	30.9
35	4	Iosco	7.7	26,892	349,247	1,111,089	41.3	3.2
36	1	Iron	2.2	16,376	744,371	129,737	7.9	0.2
37	4	Isabella	43.1	158,954	368,803	6,701,221	42.2	18.2
38	6	Jackson	35.7	160,981	450,927	8,557,918	53.2	19.0
39	5	Kalamazoo	36.8	132,533	360,144	7,462,411	56.3	20.7
40	2	Kalkaska	3.0	10,741	358,033	342,370	31.9	1.0
41	3	Kent	29.6	163,275	551,605	7,351,554	45.0	13.3
42	1	Keweenaw	0.0	0	347,827	0	0.0	0.0
43	3	Lake	3.0	11,004	366,800	82,261	7.5	0.2
44	4	Lapeer	41.6	175,050	420,793	8,846,039	50.5	21.0
45	2	Leelanau	17.9	39,218	219,095	992,669	25.3	4.5
46	6	Lenawee	64.4	310,342	481,898	17,583,952	56.7	36.5
47	6	Livingston	27.2	99,835	367,040	4,552,807	45.6	12.4
48	1	Luce	1.4	5,787	413,357	89,431	15.5	0.2
49	1	Mackinac	2.2	14,635	665,227	34,482	2.4	0.1
50	7	Macomb	22.1	68,255	308,846	3,007,171	44.1	9.7
51	2	Manistee	8.4	29,246	348,167	547,545	18.7	1.6
52	1	Marquette	0.9	10,527	1,169,667	58,048	5.5	0.0
53	3	Mason	17.9	56,687	316,687	2,037,856	35.9	6.4
54	3	Mecosta	25.0	89,564	358,256	2,080,210	23.2	5.8

Table 16
Pesticides and Nitrogen
Used
in Michigan(Summary)

CC	RE	County	Percent Cropland	Acres of Total Cropland	Total Acres of Land	Total Pesticides Applied (lb)	Pesticides per corpland (lb/acre)	Pesticides per Totalland (lb/acre)
55	1	Menominee	9.5	63,542	668,863	1,707,644	26.9	2.6
56	4	Midland	22.3	74,957	336,130	3,108,717	41.5	9.2
57	2	Missaukee	17.1	61,912	362,058	1,600,671	25.9	4.4
58	7	Monroe	57.2	203,774	356,248	10,046,219	49.3	28.2
59	3	Montcalm	40.9	186,322	455,555	8,955,347	48.1	19.7
60	2	Montmorency	4.3	15,004	348,930	400,148	26.7	1.1
61	3	Muskegon	17.5	56,910	325,200	2,846,270	50.0	8.8
62	3	Newaygo	15.6	84,764	543,359	3,469,683	40.9	6.4
63	7	Oakland	8.5	47,708	561,271	1,645,501	34.5	2.9
64	3	Oceana	24.8	85,922	346,460	2,709,657	31.5	7.8
65	4	Ogemaw	14.7	53,732	365,524	1,450,753	27.0	4.0
66	1	Ontonagon	2.0	16,776	838,800	39,731	2.4	0.0
67	3	Osceola	20.6	75,019	364,170	1,208,159	16.1	3.3
68	2	Oscoda	2.9	10,679	368,241	114,942	10.8	0.3
69	2	Otsego	5.5	18,017	327,582	370,819	20.6	1.1
70	3	Ottawa	40.3	146,152	362,660	6,428,295	44.0	17.7
71	2	Presque Isle	12.3	51,610	419,593	1,093,773	21.2	2.6
72	4	Roscommon	1.0	2,362	236,200	1,200	0.5	0.0
73	4	Saginaw	53.1	277,062	521,774	12,362,966	44.6	23.7
76	4	Sanilac	63.3	390,529	616,949	19,462,320	49.8	31.5
77	1	Schoolcraft	1.7	9,323	548,412	33,841	3.6	0.1
78	6	Shiawassee	58.7	203,050	345,911	9,126,549	44.9	26.4
74	7	St. Clair	31.7	148,961	469,909	5,285,762	35.5	11.2
75	5	St. Joseph	55.9	179,703	321,472	12,489,559	69.5	38.9
79	4	Tuscola	56.6	294,089	519,592	13,418,740	45.6	25.8
80	5	Van Buren	37.8	147,853	391,146	5,805,884	39.3	14.8
81	6	Washtenaw	37.6	170,968	454,702	8,124,392	47.5	17.9
82	7	Wayne	4.8	19,024	396,333	658,664	34.6	1.7
83	2	Wexford	5.1	18,547	363,667	485,189	26.2	1.3
Total		Michigan	23.0	8,186,638	35,557,933	374,137,279	45.7	10.5

APPENDIX D

THE RESULTS OF ASI & SRI SEARCH

Table 17. Results of ASI and SRI query for information on pesticide use

Index	Citation	Comment
ASI	The overview of consumption of fertilize by type and state,1991	General information on fertilizers consumed by type and state from 1990 to 1991
ASI	Onion farm acreage, pesticide use, operators, and other characteristics, for 6 producer stat (CA,CO,ID,MI,NY,OR),1989	Information on percent of 1989 onion acres treated with pesticides (herbicides, insecticides, fungicides, sprout inhibitors) in six surveyed states (CA, CO, ID, MI, NY, OR)
ASI	Consumption of pesticides by type, by crop, active ingredient, and region, and impact of bans on producer and consumer costs,1950s-88	Information on proportion of planted corn and soybean acreage treated with major herbicides, insecticides, by different tillage practices (no-till, reduced-till, conventional-till) in 1980, 1982; information on overall review of proportion of selected insecticide types used on major crops and cotton
ASI	Cotton pesticide use, costs, toxicity, and application rates,and losses from pests by type and state,1981-1984	Information on cotton pesticide use, toxicity indices for each active chemical ingredients, and application rate (pounds of active ingredients of pest control chemicals per harvested acre) in several states
ASI	Ban on pesticides effects on corn and soybean production, prices, and profits, by pesticide type and region, model results,1986	Information on average cost and yield changes from banning foliar insecticides on soybeans, average cost and yield changes from banning foliar insecticides or nematicides on corn and soybeans, and average cost and yield changes from banning foliar fungicides on soybeans by region (appalachia, corn belt, delta, northeast, southeast)
ASI	Field crop pesticide use, by type of pest and pesticide, crop, and region, selected years 1976-80	Information on field crop pesticide use, by type of pest (pest category and target pest: diseases, insects, weeds, other pests such as nematodes, gophers, birds, etc) and pesticide and crop (corn, soybean, cotton, wheat, small grains, sorghum, tobacco, alfalfa and hay), and region (total, northeast, south, corn belt, lake states, northern plains, southwest and west) and information on share of acre treatments directed at target pest (share of acre treatments within pest category, application per acre treated, share of planted acres treated in pest category), 1976-80
ASI	Fruit crop pesticide use, by type of pest and pesticide, crop and region,1977-78	Information on fruit crop pesticide use, by type of pest (pest category and target pest: diseases, insects, weeds, other pests such as rats, nematodes, rabbits, field mice, etc) and pesticide and crop (orange, grapefruit, lemon, other citrus crop), and region (Florida, Texas, Arizona-California) and information on share of acre treatments directed at target pest (share of acre treatments within pest category, application per acre treated, share of planted acres treated in pest category), in 1977; information on apple, peach, pear, tart cherry target pests and share of planted acres treated by region (northeast, south, north central and west) in 1978
ASI	Water pollution from pesticides and fertilizer, and farm population health effects, 1950s-85, hearing	Information on summary of nitrate-nitrogen concentration in groundwater, by states and concentration of toxic organic compounds found in drinking water wells and surface water; information on organic compound (Trichloroethylene, Tetrachloroethylene, 1,1,1-Trichloroethane, etc) found in groundwater as reported by 18 states and pesticides found in groundwater of 23 states by pesticide type, and typical positive ppb
ASI	Water pollution from pesticides and fertilizer, population affected by state, and monitoring and remedial costs, 1987 rpt	Information on trends in agricultural pesticide use by class, 1964-84 and pesticides analysis that include pesticides in high-priority categories for EPA national survey of pesticides in well water; information on population served by all public water supplies in potentially contaminated areas, by state
SRI	Michigan fertilizer and pesticide use, by chemical and crop, 1992, annual rpt	Information on corn and fall potato fertilizer and chemical usage in Michigan; information on pesticide applications on vegetables in Michigan
SRI	Missouri herbicide and insecticide use, by product type,1992, annual rpt	Information on consumption by kind and primary commercial fertilizer, Missouri, 1987-91; information on selected herbicides and insecticides used in corn and soybean in Missouri

Table 17. Results of ASI and SRI query for information on pesticide use

Index	Citation	Comment
SRI	North Carolina pesticide use, by type, for selected crop, 1991, annual rpt	Information on frequency and extent of pesticide usage, by type, for specified crops such as corn, soybeans, peanuts, apples, peaches, blueberries, 1991, in North Carolina
SRI	Oregon pesticide use, by type and crop, 1991, annual rpt	Information on direct application fertilizer material consumption from 1987 to 1991 in Oregon; information on pesticide application:total acreage and percentage receiving applications for selected crops such as apples, sweet cherries, tart cherries, grapes, pears, prunes & plums, hazelnuts, blackberries, blueberries, and raspberries in Oregon
SRI	Indiana pesticide use for corn and soybean, by product type, 1991,1990 annual rpt	Information on herbicide and insecticide usage in corn and soybeans in 1990, in Indiana
SRI	Nevada pesticide use and acres treated, by detailed application, 1991, 1990 rpt	Information on pest problem, pesticide use and acres treated, by detailed application (rate/acre) of alfalfa, barley, beans, brush, carrot, corn, fallow, garlic, grain, mint, oats, onions, pasture, potatoes, ranch, range land, right-of-way (Railroad), unknown, wheat in 1990, in Nevada
SRI	Pennsylvania pesticide use, by type and crop, 1991,1990 annual rpt	Information on frequency and extent of fertilizer usage and pesticide usage for specified crops such as corn, fall potatoes, apples, tart cherries, grapes, peaches
SRI	Washington state pesticide (fertilizer) use, by type and crop, 1992, annual rpt	Information on fertilizer use and acres treated; information on general pesticide (herbicide, insecticide, fungicide and other chemicals)usage of apples, sweet cherries, grapes, peaches, pears, prunes & plums, raspberries, fall potatoes, winter wheat; information on agricultural chemical application by detail of apples in Washington State
SRI	Delaware herbicide use, by type, 1990, annual rpt	Information on frequency and extent of nitrogen, phosphorous and potassium fertilizer, herbicide (chlorimuron-ethyl, linuron, metolachlor) usage of soybeans in 1990, in Delaware
SRI	Kentucky pesticide (fertilizer) consumption, and prices by type, 1990 and trends, annual rpt	Information on fertilizer use, mixed grades, and fertilizer material sold in 1989-1990, in Kentucky
SRI	Ohio pesticide use on grain crops, 1990, 1989, annual rpt	Information on fertilizer use on corn, soybeans and wheat acreage in 1990, in Ohio; information on fertilizer product and nutrient ton deliveries by county July 1989 to June 1990, in Ohio
SRI	Vermont pesticides use, 1984-85, biennial rpt	Information on summary of commercial applicators' annual pesticide reports in 1984, 1985 in Vermont
SRI	Minnesota pesticide use and applications, 1984,1983, annual rpt	Information on rate of application and acreage treated with major pesticides for specified crops such as corn, soybeans, wheat, other small grains, sunflowers, sugarbeets, etc

APPENDIX E

THE COMPUTED FREQUENCIES OF MAJOR PEST, DISEASE OR WEED PROBLEMS RELATED DIFFERENT TYPES OF FIELD CROPS FROM C.A.T. ALERTS

Table 18. The major potential pest, disease, and weed problems of alfalfa in Michigan:

pest, disease, or weed problem of alfalfa	Times	Frequency
alfalfa blotch leafminer	5	0.02
alfalfa plant bug	1	0.00
alfalfa weevil larvae	28	0.11
alfalfa weevils	44	0.17
alfalfa weevils adults	7	0.03
anthracnose	1	0.00
aphid	1	0.00
armyworms	2	0.01
bean leaf beetles	2	0.01
blister beetles	1	0.00
broadleaf weeds	1	0.00
chickweed (weed)	6	0.02
common leaf spot (Pseudopeziza)	5	0.02
cricket	1	0.00
dead nettle(weed)	3	0.01
false chinch bug (Nysius ericae)	2	0.01
Fusarium sp.	1	0.00
grass	1	0.00
grasshopper	7	0.03
meadow spittle bug	3	0.01
mold	1	0.00
mustard	1	0.00
pea aphid	1	0.00
plant bugs	1	0.00
potato leaf hoppers	103	0.39
quackgrass (weed)	2	0.01
Rhizoctonia solani (pathogen)	3	0.01
sclerotinia stem and crown rot	1	0.00
slug	1	0.00
sowbug	1	0.00
spring black stem	6	0.02
tarnish plant bug	13	0.05
verticillium wilt	4	0.02
white grubs	1	0.00
yellow rocket	1	0.00
Total	262	1.00

Table 19. The major potential pest, disease, and weed problems of corn in Michigan:

pest, disease, or weed problem of corn in Michigan	Times	Frequency
1st gen. European corn borer egg masses	17	0.04
1st gen. European corn borer larvae	55	0.14
1st gen. European corn borer moth (adult)	20	0.05
2nd gen. European corn borer egg masses	12	0.03
2nd gen. European corn borer larvae	7	0.02
2nd gen. European corn borer moth (adult)	7	0.02
anthracnose	3	0.01
aphids	7	0.02
armyworm	25	0.06
Bill bugs	12	0.03
black cutworm larvae	5	0.01
black cutworms	3	0.01
broadleaves(weed)	7	0.02
cereal leaf beetle adults	1	0.00
corn borer	2	0.01
corn leaf aphids	1	0.00
corn Needle Nematode(Longidorus breviannulatus)	7	0.02
corn root aphid	3	0.01
corn root-worm adults	49	0.12
corn root-worm eggs	4	0.01
cornfield ant	2	0.01
crabgrass(weed)	1	0.00
cut worm	17	0.04
earworm adults	1	0.00
false Japanese beetle	2	0.01
flea beetle	4	0.01
Fusarium(fungus)	1	0.00
Goss's wilt (leaf freckles, caused by bacteria)	1	0.00
grass or weed	17	0.04
grasshoppers	8	0.02
green foxtails(weed)	2	0.01
hop vine borer	2	0.01
Japanese beetle	9	0.02
Johhsongrass(w/ rhizones, seedling)	2	0.01
lambsquarter(weed)	4	0.01
Northern leaf blight	2	0.01
Northern leaf spot	1	0.00
Penicillium(fungus)	1	0.00
Phythium (fungus)	1	0.00
potato stem borer	5	0.01
quackgrass(weed)	2	0.01
rag weed	2	0.01

Table 19. The major potential pest, disease, and weed problems of corn in Michigan:

pest, disease, or weed problem of corn in Michigan	Times	Frequency
Rhizochonia(fungus)	1	0.00
rust	1	0.00
seedcorn maggots	9	0.02
slug	10	0.03
smart weed	2	0.01
spider mites	2	0.01
stalk borer	14	0.04
stunt nematode problem (Tylenchorhynchus dubius)	1	0.00
thrips	2	0.01
two spotted spider mite	4	0.01
velvetleaf(weed)	2	0.01
weed escape	1	0.00
white grub	7	0.02
wireworm	8	0.02
Total	398	1.00

Table 20. The major potential pest, disease, and weed problems of dry bean in Michigan:

Pest, Disease, or weed problem of dry bean	Times	Frequency
anthrancnose (Colletotrichum lindemuthin)	4	0.03
armyworm	2	0.02
bacterial blight	1	0.01
bean aphids	2	0.02
blight	3	0.02
cutworm	3	0.02
Fusarium root rot	2	0.02
grasshoppers	3	0.02
green peach aphid	1	0.01
halo bacterial blight	1	0.01
leaf burn(disease)	1	0.01
Mexican bean beetle	5	0.04
potato leafhopper	63	0.50
seedcorn maggot	5	0.04
slugs	2	0.02
soybean cyst nematode	1	0.01
spider mite	1	0.01
tarnished plant bug	5	0.04
two spotted spider mites	1	0.01
white grubs	1	0.01
white mold (disease)	17	0.14
wireworms	1	0.01
Total	125	1.00

Table 21. The major potential pest, disease, and weed problems of potatoes in Michigan:

pest, disease, or weed problem of potatoes	Times	Frequency
Colorado potato beetles	1	0.09
potato beetle popu. and egg mass	1	0.09
grass	1	0.09
quackgrass	1	0.09
false clinch bug(Nysius ericae)	1	0.09
potato Nematode	1	0.09
potato leafhopper	1	0.09
potato early-die disease complex (caused by Pratylenchus penetrans & Verticillium dahliae)	4	0.36
Total	11	1

Table 22. The major potential pest, disease, and weed problems of small grains in Michigan:

pest, disease, or weed problem of small grain	Times	Frequency
anthracnose	1	0.02
aphid	8	0.15
armyworm	8	0.15
barley yellow(leaf)dwarfmosaic virus	4	0.07
cereal leaf beetle	8	0.15
cut worm	3	0.06
english grain aphid	7	0.13
European corn borer	1	0.02
grasshoppers	3	0.06
Helminthosporium leaf blotch	1	0.02
lady beetle adults	1	0.02
oat bird cherry aphid	2	0.04
oat cyst Nematode	1	0.02
pea aphid	4	0.07
pupa	1	0.02
weed	1	0.02
Total	54	1.00

Table 23. The major potential pest, disease, and weed problems of barley in Michigan:

pest, disease, or weed problem of barley	Times	Frequency
barley yellow(leaf)dwarfmosaic virus	5	0.71
cereal leaf beetle	1	0.14
thrips	1	0.14
Total	7	1.00

Table 24. The major potential pest, disease, and weed problems of oats in Michigan:

pest, disease, or weed problem of oats	Times	Frequency
aphid	1	0.03
barley yellow(leaf)dwarfmosaic virus	12	0.32
broadleaf weeds	3	0.08
cereal leaf beetle	6	0.16
cereal leafhopper	1	0.03
crown rust(Puccinia coronate)	1	0.03
mustard	1	0.03
red leaf virus	2	0.05
rust	4	0.11
scab	1	0.03
septoria blight(septoria avenae)	1	0.03
stem rust(Puccinia graminis avenae)	1	0.03
thrips	1	0.03
weed	3	0.08
Total	38	1.00

Table 25. The major potential pest, disease, and weed problems of soybean in Michigan:

pest, disease, or weed problem of soybean	Times	Frequency
armyworm	2	0.01
bacterial leaf blight	2	0.01
bean leaf beetles	21	0.10
broadleaf weed	5	0.02
brown stem rot	1	0.00
charcoal rot(Macrophomina phaseoli)	1	0.00
cocklebur	1	0.00
cutworm	5	0.02
downy mildew	1	0.00
Eastern black nightshade	1	0.00
foliar disease	1	0.00
grass (& weed)	26	0.13
grasshoppers	6	0.03
green cloverworm	1	0.00
Japanese beetles	7	0.03
lesser clover(leaf weevil)	1	0.00
Mexican bean beetle	8	0.04
mold	1	0.00
phytophthora megasperma var sojae	4	0.02
phytophthora root rot	9	0.04
quackgrass	2	0.01
rag weed (weed)	1	0.00
Rhizoctonia root and stem rot	2	0.01
root rot	8	0.04
seedcorn maggot	5	0.02
Septoria	2	0.01
slug	8	0.04
soybean cyst nematodes	21	0.10
soybean thrips	1	0.00
septoria brown spot	2	0.01
spider mites	5	0.02
spittlebug	1	0.00
Thistle caterpillar	2	0.01
twospotted spider mites	7	0.03
weed escapes	2	0.01
white mold	15	0.07
(potato) leafhopper	20	0.10
Total	208	1.00

Table 26. The major potential pest, disease, and weed problems of sugar beets in Michigan:

pest, disease, or weed problem of sugar beets	Times	Frequency
aphid	4	0.04
armyworm	2	0.02
bean aphid	1	0.01
beet webworm(Loxostege sticticalis)	1	0.01
black rot	1	0.01
cutworms	10	0.11
flea beetles	14	0.16
grasshopper	1	0.01
green peach aphid	1	0.01
potato leaf hopper	1	0.01
rhizoctonia	1	0.01
root rots	2	0.02
spinach leaf miner	24	0.27
springtails	3	0.03
sugar beet cyst nematode (Heterodera schacchtii)	2	0.02
sugarbeet Weevil	1	0.01
tarnished plant bug	9	0.10
weed	9	0.10
white grubs	1	0.01
wireworm	1	0.01
Total	89	1.00

Table 27. The major potential pest, disease, weed problems of wheat in Michigan:

pest, disease, or weed problem of wheat	Times	Frequency
armyworms	5	0.03
bacteria	1	0.01
bacterial mosaic	3	0.02
barley yellow dwarf virus	4	0.02
bean leaf beetle	1	0.01
bird cherry oat aphids	1	0.01
broadleaf weeds	3	0.02
cephalosporium strip	1	0.01
cereal cyst nematode	1	0.01
cereal leaf beetle	1	0.01
cereal leaf beetle	14	0.08
english grain aphid	1	0.01
European corn borer	1	0.01
foliage mildew	1	0.01
fungus:Gibberella Zea	1	0.01
fusarium graminearum	1	0.01
fusarium head scab	1	0.01
grasshopper	1	0.01
Hessian fly	5	0.03
oat cyst	1	0.01
powdery mildew	28	0.16
ragweed	1	0.01
rust(disease)	15	0.08
septoria glume blotch	14	0.08
septoria leaf blotch	21	0.12
septoria nodorum	1	0.01
sooty mold	1	0.01
stem rust(Puccinia graminis tritici)	1	0.01
take-all(Gaeumannomyce graminis)	7	0.04
thrips	3	0.02
weed	2	0.01
wheat spindle streak mosaic virus(WSSMV)	11	0.06
wheat stem maggot	2	0.01
white mold	1	0.01
(grain) aphid	5	0.03
(head) scab (disease)	16	0.09
Total	177	1.00

Table 28. The major potential pest, disease and weed problems of grass hay in Michigan

pest, disease or weed problem of grass hay	Times	Frequency
adult European skipper	5	0.29
grasshopper	5	0.29
potato leafhopper	1	0.06
cutworm	2	0.12
armyworm	4	0.24
Total	17	1.00

Table 29. The major potential pest, disease, and weed problems of birdsfoot trefoil:

pest, disease, or weed problem of birdsfoot trefoil	Times	Frequency
tarnished plant bugs	3	0.75
alfalfa plant bugs	1	0.25
Total	4	1.00

Table 30. The major potential pest, disease and weed problems of legumes in Michigan:

pest, disease, or weed problem of legumes	Times	Frequency
adult European skipper	3	1.00
Total	3	1.00

Table 31. The major potential pest, disease, and weed problems of canola in Michigan:

pest, disease, of weed problem of canola	Times	Frequency
flea beetle	2	1.00
Total	2	1.00

Table 32. The major potential pest, disease, and weed problems of lupine in Michigan:

pest, disease or weed problem of lupine	Times	Frequency
leafhopper (not potato leafhopper)	1	0.25
potato leafhopper	2	0.50
seedcorn maggot	1	0.25
Total	4	1.00