Preliminary Interpretation of the Ecological Significance of Atrazine Stream-Water Concentrations Using a Statistically-Designed Monitoring Program

In Support of an
Interim Reregistration Eligibility Decision
on Atrazine

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for Review and Comment
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I. Introduction

A. Purpose of the Scientific Advisory Panel Meeting

In January, 2003, the US Environmental Protection Agency (US EPA) issued an ecological risk assessment as part of the Interim Registration Eligibility Decision (IRED) for atrazine (US EPA, 2003a). As a condition of re-registration, the atrazine registrants were required to develop a monitoring program to determine whether atrazine concentrations in streams associated with corn and sorghum production were exceeding a designated effects-based threshold. This threshold was based on aquatic plant community effects. If this threshold is exceeded, then a watershed-based mitigation program would be required.

This document summarizes the Agency's preliminary review and interpretation of the results of a three-year atrazine monitoring program conducted in flowing water bodies associated with corn and sorghum production. The Agency is consulting with this Scientific Advisory Panel (SAP) on scientific issues related to the interpretation of the results of the monitoring program and the extent to which the methods used by the Agency could be used or adapted in any future atrazine aquatic assessments or monitoring efforts to determine the extent to which water bodies exceed atrazine thresholds of concern for aquatic community effects.

In its review and sensitivity analysis of the aquatic community model used to relate atrazine monitoring concentrations to effects found in microcosm and mesocosm studies, the Agency identified some issues related to the model's response to low concentrations and to slope responses. The Agency has posed questions for the SAP on these issues and, once they are resolved, will return to the SAP with an update.

B. Background

Atrazine, a triazine herbicide currently registered for use against broadleaf and some grassy weeds, was first registered for use in 1958, and is estimated to be one of the most widely used herbicides in the United States. Atrazine inhibits primary production by reversibly blocking photosynthesis. It is both mobile and persistent in the environment.

The atrazine ecological risk assessment for the January 2003 IRED identified ecological risk concerns from the use of atrazine based on the potential for community- and population-level risks to aquatic ecosystems at prolonged concentrations of atrazine ranging from 10 to 20 µg/L. The Agency required the atrazine registrants, in consultation with the US EPA, to develop a program under which the registrants monitor for atrazine concentrations and mitigate environmental exposures if the US EPA determines that mitigation is necessary. This program was to focus on stream systems within a watershed context (US EPA, 2003a).

The scope of the monitoring program included identification of an appropriate ecological level of concern (LOC) based on the IRED and development of a protocol for monitoring that specifies the frequency, location, and timing of sampling. The program also identified atrazine exposures that would trigger mitigation measures and described resultant mitigation measures. This monitoring and mitigation program was designed, conducted and implemented on a tiered watershed level basis consistent with existing state and federal water quality programs (US EPA, 2003a).

On October 31, 2003, the US EPA issued an addendum to update the January 2003 IRED. This addendum specified the key questions the US EPA wanted the monitoring study to address, outlined the methodology for determining the LOC trigger, and briefly described the monitoring study design and proposed protocol submitted by Syngenta Crop Protection, Inc., the principal atrazine registrant. The LOC trigger was based on results of microcosm and mesocosm studies. An existing, previously published aquatic community model was used to compare atrazine atrazine monitoring data to exposure profiles observed in the microcosm and mesocosm studies to ascertain if the level of concern derived from these studies was exceeded. The monitoring protocol described a watershed-based approach that identified 40 monitoring sites representing watersheds associated with corn and sorghum production that are the most vulnerable watersheds for atrazine contamination and specified a minimum of two years of monitoring to determine if LOC triggers were exceeded. The 40 watersheds are statistically representative of 1,172 potentially vulnerable watersheds. Results of the monitoring study will be used to determine if further monitoring or remedial efforts are needed (US EPA, 2003b).

Mitigation actions in the watershed were triggered if atrazine concentrations from the monitoring site exceeded the LOC trigger for two years. If the site exceeded the LOC trigger in any one year, then a third year of monitoring would be required before mitigation actions would be undertaken (US EPA, 2003b).

C. Monitoring Study Objectives

Based on the 2003 ecological risk assessment for atrazine, the Agency identified several key questions to be addressed in the monitoring study (US EPA, 2003b). These questions formed the study objectives required to meet the US EPA's needs under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) and support the development of an atrazine aquatic life criterion under the Clean Water Act.

1) Identify aquatic community level thresholds of concern based on available microcosm and mesocosm studies and develop a method that relates these aquatic community responses to atrazine exposure profiles in a reasonable and transparent manner.

2) Design a monitoring program to estimate the extent of watersheds in corn and sorghum producing areas that have flowing waters which exceed atrazine LOC triggers for aquatic community effects.

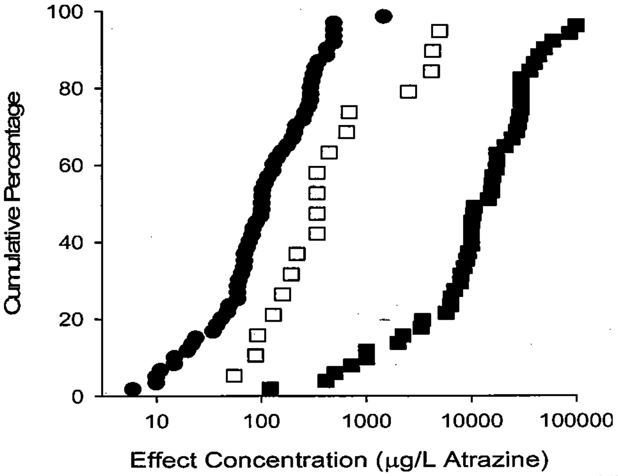
3) Based on results of the monitoring study, identify watershed attributes that can be used to identify where these higher atrazine exposure areas are likely to occur.

Syngenta designed the study to address these objectives. This document focuses on the first two objectives. While initial approaches concerning the third objective are presented, a subsequent document and SAP consultation will focus on the final objective.

D. Ecological Endpoint and Level of Concern for Atrazine

1. Freshwater Microcosm/Mesocosm Studies on Atrazine

Figure I-1 Species sensitivity distributions of various atrazine-induced toxicity endpoints. **EC50s for aquatic plant growth (•), LC50s/EC50s for aquatic animal acute lethality/immobiliation (□) and various chronic/ sublethal animal toxicity endpoints (■), from Tables 5.1 and 5.2 of Giddings**



Numerous toxicity tests with a variety of plant and animal species have shown aquatic plant growth to generally be much more sensitive to atrazine than are various effects on aquatic animals. Figure I-1 shows species sensitivity distributions of EC50s for plant growth, EC50s for acute lethality/immobilization to aquatic animals, and various chronic/sublethal endpoints for aquatic animals, based on the Table 5.1 and 5.2 summaries of Giddings et al. (2000). At comparable percentages in these cumulative distributions, plant growth is circa 3-10 times more sensitive than chronic endpoints for animals and circa 20-100 times more sensitive than acute toxicity to animals. Within each distribution, the data used for Figure I-1 vary with respect to the duration of exposure and nature of effects, so this figure is intended to only illustrate general differences in taxa sensitivity, not rigorously define these distributions. Because of the plant sensitivity illustrated in Figure I-1, the problem definition here focused on effects to the aquatic plant community.

Applying individual toxicity tests such as those summarized in Figure I-1 to plant community risk assessments is made difficult by issues related to the rapid, reversible nature of small to moderate effects of atrazine on plants, the influences of competition and compensation within the community, recovery rates of community perturbations, and the seasonality of community sensitivity. In contrast, microcosm and mesocosm studies with atrazine address the aggregate responses of multiple species in aquatic plant communities. Mesocosm and microcosm studies also allow observation of population and community recovery from atrazine effects and of indirect effects on higher trophic levels.

Atrazine has been the subject of many mesocosm and microcosm studies. The durations of these studies have ranged from a few weeks to several years at exposure concentrations ranging from 0.1 to 10,000 µg/L. Most of the studies have focused on atrazine effects on phytoplankton, periphyton, and macrophytes; however, some also included measurements on animals.

Based on these studies, as described in the 2003 IRED for atrazine (U.S. EPA, 2003a), potential adverse effects on sensitive aquatic plants and non-target aquatic organisms, including populations and communities, are likely to be greatest when atrazine concentrations in water equal or exceed approximately 10 to 20 µg/L on a recurrent basis or over a prolonged period of time. Appendix 1 summarizes the freshwater aquatic microcosm, mesocosm, and field studies that were reviewed as part of the 2003 IRED. An open literature search for studies not included in the 2003 IRED was completed in May 2007. It found that the available studies all showed effects levels to freshwater fish, invertebrates, and aquatic plants at concentrations greater than 10 µg/L.

2. Determining a Level of Concern Based on Microcosm/Mesocosm Studies

Based on the results of available micro- and mesocosm studies for atrazine, the US EPA identified changes in the aquatic plant community structure as the endpoint of concern. This appeared to be the most sensitive endpoint affecting aquatic plants. Further, the effect of atrazine on aquatic plants, whether direct or indirect, appeared to be more sensitive than effects on other organisms in the aquatic ecosystem, e.g., aquatic invertebrates or fish. Thus, by focusing on aquatic plant community structural changes, the Agency would, in effect, protect against adverse effects on the rest of the aquatic community.

The degradates of atrazine were not included in the determination of the endpoint of concern since their toxicity to aquatic plants, freshwater fish, and aquatic invertebrates is much lower than that of the parent molecule (US EPA, 2007, 2003a). Given the lesser toxicity of the degradates compared to the parent, and the relatively small proportion of the degradates expected to be in the environment and available for exposure relative to atrazine, the focus of this assessment is parent atrazine.

The ecological level of concern (LOC) was based on 77 results from 25 micro- and mesocosm studies on atrazine (Appendix 1). The analysis evaluated the change in aquatic community structure and function of primary producers. The studies measured growth (rate) and biomass in the laboratory and reduction in primary production and changes in structure of primary producer communities in the field.

Establishing the LOC required quantifying the results of the microcosm and mesocosm studies using a comparable measure of effects on aquatic plant productivity and community structure. An analysis of the reported effect(s) and the atrazine exposure profile (i.e., the magnitude and duration of atrazine concentrations) revealed a wide range of study designs and quality and also indicated that a wide range of atrazine exposure profiles could result in significant change in aquatic community productivity and structure. A method was developed to separate the reported results on plant community productivity and structure observed in these studies into those that were significant versus those with slight to no effects.

First, the severity of effects of atrazine on the aquatic plant community were quantified. Because there was not a single, consistent, quantitative effects measure that could be compared among these studies, Brock et al. (2000) analyzed many of these microcosm/mesocosm studies using an effects score summarized below:

<u>Effect Scores:</u>

1 = no effect
2 = slight effect
3 = significant effect followed by return to control levels within 56 d
4 = significant effect without return to control levels during an observation period of less than 56 d
5 = significant effect without return to control levels for more than 56 d

The US EPA subjected those studies not included in the Brock analysis to the same scoring system. For the 77 results from the microcosm/mesocosm studies, 15 had a Brock score of 1,,12 had a score of 2, 12 had a score of 3, 23 had a score of 4, and 15 had a score of 5.

Since atrazine exposure profiles in natural systems, in this case streams, are typically complex, a method was needed to analyze monitoring data to determine when monitored exposure profiles are functionally equivalent to those profiles observed in mesocosm and microcosm studies that showed significant changes or, conversely, that showed no significant effects. A model that predicts changes in aquatic communities in streams, the Comprehensive Aquatic Systems Model (CASM) (DeAngelis et al. 1989; Bartell et al. 1999, 2000; Bartell 2003), was used to assess whether an atrazine exposure profile from a monitoring study would likely be associated with a significant effect on aquatic communities. CASM is an ecological food web model that can indicate changes in the aquatic community structure and function of primary producers due to the addition of a chemical to the system. CASM can include a large number of species in the model structure and readily accepts complicated chemical exposure profile inputs.

Syngenta commissioned the CASM model developer to provide the Agency with a version of the model specifically tailored to atrazine, containing information on how atrazine affects different species. This model, the Copmprehensive Aquatic Systems Model for Atrazine (CASM_Atrazine), was developed to simulate complex ecological production dynamics of a 2^{nd} or 3^{rd} order Midwestern stream. (Volz, et al., 2007) This Agency is using this model version to interpret the data generated by the ecological monitoring program. This current version has a shell which will allow users to input their data. Once current development and testing are concluded, it will be made publicly available

One output from the CASM_Atrazine model, the Steinhaus Similarity Index (SSI) deviation, represents the relative magnitude of change in aquatic community structure and function of primary producers between results of the simulated atrazine concentration profile and results of a control simulation, i.e., the same community over the same time period with no atrazine input. SSI deviation is expressed as a percentage, with higher percentages indicating greater deviation of the atrazine-exposed aquatic community from the control.

With model simulations of the exposure profiles in the microcosm and mesocosm studies, a value for the SSI can be selected to segregate those studies that exhibited significant effects (Brock scores of 3-5) from those that did not (Brock scores of 1-2). An initial assessment of such an LOC was provided in the IRED addendum (US EPA 2003b) and is updated in Section II of this document.

CASM simulations can be used to test whether the LOC was exceeded for any exposure time-series (e.g., a chemograph from a monitoring study). Section II also provides examples of this approach and describes a sensitivity analysis of the CASM model that addresses possible sources of uncertainty in the approach.

E. Atrazine Ecological Monitoring Program

The next step in the assessment involved designing a monitoring program that generated chemographs sufficient to assess the magnitude, duration, and frequency of atrazine exposures, given the potentially flashy nature of atrazine exposure in stream systems. Because the LOC trigger reflects both magnitude and duration of exposure, the chemograph must reflect sampling at a sufficient frequency to characterize atrazine exposure in flowing waters. The monitoring program needed to determine the extent to which waters in vulnerable watersheds exceed the effects-based thresholds for atrazine. In addition, Syngenta was asked to collect watershed and sub-watershed data that could be used to identify other areas where waters exceeding the LOC thresholds are located.

Syngenta monitored 40 sites for at least 2 years based on a probability-based survey design that sampled 1,172 vulnerable watersheds. The study used a watershed-based approach to focus on those water bodies that would likely be most vulnerable to atrazine loadings. Surveying vulnerable watersheds increases the probability of finding waters with atrazine exposures above the levels of concern. Conversely, if no problems were found in these watersheds, the probability is low that problems would exist in less vulnerable watersheds. HUC-10/11 scale watersheds (typically 40,000 to 250,000 acres in size) provided a workable scale for evaluating the vulnerability of watersheds and establishing the watershed population of interest. A tiered approach based first on atrazine use intensity and then on the USGS' Watershed Regression for Pesticides (WARP) model (Larson et al, 2004) defined the most potentially vulnerable tier of watersheds based on a ranking of WARP values. From this tier, a spatially-balanced survey design was used to select a representative sample of 40 watersheds. Williams et al. (2004a) describe the watershed vulnerability approach and site selection process. Section III of this document provides the US EPA review of the approach and interpretation in relation to the monitoring study objectives.

Section III also presents the Agency's review and interpretation of Syngenta's monitoring study for the 40 watersheds (Hampton et al., 2007a). Both Syngenta (Hampton et al., 2007b) and the US EPA are continuing to evaluate the results to address the third study objective relating to identifying where the watersheds that exceed the LOC might occur. With regard to this latter issue, Section IV of this document describes some approaches the US EPA is considering and requests comment from the SAP. A future SAP consultation will focus on interpretations of the study results with a particular focus on applying the results to identify watershed attributes and watersheds with corn and sorghum production most likely to have streams with the highest atrazine concentrations.

F. Key Study Documents

Syngenta has submitted a number of documents to the US EPA related to the development of a method of determining the threshold trigger for atrazine impacts on aquatic communities and to monitoring for atrazine in watersheds representative of the most vulnerable watersheds. The Agency is reviewing these studies as a part of its assessment of the monitoring program and is presenting its preliminary assessment to the SAP. The following documents sufficiently capture the details and results of the study and have been provided to the SAP for additional background.

1. CASM Model Development

Volz, D.C., S.M. Bartell, S.K. Nair, and P. Hendley. 2007. Modeling the Potential for Atrazine-Induced Changes in Midwestern Stream Ecosystems using the Comprehensive Aquatic Systems Model (CASM). Final Report. MRID 47174103.

This report contains background on the CASM model, documentation of the development of the model specifically for atrazine (CASM_Atrazine), development of rolling average triggers, and an uncertainty analysis conducted by the model developer. The report concludes that the model provides a flexible tool for predicting community-level impacts from atrazine exposure in low-order Midwestern streams using monitoring data.

As a result of the US EPA evaluation, some model parameters have been revised, resulting in a revised LOC trigger. The US EPA evaluation and sensitivity analyses are reported in Section II.

2. Watershed Selection Process

Williams, W. M., C.M. Harbourt, M.K. Matella, M.H. Ball, and J.R. Trask. 2004a. Atrazine Ecological Exposure Flowing Water Chemical Monitoring Study in Vulnerable Watersheds Interim Report: Watershed Selection Process. Prepared by Waterborne Environmental, Inc., Leesburg, VA for Syngenta Crop Protection, Inc., Greensboro, NC.

Williams, W. M., C.M. Harbourt, M.H. Ball, M.K. Matella, J.R. Trask, and N.J. Snyder. 2004b. Atrazine Ecological Exposure Monitoring Program Interim Report: Supporting Spatial Data. Prepared by Waterborne Environmental, Inc., Leesburg, VA for Syngenta Crop Protection, Inc., Greensboro, NC.

Williams et al (2004a) describes the steps Syngenta used to identify the most vulnerable watersheds based on atrazine use intensity and factors affecting the potential for atrazine runoff using the USGS Watershed Regression on Pesticides (WARP) model. It also describes the criteria used for selecting a monitoring site within the watersheds. Williams et al (2004b) provides detailed documentation on the spatial and monitoring data used in the watershed vulnerability assessment and site selection process.

Section III describes US EPA's evaluation of the watershed vulnerability and selection approach.

3. Overview of Atrazine Monitoring Study Results

Hampton, M., Burnett, G., Carver, L.S., Harbourt, C.M., Hendley, P., Johnston, E.A., Perez, S., Snyder, N.J., and Trask, J.R., 2007a. 2007 Interim Report - 2004 - 2006 Data Overview - Atrazine Ecological Exposure Flowing Water Chemical Monitoring Study in Vulnerable Watersheds Interim Report. Prepared by Waterborne Environmental, Inc., Leesburg, VA for Syngenta Crop Protection, Inc., Greensboro, NC. MRID 47174102.

This report includes a description of the sampling instrumentation and methods and provides the monitoring results for the 40 sites.

The US EPA used the data in this report for its analysis of the monitoring results in Section III. In addition, the US EPA has interpreted the results based on a revised version of the CASM-Atrazine model described in Section II. The results, compared against a revised LOC, are discussed in Section III.

4. Sampling Frequency Analyses

Snyder, N.J., Harbourt, C.M., Miller, P.S., Trask, J.R., Prenger, J.J., Hendley, P., and Johnston, E.A., 2007. Atrazine Ecological Exposure Flowing Water Chemical Monitoring Study in Vulnerable Watersheds: Analysis of Chemograph Behavior between Grab Samples - Measurement and Hybrid PRZM Approaches. Prepared by Waterborne Environmental, Inc., Leesburg, VA for Syngenta Crop Protection, Inc., Greensboro, NC.

Snyder et al (2007) compared the results of the 4-day grab samples to both autosampler data triggered by flow events at selected sites and to data where the Pesticide Root Zone Model (PRZM) version 3.12.2 (Carsel et al, 1998) was used to estimate atrazine concentrations between sampling events. While the CASM SSI deviation values generally increased with both the autosample data and the PRZM-estimated concentrations, neither resulted in chemographs that triggered the threshold LOC.

The USEPA also evaluated sampling frequency uncertainties and various approaches for describing this uncertainty in Section III.

5. GIS Approaches to Assessing Watershed Vulnerability

Hampton, M. Prenger, J.J., Harbourt, C.M., Hendley, P., and Miller, P.S., 2007b. Atrazine Ecological Exposure Flowing Water Chemical Monitoring Study in Vulnerable Watersheds: Approaches to Assessing Potential Watershed Scale Vulnerability for Atrazine Runoff. Prepared by Waterborne Environmental, Inc., Leesburg, VA for Syngenta Crop Protection, Inc., Greensboro, NC. MRID 47174101.

This report provides a brief summary of the original approach for identifying watersheds vulnerable to atrazine runoff (see Williams et al, 2004a) but focuses primarily on additional analyses with spatial data that was not as readily available at the time of the original study design.

The USEPA has completed preliminary analyses of this study, as well as its own assessments. Those analyses are discussed briefly in Section IV in terms of future directions, but will be the subject of a future SAP.

G. Issues To Be Addressed in Future SAP Consultations

As noted in the purpose section, the Agency is consulting with this SAP on the use of a community simulation model as a means of extrapolating the results of microcosm/mesocosm studies to stream monitoring exposure data and on the preliminary interpretation of the results of a watershed-based monitoring study in the corn and sorghum growing region. Several issues noted in this document will be brought to a future SAP. These are highlighted below:

- Once issues related to the way in which the CASM model appears to both overestimate the effects of extended-duration, low-level exposures and underestimate the effects of short-term, high-level exposures are resolved (see Section II.D), the Agency will return to the SAP with a revised interpretation of the monitoring study.

- Monitoring continues in 2007 for a number of sites. The results of this monitoring may change the current interpretation of some of the monitoring sites (see Section III.D.2). These updates will be folded into the revised interpretation.

- A separate pilot monitoring study is underway for water bodies in sugarcane areas. Additionally, the Agency is evaluating existing monitoring of reservoirs to determine the potential impact of atrazine on aquatic communities in static water bodies. The interpretation of these results may require an aquatic community model specific for the sugarcane areas. To the extent that such a model departs from the current CASM approach, the Agency may determine that a consultation with the SAP is warranted.

- Based on input from this SAP, the Agency will continue to work on approaches to (a) identify streams that exceed the LOC and (b) identify additional watersheds and/or streams beyond the 40 monitoring sites that exceed the LOC. The Agency plans a future SAP consultation on the results of this effort.

II. Use of a Community Simulation Model for Extrapolation of Atrazine Levels of Concern for Exposure Time-Series

This section addresses procedures for assessing the ecological level of concern (LOC) for atrazine exposures in freshwater systems. It first defines the problem and presents a general strategy for the assessment methodology. Second, it describes the formulation and parameterization of a community simulation model to be used in the methodology. After a discussion of the implementation of the model with example applications, a sensitivity analysis is presented to address the uncertainties introduced into assessments due to various choices for model formulation and parameterization.

A. Problem Definition and General Strategy

1. Nature of Assessment Problem

The problem being addressed here is a common one in aquatic risk assessments, namely that exposure time-series in natural ecosystems for which risks need to be assessed are markedly different from exposure time-series in experimental systems for which effects have been determined. Experimental system exposures usually involve a relatively constant concentration over a pre-determined duration, sometimes followed by assessment of recovery after exposure termination. Field exposures tend to be more variable and open-ended, without a fixed duration. This is particularly true for atrazine, which enters aquatic systems largely in rainfall-driven runoff, resulting in highly variable and episodic exposures that depend on rainfall distribution, atrazine application patterns, topography, and soil properties. The assessment methodology therefore needs to address effects under exposure scenarios such as those in Figure II-1, which includes a variety of exposure time-series derived from atrazine monitoring efforts.

As summarized in Section I.D, LOCs are based on plant community effects observed in micro/mesocosm studies, discriminating between no or slight effects (Brock Scores 1-2) and significant effects (Brock Scores 3-5). A major assumption here is that these micro/mesocosm data collectively describe a relationship of effects to exposure that is applicable to the field sites of interest. Although concentrations during the exposure periods in these studies are not absolutely constant, exposures can be approximately characterized by a concentration and duration, which are related to the effect scores in Figure II-2. The two groups of scores to be discriminated in setting an LOC (1-2 versus 3-5) are largely separated (Figure II-2); however, some overlap exists, indicative of variable effects among the different types of systems and/or uncertainty in evaluation methods, the causes of which are uncertain. The assessment methodology must therefore address how LOCs should be defined relative to the presence of false negatives (micro/mesocosm scores of 3-5 which lie below the LOC) and false positives (scores of 1-2 which lie above the LOC).

Figure II-1 Examples of atrazine exposure time series (chemographs) in natural systems. Chemograph numbers 7 and 9 are not shown because they are identical to numbers 6 and 8, respectively, except shifted to two weeks earlier.

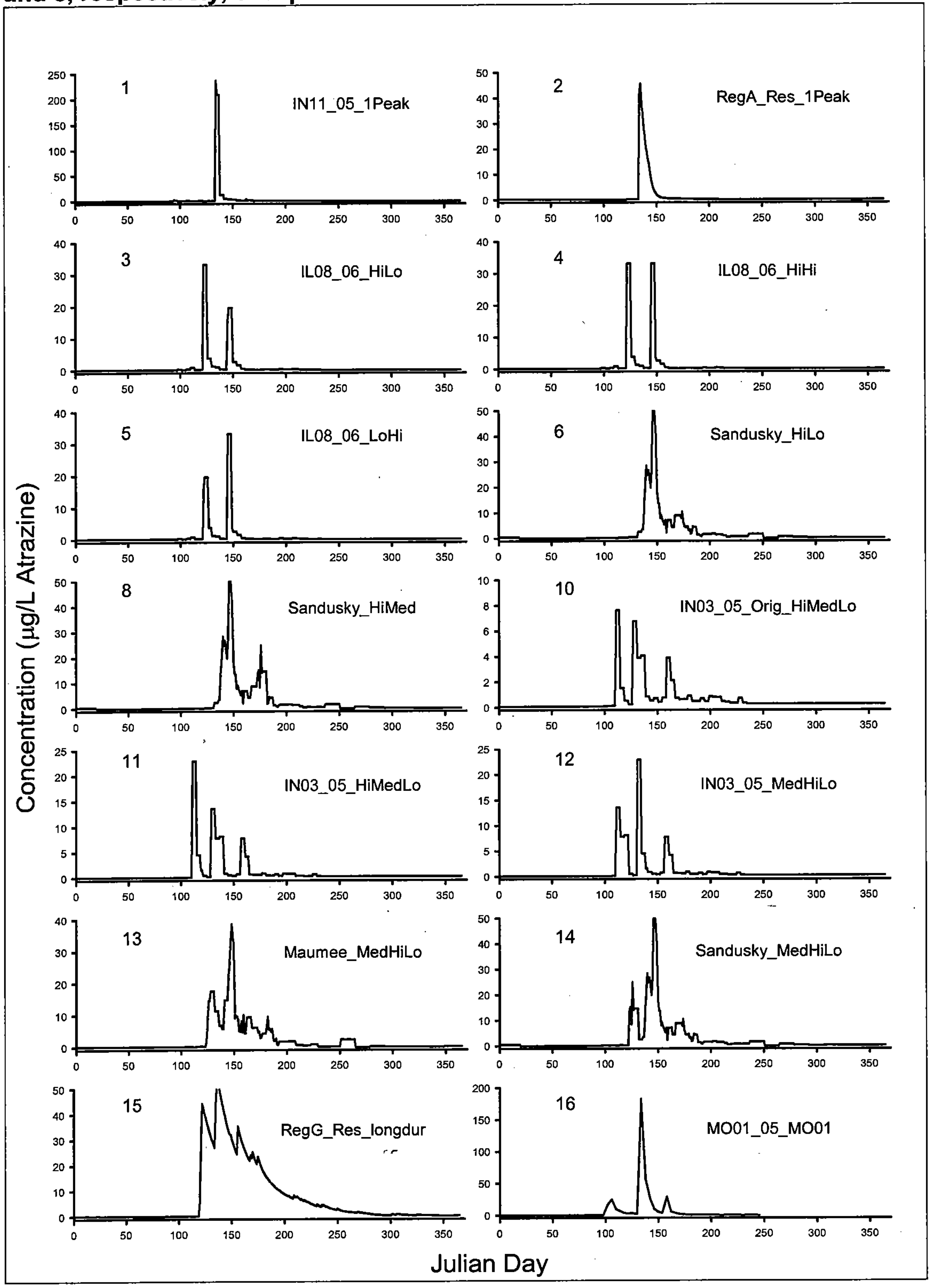
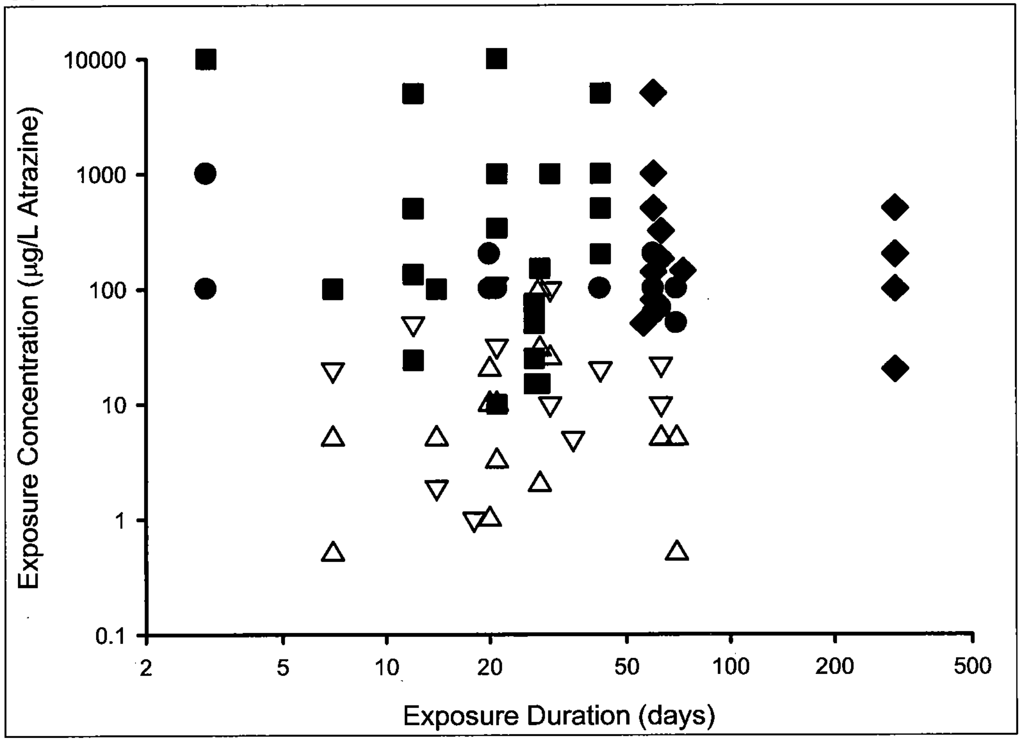


Figure II-2 Score for the severity of effects in microcosm and mesocosm atrazine exposures versus exposure duration and average concentration.
♦ denotes score 5, ■ denotes score 4, ● denotes score 3, ▽ denotes score 2, and Δ denotes score 1.



2. General Strategy for Assessment Methodology

Although the use of the micro/mesocosm data better addresses integrated and cumulative aquatic community effects than would application of toxicity test results for individual plant species, it still presents the challenge of extrapolating to highly variable field exposures (Figure II-1) from the more regular exposures in the experimental systems. Thus a method is needed to provide a consistent, quantitative index of effect for the entire range of exposures in both the experimental systems and the field systems of interest. This methodology does not need to provide any ***absolute*** predictions of effects in any system, but rather must be able to provide a measure of the ***relative*** severity of effects resulting from different exposure patterns. Conceptually, this would allow LOCs defined based on micro/mesocosm data to be extrapolated to different exposure time-series in field systems. It should be emphasized that the purpose of this methodology is only to address extrapolations across exposure time-series, and not to address other factors which might make atrazine effects vary between systems (such as might be partly responsible for the overlap of the score on Figure II-2) and which are not predictable based on current knowledge.

Just as it was decided to base LOCs on plant community effects observed in experimental ecosystems rather than individual species toxicity tests, it was decided to use a simulation model that addresses an entire aquatic community for the desired extrapolations among exposure time-series. By incorporating representations of major aquatic community processes and the effects of atrazine on these processes, this model is expected to provide useful assessments of the relative impacts of different exposures, and thereby support extrapolations among exposure time-series for different experimental and field ecosystems. For example, if 100 ug/L atrazine was the LOC for a 60 day constant exposure, what would be the LOC for a 30-day constant exposure? Or what would be the LOC based on the highest peak (or some average concentration) in a chemograph with a complex shape, such as any of those in Figure II-1?

The general steps in the assessment methodology are as follows:

(1) A single version of an aquatic community model is formulated and parameterized. This model formulation should include a sufficient number of plant species to accommodate assigning a range of atrazine sensitivities reflective of available single-species toxicity tests (Figure II-2). Because relative effects of different exposures are of concern, rather than absolute effects on a specific system, this formulation and parameterization will not address any specific system of interest, but still should have some general relevance to the types of experimental and natural systems of interest. Just as it was assumed that the micro/mesocosm results have generic relevance to field assessments, it is assumed that exposure extrapolations based on this single model version would have generic applicability to the experimental and field ecosystems. The sensitivity analysis in Section II.D will evaluate this assumption and some uncertainties associated with it.

(2) A model simulation is conducted for each of the atrazine concentration/duration combinations in the micro/mesocosm data set, as well as for the absence of atrazine exposure (control). The duration of the model simulations is not the exposure duration, but rather a fixed length long enough to assess effects over an entire growing season (with the exposure period being a subset of the total simulation). The model simulation also should be timed to start at a typical expected onset date of significant atrazine exposure in natural systems. A measure of the change of the model output variables between control and exposed conditions that provides a consistent measure of effects independent of exposure duration is designated as a ***model effects index***.

(3) The observed effects scores (1-5) for each micro/mesocosm treatment are then correlated to the model effects index values computed by the model for the exposure concentrations/durations of each treatment. An LOC for the model effects index is selected that provides the best discrimination between the effects score groups (i.e., 1-2 vs 3-5). The model output is thus "calibrated" to the micro/mesocosm data so that the LOC for the model effects index is related to effects of concern identified in the micro/mesocosm experiments. It is important to emphasize that the model effects index value selected as the LOC ***does not define the level of ecological protection being provided***. Rather, the significance of the model LOC is in (a) its correlation to the effects in the micro/mesocosm experiments that do define the desired level of ecological protection and (b) its utility as a reference value for assessing the relative impact of different exposure time-series.

(4) A model simulation is then conducted for each of the field exposure time-series of interest, and the model effects indices for these exposures are examined to determine if the LOC is exceeded. In addition, the model could iteratively estimate the factor (***multiplication factor***) by which the time-series would need to be increased or decreased for the model effects index to exactly equal the LOC, thereby providing further information useful for risk assessment and management.

B. Model Formulation and Parameterization

1. General Model Formulation and Parameterization for Reference Conditions

The aquatic community simulation model selected to provide the desired extrapolation tool was the "Comprehensive Aquatic Systems Model" (CASM). This selection was based on the extensive history of this model (and it predecessors and derivatives) in aquatic risk assessments (O'Neill et al. 1981, 1983; DeAngelis et al. 1989; Bartell et al. 1992, 1999, 2000; Hanratty and Stay 1994; Hanratty and Liber 1996; Naito et al. 2002, 2003; Bartell 2003) and its ready adaptability for use in the atrazine assessment methodology. Other conceptually similar models (e.g. AQUATOX) could have been used and would likely have provided similar extrapolations if comparably formulated and parameterized. General information regarding the CASM model in the aforementioned references and its specific adaptation for atrazine is described in Volz et al. (2007). Only a summary of the general nature of the model and its basic parameterization for reference conditions will be given here.

The state variables for CASM are (a) the biomasses for various species defining a simplified aquatic community and (b) concentrations for dissolved oxygen, dissolved and particular organic matter, and certain nutrients. The state equation for each biological species is a bioenergetics equation that includes terms, as appropriate to each species, which define gains/losses of biomass from photosynthesis, respiration, food consumption, export/import, mortality, etc. For example, for phytoplankton species ***i***, the basic bioenergetics equation is:

$$\frac{dB_i}{dt} = p_i - r_i - s_i - m_i - g_{ij} \qquad (1)$$

where B_i is the biomass of the species, t is time, p_i is the gross photosynthesis rate, r_i is the respiration rate, s_i is a sinking rate, m_i is a natural mortality rate, and g_{ij} is the grazing rate by a consumer species j. Each of these rates requires specification of (a) a functional form that relates the rate to various state and input variables and (b) one to several parameters required for function; for example, p_i is a function of light, temperature, and nutrients which includes parameters for maximum photosynthesis rate, light saturation, optimal temperature, and nutrient half-saturation concentrations (DeAngelis et al. 1989; Bartell et al. 1999, 2000; Bartell 2003). Input variables to CASM include light, temperature, nutrient imports, water flow, and depth.

For atrazine assessment needs, a version of CASM was formulated and parameterized to represent a second- to third-order midwestern U.S. stream that would be a typical recipient of runoff from atrazine corn applications (Volz et al. 2007). This model aquatic community includes ten species of phytoplankton, ten species of periphyton, six species of macrophytes, two species of zooplankton, five species of benthic invertebrates, seven species of fish, and bacteria in both the water column and sediment. Physicochemical environmental input variables were based on data for an Ohio stream, and parameters for the bioenergetics equations were obtained from peer-reviewed technical literature (Volz et al. 2007). The simulation is for a calendar year and, in the absence of atrazine exposures, the model shows seasonal trends for the populations of different taxa that made the model appropriate for assessing stressor effects on community dynamics (Volz et al. 2007).

2. Incorporation of Toxicity Information into the Model

One challenge in applying a bioenergetics-based community model such as CASM to toxicity assessments is that toxicity tests do not directly address the effects of the chemical on the specific parameters within the bioenergetics state equation (e.g., Equation 1). For example, a plant growth test will provide information on the net growth rate, but not on how specific parameters within the photosynthesis and respiration functions are being affected. There is just not enough information in the toxicity tests to independently adjust all the model parameters.

To address this problem, CASM uses the bioenergetics equations to simulate the concentration/effects curve of toxicity tests, and estimates a "toxic effects factor" (TEF) for each concentration that, when used to adjust several model parameters, will reproduce the effect level at that concentration (DeAngelis et al. 1989; Bartell et al. 1999, 2000; Bartell 2003; Volz et al. 2007). For plants, the version of CASM developed for this atrazine assessment offers two alternatives regarding what model parameters are altered by the TEF. For the "General Stress Syndrome" (GSS), the TEF is used to (a) reduce photosynthesis by decreasing the maximum photosynthesis and increasing light and nutrient saturation parameters and (b) increase the various loss terms, such as respiration, in the bioenergetics equation. For the "Photosynthesis Stress Syndrome" (PSS), only the maximum photosynthesis parameter is modified.

To model the response of each plant species, CASM therefore requires the specification of a function for the fraction reduction in plant growth versus atrazine concentration over a specified exposure duration. The assumed functional shape of percent growth inhibition versus $\log_{10}$(concentration) is the cumulative Gaussian distribution, so that the probit-transform of the percent growth reduction versus $\log_{10}$(concentration) is linear. This function can be specified by inputting either (1) the slope and intercept of this linear transform or (2) an exposure concentration showint 50% effect (EC50) and No Observed Adverse Effect (NOEC) which defines the function under an assumption that the NOEC is five probit units below the EC50. For the exposure concentration on each day of a simulation, CASM estimates a TEF that causes the bioenergetics equation to produce the growth reduction specified by the toxicity function over the specified test duration under optimal nutrient, light, and temperature conditions.

To provide the needed plant toxicity information, individual plant species toxicity tests collated by Giddings et al. (2000) and identified from other sources were reviewed. A subset of these were identified for use in model parameterization based on a suitably-defined growth EC50 over a specified duration (Table II-1). Next, the geometric mean EC50s for each species were computed, and assigned to the various plant species within CASM based on bioenergetics similarity of the test species to the modeled species (Table II-1). The probit versus $\log_{10}$(concentration) slope for each species was set to 3.3 based on the mean of the slopes reported in the U.S.EPA Office of Pesticide Programs one-liner database (Montague 1998). This slope and the mean EC50s for each species were used to calculate the probit line intercepts for input into CASM.

The assignment of EC50s to the modelled plant species is a possible major source of uncertainty given the variability of results within species (Table II-1). The EC50s in Table II-1 were subject to an analysis of variance to compare between-species and within-species variability. For $\log_{10}$-transformed EC50s, this analysis indicated an overall mean of 2.01 (corresponding to an untransformed EC50 of 103), a within species mean squared error of 0.481 (df=45), a between species mean squared error of 0.486 (df=36), and a non-significant F-statistic (1.02). This lack of a demonstrated difference between the within-species and between-species variability indicates a source of variability which makes any single EC50 for a species subject to considerable uncertainty. Additionally, it may also make mean EC50s based on a large number of tests subject to some amount of uncertainty in any particular situation. This is not to say that sensitivity to atrazine does not vary among species, but rather that various sources of variability make the selection of specific EC50s uncertain. Alternative sets of plant EC50s should therefore be examined (see Section II.D).

Toxicity values were also assigned to the animal species (Volz et al. 2007). Because the lowest EC50 assigned to an animal species was much greater than the EC50s for most of the plant species, substantial effects on the plant community would occur at concentrations below any toxic effects on animals in these simulations. Thus, assessment results are not sensitive to the animal toxicity value selection, which will not be further discussed or evaluated here.

Table II-1 Atrazine plant toxicity tests used in assessment methodology.

Species	*EC50 (ppb)*	*Duration (d)*	*Reference*	*Species Geometric Mean EC50*	*CASM Population Assignment*
			GREEN ALGAE		
Ankistrodesmus braunii	60	11	Burrell et al. 1985	61	*#5 – Phytoplankton* *#15 - Periphyton*
	61	24	Larsen et al. 1986		
Chlamydomonas nostigana	330	3	Kallqvist and Romstad 1994	330	
Chlamydomonas reinhardi	10	10	Schafer et al. 1993	59	*#4 - Phytoplankton*
	19	1	Larsen et al. 1986		
	176	4	Fairchild et al. 1998		

Species	**EC50 (ppb)**	**Dura-tion (d)**	**Reference**	**Species Geometric Mean EC50**	**CASM Population Assignment**
	350	3	Schafer et al. 1994		
Chlorella fusca	15	1	Faust et al. 1993	15	
Chlorella pyrenoidosa	125	1	Stratton and Giles 1990	280	
	175	5	Gramlich and Frans 1964		
	282	5	Montague 1998		
	1000	14	Stratton 1984		
Chlorella vulgaris	94	4	Fairchild et al. 1998	88	*#6 – Phytoplankton* *#20 - Periphyton*
	25	11	Burrell et al. 1985		
	293	1	Larsen et al. 1986		
Scenedesmus obliquus	38	1	Larsen et al. 1986	38	*#3 – Phytoplankton* *#14 - Periphyton*
Scenedesmus quadricauda	169	4	Fairchild et al. 1998	169	
Scenedesmus subspicatus	21	4	Kirby and Sheahan 1994	76	
	72	3	Schafer et al. 1994		
	110	4	Geyer et al. 1985		
	200	*3*	*Zagorc-Koncan 1996*		
Selenastrum capricornutum	*4*	*4*	*University of Mississippi 1991*	*84*	*#16 - Periphyton*
	26	*4*	*Caux et al. 1996*		
	50	*4*	*Versteeg 1990*		
	53	*5*	*Montague 1998*		
	55	*5*	*Hoberg 1993c*		
	70	*1*	*Turbak et al. 1986*		
	95	*5*	*Roberts et al. 1990*		
	117	*4*	*Fairchild et al. 1998*		
	118	*3*	*Radetski et al. 1995*		
	128	*4*	*Gala and Giesy 1990*		
	130	*4*	*Hoberg 1993b*		
	158	*3*	*Mayer et al. 1998*		
	200	*3*	*Kallqvist and Romstad 1994*		
	214	*7*	*Abou-Waly et al. 1991*		
	235	*4*	*Fairchild et al. 1997, 1999*		
	359	*3*	*van der Heever and Grobbelaar 1996*		
	42	*1*	*Larsen et al. 1986*		
			CRYPTOMONADS		
Cryptomonas pyrinoidifera	*500*	*6*	*Kallqvist and Romstad 1994*	*500*	*#17 - Periphyton*
			BLUEGREEN ALGAE		

Species	EC50 (ppb)	Duration (d)	Reference	Species Geometric Mean EC50	CASM Population Assignment
Anabaena cylindrica	178	1	Stratton 1984	178	#19 - Periphyton
Anabaena flos-aquae	58	3	Abou-Waly et al. 1991	342	#10 - Phytoplankton
	230	5	Hughes et al. 1988		
	3000	4	Fairchild et al. 1998		
Anabaena inaequalis	100	14	Stratton 1984	100	#8 - Phytoplankton
Microcystis aeruginosa	129	5	Parrish 1978; Montague 1998	285	
	630	6	Kallqvist and Romstad 1994		
Microcystis sp.	90	4	Fairchild et al. 1998	90	#7 – Phytoplankton #18 - Periphyton
Synechococcus leopoliensis	130	3	Kallqvist and Romstad 1994	130	#9 - Phytoplankton
DIATOMS					
Cyclotella sp.	430	6	Kallqvist and Romstad 1994	430	#13 - Periphyton
Navicula pelliculosa	60	5	Hughes et al. 1988	60	#1 – Phytoplankton #11 - Periphyton
Skeletonema costatum	265	2	Walsh 1983	69	#2 – Phytoplanton #12 - Periphyton
	260	2	Mayer 1987		
	50	2	Walsh et al. 1988		
	24	5	Parrish 1978; Montague 1998		
	55	5	Hoberg 1993c		
	24	4	Montague 1998		
MACROPHYTES					
Ceratophyllum demersum	22	14	Fairchild et al. 1998	22	#23 - Macrophyte
Elodea canadensis	1200	10	University of Mississippi 1991	159	#24 - Macrophyte
	21	14	Fairchild et al. 1998		
Hydrilla verticillata	110	14	Hinman 1989	110	
Lemna gibba	22	14	Hoberg 1993a	159 (Genus Mean)	#25 – Macrophyte
	180	7	Hoberg 1991		
	170	5	Montague 1998		
Lemna minor	8700	14	University of Mississippi 1991		
	92	4	Fairchild et al. 1998		
	56	10	Kirby and Sheehan 1994		
	153	4	Fairchild et al. 1997		
Myriophyllum heterophyllum	132	14	Fairchild et al. 1998	132	#22 - Macrophyte
Najas sp.	24	14	Fairchild et al. 1998	24	
Thallassia testudinum	320	1.7	University of Mississippi 1991	320	

Species	**EC50 (ppb)**	**Duration (d)**	**Reference**	**Species Geometric Mean EC50**	**CASM Population Assignment**
Potamogeton perfoliatus	*474*	*21*	*Forney and Davis 1981*	*170*	*#26 - Macrophyte*
	130	*28*	*Kemp et al. 1985*		
	80	*0.1*	*Jones et al. 1986*		
Vallisneria americana	*163*	*42*	*Forney and Davis 1981*	*163*	*#21 - Macrophyte*

C. Model Implementation and Example Application

1. Model Effects Index Selection

The basic output of CASM is a time series of daily biomass values for each modeled species over the simulation year. Various possibilities exist for synthesizing this information into a model effects index for the primary producer community. The index might address how just total plant biomass or production is perturbed in an exposed system compared to an unexposed system, or might also reflect perturbations in the relative biomasses of each species. The index might indicate the maximum perturbation across the entire simulation, the average perturbation over the entire simulation, an average perturbation during a fixed time window during the simulation, or a maximum running average of the perturbations.

The model effects index selected is based on the average, over the entire simulation, of the daily Steinhaus Similarity Indices (SSI). The SSI quantifies the similarity between two communities (in this case, exposed and control model-calculated communities). For each day of the simulation, the SSI is calculated as:

$$SSI = 2 \cdot \frac{\sum_{i=1}^{n} min\left(B_{R,i}, B_{E,i}\right)}{\sum_{i=1}^{n} B_{R,i} + \sum_{i=1}^{n} B_{E,i}}$$

where $B_{R,i}$ is the daily biomass of the ith species in the reference (control) simulation and $B_{E,i}$ is the daily biomass of the ith species in the atrazine-exposed simulation. SSI values thus reflect changes in both absolute and relative population sizes, ranging from 1.0 for identical community structures to 0.0 for completely disjoint communities. The model effects index will be expressed as the percent reduction of this average SSI from the maximum value of 1.0 (i.e., a model effects index of 10 represents an average SSI of 0.90).

This type of measure was selected in order to include changes in relative species abundance as part of the risk assessment, rather than just some measure of total primary productivity. The entire simulation period was chosen as the averaging period to provide a consistent measure appropriate to a variety of exposure time series shapes. For example, two exposure time series might have the same initial atrazine peak that produces the same maximum perturbation of the SSI, but one of the time series might have additional peaks that cause more effects on average than the other time series. Although a year-long average for the model effects index will be reduced by including pre-exposure periods in which both the control and exposed communities are identical (daily SSI=1.0), this will not alter risk assessments significantly because both the LOC and model effects indices for systems of interest will be reduced to similar degrees.

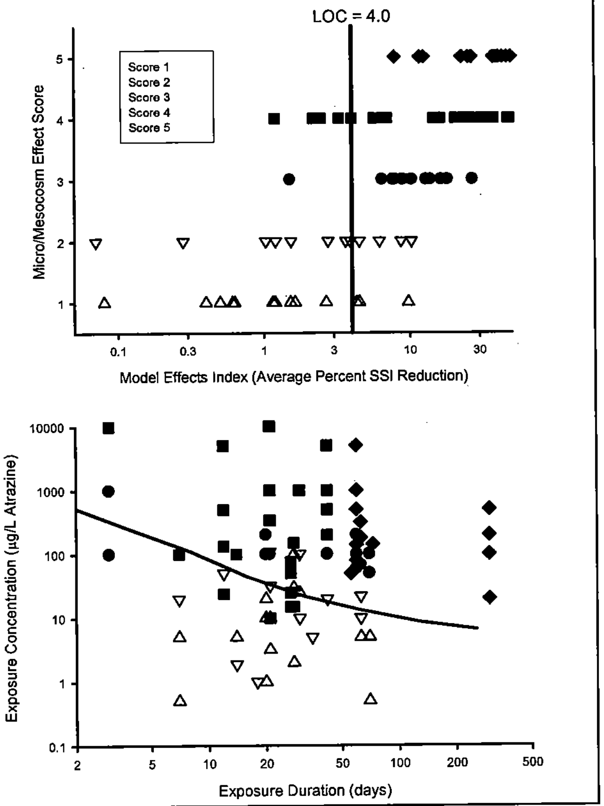
Although the rationale for choosing the average SSI over the entire simulation as the model effects index has been described above, it is not certain *a priori* how well this choice will support discrimination of micro/mesocosm effects scores or their extrapolation to field exposures. Therefore, the sensitivity analysis below will address what level of uncertainty in risk assessments might exist because of other possible choices for the model effects index.

2. LOC Determination for Base Model Configuration

A "base model configuration" was selected for conducting assessments that was (a) the Midwestern U.S. stream community structure discussed above and described in Volz et al. 2007, (b) the Ohio stream physicochemical parameters also discussed above and in Volz et al. 2007, (c) the use of the GSS for toxicity calculations, and (d) the toxicity relationships summarized in Table II-1. In addition, for model simulations of the exposures used in the micro/mesocosm data base, exposures were started on Julian day 105, selected as a typical average starting date for atrazine applications in the corn belt.

Simulations were conducted without atrazine exposure (control) and with each atrazine exposure concentration/duration from the micro/mesocosm database, and used to calculate a year-long average SSI for each atrazine exposure. For each micro/mesocosm exposure, the upper panel of Figure II-3 compares the micro/mesocosm effects score to the model effect index (percent reduction in the average modeled SSI from its maximum value of 1.0). The LOC for the model effects index for this consultation was selected simply by determining the midpoint of the range of values for which false negatives (i.e., micro/mesocosm scores of 3-5 for exposures with a model effect index below the LOC) equaled false positives (i.e., micro/mesocosm scores of 1-2 for exposures with a model effect index above the LOC). In a similar fashion, the LOC could also be identified in order to minimize the number of false negatives. Figure II-3 illustrates the LOC determination of 4.0, with seven false positives and seven false negatives, all of which are within a factor of 3 of the LOC.

Figure II-3 LOC=4.0 based on correlation of micro/mesocosm effect scores with model effect index values (upper panel), and comparison of model LOC to micro/ mesocosm effect scores at different exposure concentration/ durations (lower panel)



The lower panel of Figure II-3 illustrates the discrimination of the micro/mesocosm 1-2 and 3-5 score groups with the model LOC=4.0. This figure shows the concentration/duration dependence of micro/mesocosm scores and includes a model-calculated line showing the concentration/duration dependence of the LOC. It also shows how close the false negatives and false positives are to the LOC on an exposure concentration scale, differing again by no more than a factor of 3. Better performance than this would not be expected given the overlap between the score groups. The model does show more time dependence than is evident in the micro/mesocosm data, because the model effects index reflects effects over an entire season, and not just during the exposure period. This results in some tendency for the false positives to be at longer durations than the false negatives.

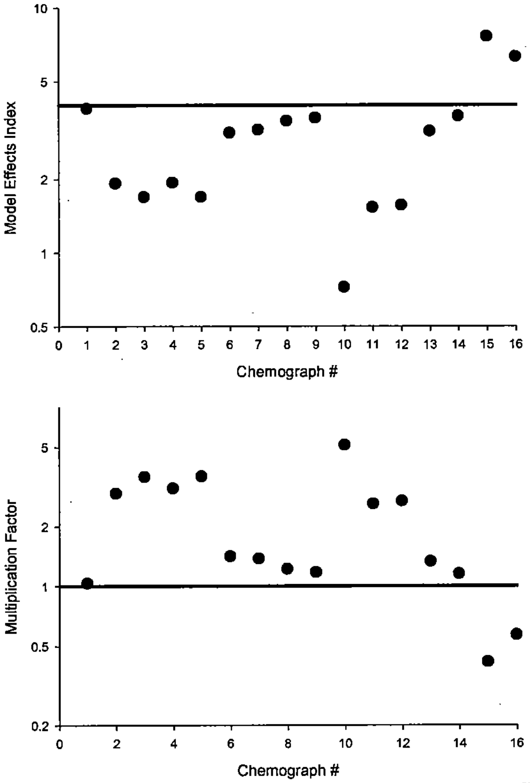
The base model described here differs somewhat from that described in the October 2003 IRED addendum (US EPA, 2003b) or by Volz et al (2007), most notably that the LOC is 4.0 rather than 5. Several changes are responsible for this change in the LOC. Most importantly, the model effects index previously had only been averaged from Julian Day 105 to the end of the year, but is now averaged over the entire year to include any effects before this date. Because the early parts of the year typically have low enough exposures to have no effects, this longer averaging period will include significant stretches of time when the SSI deviation is zero, thus reducing the average deviation (by a factor of 1.4). This has little impact on actual assessments because the model effects index for the field chemographs of interest will be reduced by the same factor as the LOC (i.e., this change will result in a greater likelihood of exceeding the LOC only for those field chemographs with early exposures). To a lesser degree, the LOC has also been affected by other changes from the earlier version, including improvements in how toxicity test information is translated into bioenergetics equations, applying the results of just one simulation using the best estimate for toxicity factors rather than the median results of multiple simulations based on random selections from a distribution of toxicity factors, and direct simulations of each exposure in the micro/mesocosm dataset rather than interpolations from a matrix of different exposure/duration combinations. Again, however, higher or lower values for the LOC are largely compensated for by higher or lower effects in the simulations for the field chemographs of interest. The previous CASM implementation also differed in having average screening concentrations that needed to be exceeded before CASM was even run; the purpose of this was to avoid unnecessary use of the substantial computing resources this earlier CASM implementation required. In the current version, this is no longer an issue due to faster computing resources and the elimination of multiple simulations .

3. Example Applications

Once an LOC is determined based on comparing micro/mesocosm effect scores with the model effects indices, application of the model simply involves conducting a simulation for an exposure time series of interest and determining whether the model effects index from this simulation exceeds the LOC. The upper panel of Figure II-4 shows the model effects indices for sixteen such simulations, using the example chemographs from Figure II-1. Only two of the chemographs exceeded the LOC, but a few others have model effects index values close to the LOC.

In addition to simply determining whether the model effect index exceeds the LOC, the model can also evaluate the multiplication factor by which the exposure time-series must be changed so that the model effects index equals the LOC. If the LOC is exceeded, this factor indicates the reduction in exposure necessary to be below the LOC. If the LOC is not exceeded, this factor indicates the amount exposure could be increased and still not exceed the LOC. Such information can benefit remediation efforts, evaluations of "margins of safety", and assessments of possible risks from future activities and conditions. The lower panel of Figure II-4 provides the multiplication factors for the sixteen example chemographs. The multiplication factors for the two chemographs that exceeded the LOC trigger are less than 1, indicating the amount of reduction needed to reduce effects to the LOC. The other multiplication factors range from barely over 1 to about 5, indicating the margin of safety present in these exposure time series.

Figure II-4 Model effect index values and multiplication factors for sixteen sample chemographs, using base model configuration



D. Sensitivity Analysis

1. Overview

The proposed methodology depends on whether the predicted relative effects in different exposure time-series from a single model configuration are useful approximations for extrapolations among a range of experimental and natural ecosystems. Although suitable data from experimental and natural ecosystems are not available to directly validate the utility of such extrapolations, this methodology can be validated to some degree by evaluating how sensitive results compare to alternative model configurations. Such a sensitivity analysis has three potential benefits. First, if relative effects are sufficiently similar across a range of possible model configurations, the need to independently justify specific options for model configuration is reduced. Second, a lack of sensitivity of results to a range of possibilities in a simulated system increases confidence that extrapolations among natural systems also would not be highly sensitive to system properties. Third, a sensitivity analysis will provide some quantitative information on certain sources of uncertainty, which can inform risk management decisions for assessments with exposures near the LOC.

A variety of decisions went into formulating the base model configuration used in Section II.C and warrant consideration in this sensitivity analysis. The community structure and bioenergetics equations of the base model configuration were intended to describe a second- to third-order Midwestern stream. Alternative community structures currently under development will be part of an expanded sensitivity analysis in the future and thus are not considered here. Areas of method development that are part of the sensitivity analysis include (a) the selection of the model effects index, (b) the start date for model simulations of the micro/mesocosm exposures, (c) the environmental driving variables (nutrients, temperature, and light), and (d) the EC50 selection. A comparison was also made regarding use of the GSS versus the PSS, but no significant differences in results were found.

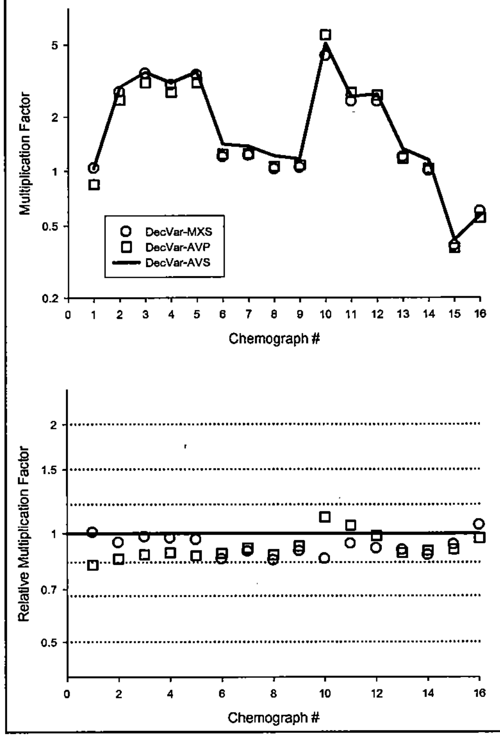
Because the LOC is dependent on the model configuration and parameterization, the LOC for each model configuration addressed in the sensitivity analysis must first be determined. Each model configuration requires new simulations of an unexposed system and of each exposure concentration/duration in the micro/mesocosm data set, after which a new LOC is selected for discriminating the micro/mesocosm scores with this model configuration. Simulations are then done again for the 16 example time series in Figure II-1, determining the model effects index to compare to the LOC and also the multiplication factors that specify how much the exposure must be changed to equal the LOC. Because each model configuration has its own LOC, the absolute model effects index values cannot be compared across model configurations to assess their similarity. However, the multiplication factors for each configuration can be compared, because they each address changing the exposure to equal the respective LOCs, and thus address how similar the risk assessments are for each configuration. Therefore, the basic criterion for assessing similarity in the subsequent sections will be to compare the multiplication factors for the alternative model configurations to the base model configuration.

2. Model Effects Index

As already noted, alternatives to the selected model effects index (the percent reduction in the annual average of the daily SSI values from the maximum value of 1.0) could include (a) a measure of total plant community biomass/production, not considering relative changes in different plant species, and (b) a different averaging period. For this sensitivity analysis, two alternatives were examined. One alternative (AVP) used the difference between the total plant biomass in the control and exposure simulations, but still averaging over the entire simulation. The other alternative (MXS) still used the daily SSI values, but used the maximum percentage deviation from 1.0 anytime during the simulation as the effects index, to contrast the smallest averaging period (one day) with the average over the entire simulation.

The upper panel of Figure II-5 contrasts the multiplication factors for these two alternative effects indices with the effects index for the base model configuration (solid line). To better show the magnitude of deviations, the lower panel of Figure II-5 show the relative multiplication factors (the multiplication for the alternatives divided by that for the base model configuration) on a finer scale, with horizontal lines denoting deviations of a factor of 1.2, 1.5, and 2.0.

Figure II-5 Comparison of multiplication factors for the base model configuration to alternatives with different model effect indices



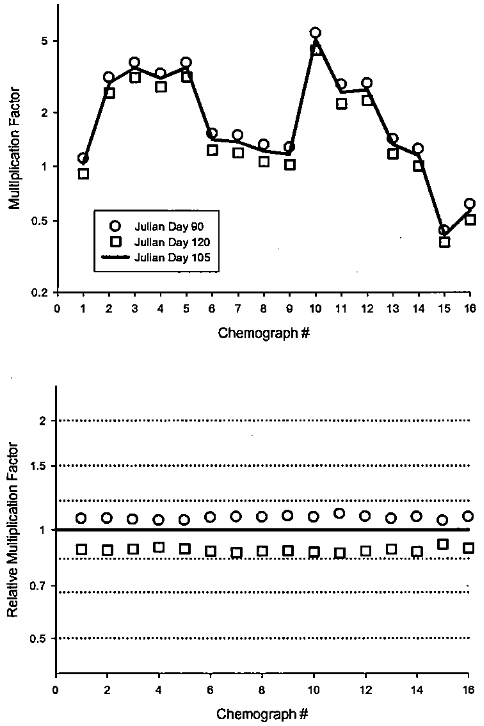
Although the AVP endpoint had a markedly lower LOC (2.70) and the MXS endpoint a markedly higher LOC (7.45), than the base case (4.00), the multiplication factors for these different model configurations are all approximately the same. This is because a change in the LOC arises from an alternative model configuration producing generally higher or lower effects than the base case for all exposures, so that a higher LOC is being compared to a similarly higher effects index for any simulation, and a lower LOC is being compared to lower model effects indices. Therefore, there is little change in the multiplication factors. In Figure II-5, alternative model effects indices indicate exposures of concern within 20% of that of the base model effects index for all the example exposures, with average deviations of less than 10%. This close agreement indicates that the choice of model effects index does not result in any substantial changes to risk assessments using this methodology, so that the index selected for the base model has general applicability within reasonable uncertainty.

3. Exposure Start Date

The simulations of the exposures of the micro/mesocosm data set to determine an LOC for the model effects index assume a start date for the model exposure on Julian day 105 (April 15) for the base model configuration. In natural systems, the first significant atrazine exposure will vary depending on application practices and rainfall, and so different options for this start date are of obvious interest. Start dates 15 days before and after the base choice were therefore tested. This shift only affects simulations of the constant exposure/fixed duration combinations used in the LOC determination, and does not affect the example field time series to which the model is then applied. Thus any change in LOC will lower or raise the multiplication factor by a fairly uniform amount.

Figure II-6 shows the results for these alternative start dates. An earlier start slightly increases model effect index values, leading to a higher LOC (4.25). Because model simulations for the example time series are not affected by the changed start date, multiplication factors are slightly elevated, but by less than 10%. In contrast, a later start slightly decreases model effect index values, lead to a lower LOC (3.60) and slightly lower multiplication factors (range from 10-18% lower (average 14%). As was true for the choice of the model effects index, these limited effects indicate little sensitivity of results to the choice of start date and good applicability of the start date choice for the base model configuration.

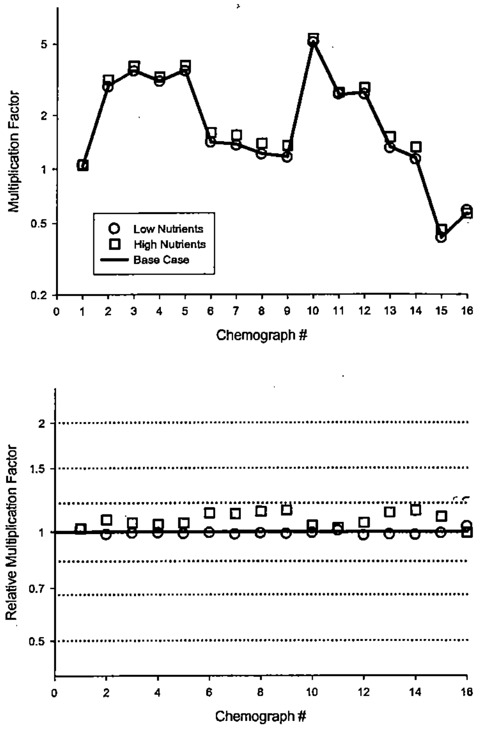
Figure II-6 Comparison of multiplication factors for base model configuration to alternative configurations with different start dates



4. Environmental Parameters

The base model configuration employs environmental data (nutrients, light, temperature) based on an Ohio stream (Volz et al. 2007). Figure II-7 shows the effect of altering nutrients (nitrogen, phosphorus, silicon) up or down, together, by a factor of 2. Figure II-8 shows effects of changing temperature up or down by 5° C. Figure II-9 shows the effects of halving or doubling light intensity.

Figure II-7 Comparison of multiplication factors for the base model configuration to alternative configurations with lower and higher nutrients.



For all these variables, the multiplication factors were never more than 20% different from those for the base model configuration, and the mean deviation was less than 10%. As for the model effects index and the starting date, risk assessments using this methodology are insensitive to the choices for these environmental variables.

5. Plant Toxicity EC50s

As discussed in Section II.B.2, there is considerable uncertainty in the assignment of EC50s to the modeled plant species, especially because of the large variation of values within a species. Based on the analysis of variance of the plant toxicity data discussed in Section B.2, ten alternative sets of plant EC50s were randomly selected from a log-normal distribution with median 100 ug/L and log standard deviation of 0.4 (Table II-2). The methodology was applied using each of these toxicity data sets, and the mean and standard deviation of the log multiplication factors was computed for each sample chemograph.

Figure II-8 Comparison of multiplication factors for the base model configuration to alternative configurations with lower and higher temperature

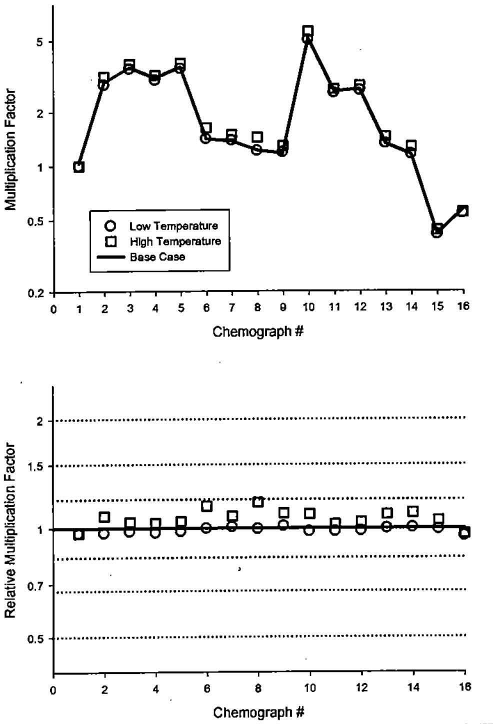


Figure II-9 Comparison of multiplication factors for the base model configuration to alternative configurations with lower and higher light.

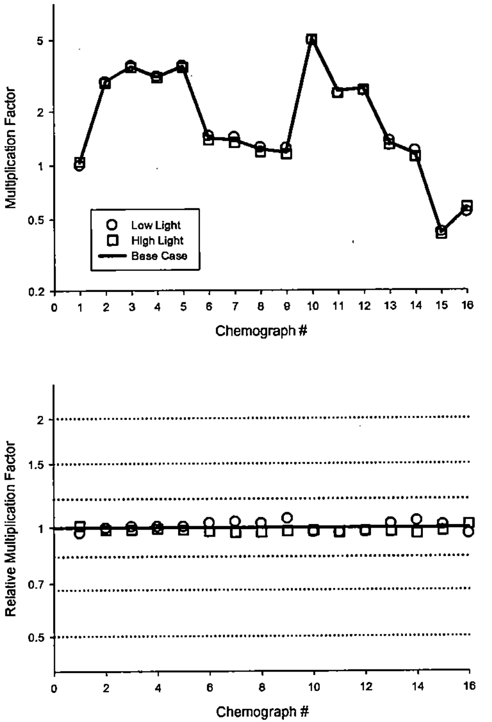
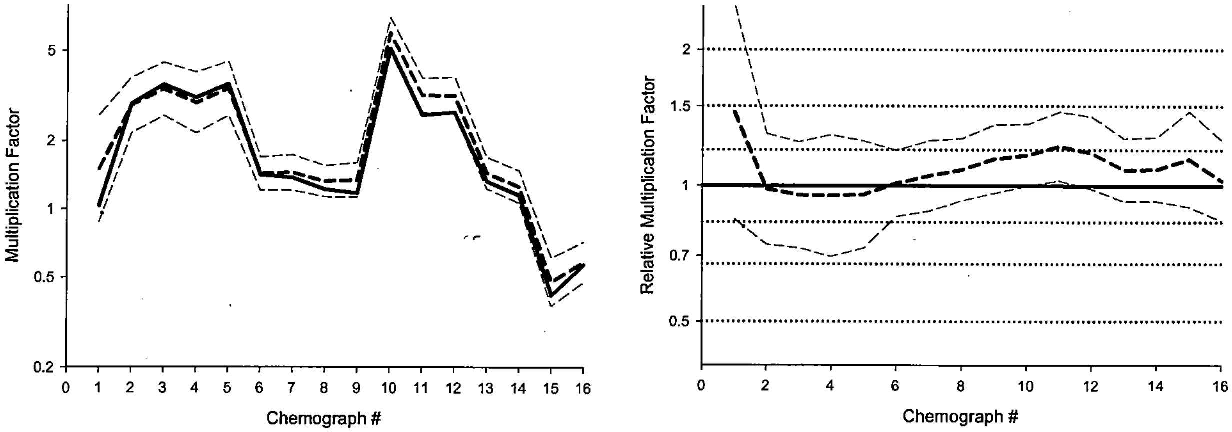


Figure II-10 compares the mean and standard deviation of the multiplication factors for the alternative plant EC50 sets to the multiplication factors for the base model configuration. Compared to the other factors in this sensitivity analysis, this variation of EC50s resulted in greater deviations of multiplication factors from that of the base case, and thus represents the greatest source of uncertainty. However, the base model configuration is still within one standard deviation of the mean of the alternative toxicity data sets and within 20% of the mean except for chemograph #1. Furthermore, even if the range of the alternative toxicity values were extended to two standard deviations, this differs by no more than a factor of two, except for the upper tail of chemograph #1, for which the base configuration is more conservative. This justifies the use of the base model configuration as being within this uncertainty of toxicity values, and documents the magnitude of an important uncertainty.

Table II-2 Ten sets of randomly selected EC50s (ug/L atrazine) for sensitivity analysis.

Mode Species	Set 1	Set 2	Set 3	Set 4	Set 5	Set 6	Set 7	Set 8	Set 9	Set 10
Phytoplankton 1	48	241	34	200	225	179	109	102	1196	292
Phytoplankton 2	125	96	89	65	84	112	11	42	150	160
Phytoplankton 3	54	42	65	55	168	167	641	63	162	89
Phytoplankton 4	149	185	438	41	122	148	31	164	351	788
Phytoplankton 5	198	53	241	56	13	283	67	22	133	324
Phytoplankton 6	66	23	44	121	325	384	208	205	90	12
Phytoplankton 7	1077	282	411	116	107	16	148	78	31	167
Phytoplankton 8	37	39	141	410	154	109	131	220	76	836
Phytoplankton 9	142	16	137	252	29	203	176	108	528	58
Phytoplankton 10	365	64	102	58	188	234	248	62	94	130
Periphyton 1	62	561	57	14	164	111	74	25	94	63
Periphyton 2	24	336	112	113	66	82	231	106	26	23
Periphyton 3	204	204	102	125	819	107	140	112	388	51
Periphyton 4	73	121	74	80	329	158	112	245	124	128
Periphyton 5	41	341	31	23	48	47	97	187	63	241
Periphyton 6	289	151	59	143	94	161	207	326	30	50
Periphyton 7	163	58	29	232	420	83	55	33	160	97
Periphyton 8	47	156	300	87	220	128	67	308	69	84
Periphyton 9	187	142	68	140	118	16	96	152	128	107
Periphyton 10	317	54	20	84	59	99	200	852	53	823
Macrophyte 1	269	62	285	407	86	105	85	136	44	90
Macrophyte 2	70	246	101	92	59	19	51	30	86	334
Macrophyte 3	288	50	61	51	214	116	76	123	27	677
Macrophyte 4	88	6	46	477	192	51	50	55	130	59
Macrophyte 5	55	55	30	38	136	58	485	230	248	16
Macrophyte 6	47	419	708	81	47	49	129	416	176	116

Figure II-10 Comparison of multiplication factors for the base model configuration (bold solid line) to the mean (bold dashed line) and mean +/- one standard deviation (narrow dashed lines) of the multiplication factors for ten alternative plant EC50 sets.



6. Chronic, Low-Level Exposures

Although this sensitivity analysis was oriented to choices for model configuration and inputs, it required testing of a broad set of representative chemographs (Figure II-1) to define a universe of exposures to which conclusions about sensitivity apply. These chemographs all lacked any significant atrazine exposure during the first few months of the year, but other recent model simulations with extended exposures of a few ug/L during this period indicated significant model responses which could have significance to risk assessments. Further evaluations of these responses have identified possible problems in CASM regarding (a) translation of the lower tails of the toxicity dose/response curves into the bioenergetics equations and (b) the sensitivity of some components of the modeled community to small, prolonged effects during the first few months of the year. These issues are currently being addressed, and will entail the development of alternative model configurations which more appropriately address low concentration and early-year exposures. Once these changes are made, they will support revisions to the analyses reported in this paper.

7. Slope of the Toxicity Curve

The current CASM_Atrazine configuration used a default probit slope of 3.31. This sensitivity analysis did not assess the performance of the model with varying the slope of the toxicity curve or the EC50 within the bounds of uncertainty. The slope of the toxicity curve might impact whether certain types of chemographs – in particular, short-term, high concentration exposures characteristic of Midwestern streams – exceed the LOC trigger. While the Agency plans to include this in future sensitivity analyses, it is also seeking SAP input on this issue.

E. Summary and Next Steps

The methodology described here addresses the need to assess the likely ecological effects of diverse, highly time-variable atrazine exposures. This was accomplished by using a community simulation model to estimate the relative effects of different exposure time series, with the absolute level of concern for model-predicted effects based on correlations with effects observed in microcosm and mesocosm studies. The feasibility of this methodology has been established for well-defined exposure time-series and the model-defined level of concern has been demonstrated to discriminate well between acceptable and unacceptable effects in the microcosm and mesocosm studies. A sensitivity analysis demonstrated that results are similar across a wide range of options for model formulation, parameterization, and inputs. Additional work in progress will expand the sensitivity analysis, further refine estimates for uncertainty associated with the base model configuration, address further changes to CASM algorithms for incorporating toxicity information, and quality assure the software being used.

F. SAP Charge Questions on the Use of the CASM Model

(1) Please comment on the use of a community simulation model for assessing the relative effects of different exposure time series. Please provide any

recommendations for a community response model other than, or along with, CASM that could be used for assessing the effects of atrazine. What are the strengths and weaknesses associated with the other model(s). Please comment on approaches that do not require an aquatic community response model and discuss the advantages and disadvantages of any alternative non-modeling approaches for extrapolating the effects seen in micro/mesocosm data to the effects resulting from field exposure.

(2) The general methodology employed in this analysis consists of (a) correlating model outputs to micro/mesocosm data to determine a model LOC and (b) applying the model to chemographs of interest to determine whether the LOC is exceeded. Please comment on the scientific strengths and limitations of this approach.

(3) Please comment on the reasonableness of the general CASM_Atrazine model formulation and parameterization, and the various options selected for the base model configuration.

(4) Please comment on whether the described sensitivity analyses are suitable for characterizing uncertainties associated with the choice of options for configuration of the base model and the input variables. What additional sources of uncertainty alternatives should be examined in this analysis? Please comment on whether the sensitivity of results to the slope of the toxicity curve, as well as the EC50, should be examined to address possible effects on responses to short pulses.

(5) During its review of the CASM_Atrazine model, the Agency found that the model appears to overestimate the effects of low, chronic concentrations possibly due to the way the model simulates population levels and decline of macrophytes early in the year.

- The Agency sees two approaches for addressing this issue: (1) exclude early season atrazine exposures from the chemograph inputs, or (2) modify the model to better account for the impacts of early-season exposures. Please comment on the strengths and weaknesses of the Agency's approaches and provide recommendations for any alternatives.
- Given that the Agency identified this issue during the exposure evaluation, please provide recommendations on additional steps the Agency could take for quality assurance for the model and methodology.

III. Atrazine Monitoring Program For Ecological Effects: Determining The Extent Of Waters Exceeding Effects-Based Thresholds For Atrazine

Over the years, atrazine surface water monitoring data have been collected by numerous programs and sources, including the U.S. Geological Survey (Goolsby and Battaglin, 2003; USGS, 2006b; USGS, 2007), registrants, states, and universities (see Williams et al, 2004b for a listing and description of atrazine monitoring studies). However, these monitoring studies were conducted for different purposes and were not intended to evaluate the extent to which atrazine concentrations in water bodies would exceed the LOC or to identify the areas/conditions under which the LOCs might be exceeded.

This section describes the objectives of the monitoring study, the watershed selection process, and the design and conduct of the monitoring study. The subsequent analysis of the monitoring results includes an evaluation of whether exposure exceeds the LOC, sensitivity analyses of the impacts of sampling and environmental factors, and extrapolation of the results for the monitoring sites to the larger population of vulnerable watersheds. The Agency is soliciting feedback from the SAP related to the interpretation of the results and sampling/study design issues critical to the application of this approach for assessing potential atrazine impacts to other water bodies.

A. Monitoring Study Objectives

The purpose of the monitoring program in flowing waters is to measure the magnitude and extent of atrazine concentrations in water bodies with the greatest potential vulnerability to atrazine exposure from use in corn and sorghum production (based on atrazine use and runoff potential) and to estimate percentage that exceed the LOC. The study focused on water bodies in the most vulnerable watersheds because this is where elevated concentrations of atrazine were most likely to occur, increasing the likelihood of identifying water bodies that might exceed the ecological thresholds of concern. If no exceedances occurred in these watersheds, the likelihood of finding atrazine exposures of concern would be lower in less vulnerable watersheds.

The 2003 addendum to the Atrazine IRED specified that the monitoring program initially focus on flowing waters associated with corn and sorghum production (US EPA, 2003b). A separate pilot monitoring study is underway for water bodies in sugarcane areas. Additionally, the Agency is evaluating existing monitoring of reservoirs to determine the potential impact of atrazine on aquatic communities in static water bodies. The sugarcane and reservoir efforts are not the subject of this SAP.

The atrazine monitoring program was intended to identify watersheds in corn and sorghum areas that contained water bodies exceeding the effects-based LOC trigger described in Section II. The monitoring program also gathered additional information on atrazine use and practices, watershed and water body characteristics, and other factors to facilitate identifying water bodies beyond the initial sampling pool that have the potential for atrazine loadings that exceed effects-based thresholds.

The atrazine ecological monitoring program was designed to:

(1) Determine the extent to which waters in vulnerable watersheds exceed effects-based thresholds for atrazine, and

(2) Collect information that will help identify where the waters that exceed the effects-based atrazine thresholds occur.

This section focuses on the first objective. Section IV describes the approach the USEPA proposes to take for addressing the second objective.

B. Study Design

The study design relied on the wealth of information already known about the fate and transport properties of atrazine, its use, and its history of occurrence in water. The following sections briefly describe the site selection process, from identifying vulnerable watersheds to selecting monitoring sites, and the sampling/monitoring methods. Williams et al (2004a) provide details of the study design.

1. Site Selection

The site selection process used existing knowledge about atrazine occurrence in water to maximize the potential for finding waters that exceed the LOC. Key factors were:

(2) **Use**: amount and intensity of atrazine use on corn and sorghum
(3) **Vulnerability based on use/runoff**: integrating both atrazine use and surface runoff vulnerability
(4) **Representative sampling**: 40 sites selected from most vulnerable watersheds, with probability of selection proportional to use

This section summarizes the steps used to identify those watersheds that are expected to be most potentially vulnerable to atrazine loading. From this upper tier of vulnerable watersheds, a spatially-balanced survey design was used to select a representative sample of 40 watersheds. Sub-watershed land use and flow data were used to identify candidate stream segments for monitoring within those watersheds. Details and documentation are available in Williams et al (2004a).

a) Watershed Vulnerability Assessment

The monitoring program used a watershed-based approach to target areas for monitoring. Because of the widespread use of atrazine on corn and sorghum, the initial approach focused on nationally-available data. Watershed, or hydrologic unit, boundaries define the extent of surface water drainage to a stream point and provide a framework for organizing and processing spatial data pertinent to the vulnerability of watersheds and receiving water bodies to atrazine loading.

Hydrologic unit maps defined by the USGS (Seaber et al, 1987; USGS, 2006a) provide a hierarchical system of mapping watersheds. This system includes six levels, with national maps available for the first four levels at the time the study was being designed. The assessment used the fifth, HUC-10 or HUC-11, level, representing watersheds that are typically 40,000 to 250,000 acres in size. Because mapping at this level was not available for all states, Syngenta collected the best available coverages for the 37-state area that encompassed the extent of significant atrazine use on corn and sorghum (Williams et al, 2004a, 2004b).

HUC-10/11 watershed boundaries were used to analyze a number of spatial data layers that might serve as indicators of the potential for pesticide (i.e., atrazine) movement from the fields of application to water bodies. Williams et al. (2004a, 2004b) provide details of those watershed vulnerability analyses and the spatial data sources used for the analysis, as well as documentation of additional data manipulation.

Syngenta evaluated a number of potential factors affecting pesticide runoff and watershed vulnerability, including atrazine use intensity, land use types, flow/drainage under row crops, precipitation, and soil characteristics (Williams et al., 2004a). At the same time, the US EPA looked at the potential for using the Watershed Regression for Pesticides (WARP) model, developed by the USGS for atrazine (Larson et al, 2004), as a tool for identifying the watersheds potentially most vulnerable to atrazine loading in flowing water bodies.

The WARP model integrates use intensity, watershed area, soil susceptibility to runoff and rainfall intensity with available water monitoring data (Larson et al., 2004). WARP estimates various percentiles of the annual distribution of atrazine concentrations using separate regression equations based on the following parameters:

- Atrazine use intensity: amount of atrazine applied per watershed area
- Area: Total watershed area
- Rainfall intensity: R factor from USDA/NRCS
- Soil erodibility: K factor from USDA/NRCS
- Dunne Overland Flow: fraction of runoff from saturated soils

The atrazine watershed vulnerability assessment is based on the regression equation that estimated the 95th percentile from an annual distribution of atrazine concentrations:

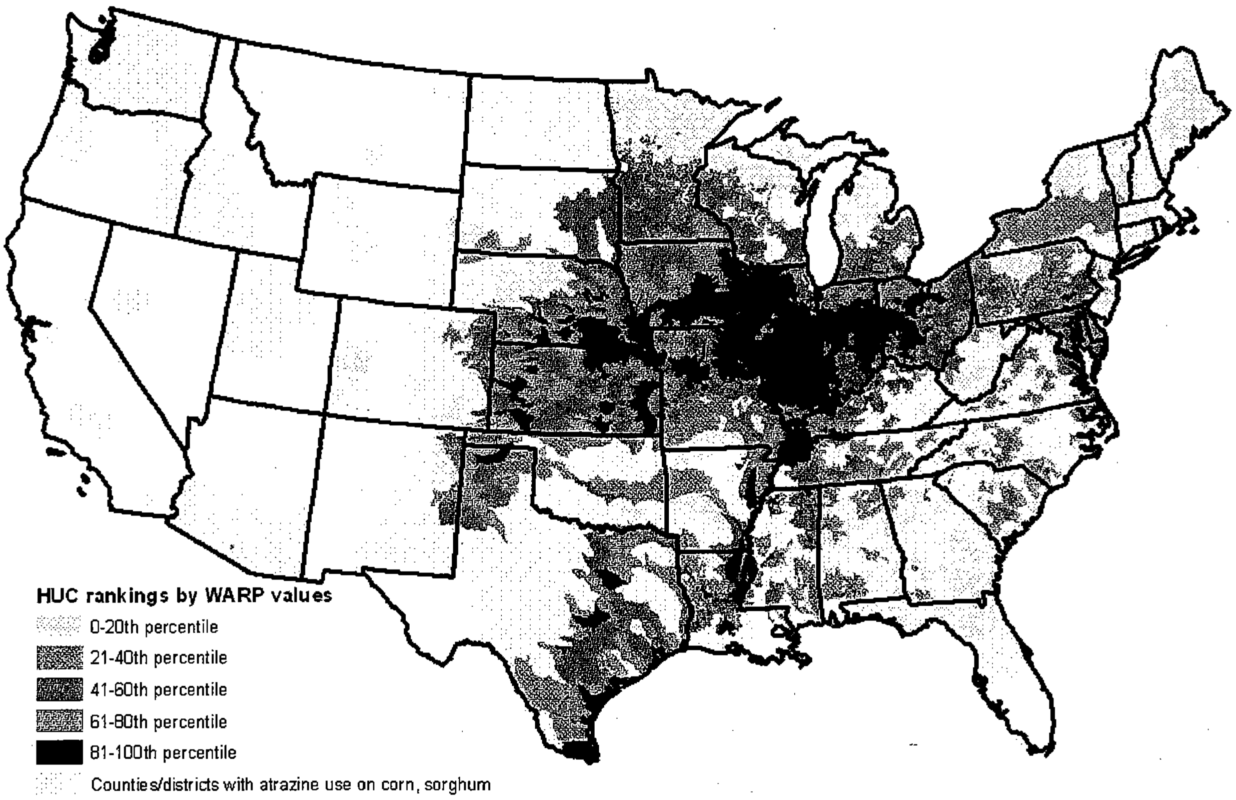
$$\text{WARP} = 10\wedge(-4.60 + (0.67U^{0.25}) + (1.12\text{Log}R) + (3.59K) + (0.0006A^{0.5}) - (0.11{*}D))$$

where,

U = watershed cropped area use intensity in kg/km^2
R = the USLE rainfall erosivity factor
K = the USLE soil erodibility factor
A = watershed area (km^2)
D = Dunne overland flow

The WARP model calculations required collecting and re-aggregating values for atrazine use intensity (market research data on atrazine use data by county, averaged across the years 1998-2002), R factor (USDA, 2001, Natural Resource Inventory), K factor (average for the STATSGO mapping units, USDA, 1994), and Dunne overland flow (Wolock, 2003) at the HUC-10/11 watershed-scale. Details are provided in Williams et al (2004a and 2004b). Figure III-1 shows the results of the WARP assessment for those watersheds that intersected counties with atrazine use intensities of 0.25 lb ai/ac or greater (5,860 watersheds). The watersheds are ranked in five quintiles based on the estimated 95th percentile WARP concentrations.

Figure III-1 Ranking of watersheds in quintiles using the USGS WAtershed Regression on Pesticides model



Williams et al. (2004a) also considered watershed vulnerability approaches based on flow accumulation under row crops (derived from the National Elevation Dataset and the 1992 National Land Cover Dataset) and a soil surface runoff potential rating based on intrinsic soil properties only (Pierce and Anderson, 1992).

Syngenta evaluated the various watershed vulnerability approaches using atrazine monitoring data from a number of sources, including USGS, their own monitoring programs, and various state and university programs (Williams et al, 2004a, 2004b). Williams et al (2004a) grouped monitoring stations with no reported atrazine concentration greater than 0.1 ppb into a "low" detection group and monitoring stations with at least one detection of atrazine greater than 3.0 ppb into a "high" group.

The low detection group included 526 monitoring stations that represented the lower 21st percentile of the atrazine monitoring data. The high detection group included 487 monitoring stations, representing the upper 18th percentile of atrazine monitoring data. Syngenta used GIS tools to evaluate how well the various watershed vulnerability approaches separated sites with detections >3 ppb from those with detections <0.1 ppb. The highest 20% of vulnerable watersheds identified using WARP provided the most effective distinction between high and low detection sites (Table III-1).

Table III-1 Evaluation of selected watershed vulnerability approaches for atrazine monitoring, based on Williams et al, 2004a

Watershed Vulnerability Approaches[1]	**Total HUCs included**	**HUCs with sample stations[2]**	**Stations with atrazine detects >3 ppb**		**Stations with atrazine detects <0.1 ppb**	
			No.	**Pct**	**No.**	**Pct**
Initial Pool of 3,440 HUCs in 11 states						
WARP upper 90th %ile	339	51	45	88%	0	0%
WARP upper 80th %ile	632	102	85	83%	0	0%
Flow Acc. Upper 90th %ile	287	32	15	47%	7	22%
Sev. Soil Runoff upper 90th %ile	304	43	17	40%	10	23%
Combined upper 90th%ile WARP + Flow Acc	626	83	60	72%	7	8%
Combined upper 90th%ile WARP + Flow Acc + Sev. Soil Runoff	930	126	77	61%	17	13%
Combined upper 95th%ile WARP + Flow Acc + Sev. Soil Runoff	493	59	39	66%	8	14%
Final Pool of 5,860 HUCs in 37 states						
WARP upper 80th %ile	1172	195	156	80%	2	1%
Flow Acc. Upper 90th %ile not included in WARP upper 80th %ile	263	26	5	19%	16	62%
Combined WARP upper 80th and Flow Acc. Upper 90th %ile	1435	221	161	73%	18	8%

1 Watershed vulnerability approaches:

WARP = Watershed Regression for Pesticides 95th percentile annual residue prediction algorithm
Flow Acc = Flow Accumulation under Row Crops (from NED, NLCD)
Sev. Soil Runoff = Soils rated as having a severe potential for surface runoff of pesticides

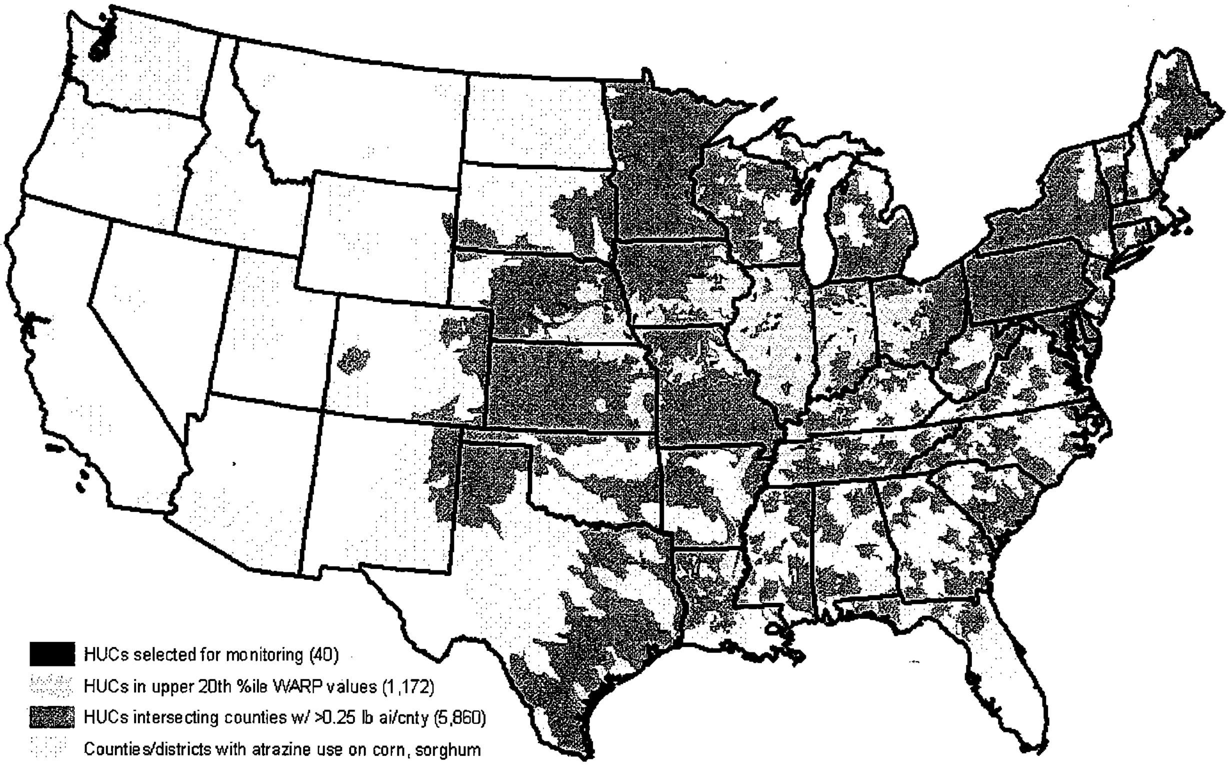
2 Pool of sampled HUC's for the 11 state group was 574 (295 in the "upper" group and 87 in the "lower" group). For the 37 state group was 797 (333 in the "upper" group and 198 in the "lower" group).

The upper 10th and upper 20th percentiles of WARP effectively grouped the highest percentile of monitoring stations with atrazine detections >3 ppb (80-88% of the stations included in these tiers of vulnerable watersheds had at least one reported detection of atrazine >3 ppb) with the fewest numbers of stations that never had detects >0.1 ppb (Table III-1). Vulnerability approaches based on flow accumulation under row crops and percentage of soils rated as having a severe potential for surface runoff included more monitoring stations with low or no atrazine detections. Most likely these approaches did not account for atrazine use and, thus, could include areas that, while vulnerable to pesticide runoff, did not have any atrazine use in the watershed.

Using the watershed vulnerability approach, the atrazine use area in the corn and sorghum-growing regions of the U.S. was divided into three tiers (Figure III-2):

(1) Approximately 10,000 HUC-10/11 watersheds in which atrazine was used on corn and sorghum.
(2) 5,860 HUC-10/11 watersheds that intersected counties with use intensities of 0.25 lb ai/county acre or higher, based on atrazine use between 1998 and 2002.
(3) High vulnerability tier of 1,172 HUC-10/11 watersheds that represent the upper 20th percentile of the second tier of watersheds, based on USGS' WARP model.

Figure III-2 Location of atrazine use area (gray), areas of use > 0.25 lb/ac (green), most vulnerable 20th percentile of watersheds (yellow), and sampled watersheds (red).



Several assumptions are implicit in the watershed vulnerability approach:

- The WARP estimates reflect watershed vulnerability over time. In particular, the approach assumes that year-to-year variability in atrazine use intensity, one of the major driving factors in the regression model estimates, will not result in drastic changes in the relative ranking of the watersheds. This assumption may not be unreasonable since atrazine use has remained relatively steady over time. However, if shifts in relative usage of atrazine on corn and sorghum or if shifts in corn-sorghum cropping patterns occur, this assumption may not hold.
- The WARP estimate of the 95th percentile atrazine concentration in a year captures the major factors affecting the relative vulnerability of watersheds to

atrazine loading in water bodies. Since WARP was based on nationally-available datasets, it does not necessarily capture locally important characteristics that may influence atrazine movement to water bodies.

- The distributional approach to atrazine concentrations (i.e., WARP estimates of the 95th percentile of atrazine concentrations in a year) are a reasonable surrogate for the magnitude-duration chemographs that impact aquatic communities.
- A watershed-based vulnerability is reflective of the relative vulnerability of the water bodies within that watershed.

b) Representative Sampling of Vulnerable Watersheds

The goal of the atrazine monitoring program was to employ a probability-based, spatial survey design to select sampling locations so that the extent to which waters are exceeding effect-based atrazine thresholds could be defensibly estimated via the use of the appropriate statistical methods. For clarity, the components of the population and sample are first summarized.

(1) Target Population

The critical question for the monitoring program was "To what extent are waters exceeding effects-based thresholds for atrazine?" One interpretation of the target population is then defined as the collection of all watersheds within the United States (the 48 conterminous states in this instance). Since watersheds are defined for all locations on streams and rivers, the monitoring question of interest can be stated as "How many kilometers of all streams and rivers within the United States exceed the established level of concern (LOC)?" In actuality, to focus the field monitoring on areas considered to be most vulnerable and to address limitations on where field monitoring could be implemented, a restricted set of watersheds, based on HUCs, was defined for the target population (Table III-2). It is important to understand this restriction and how it impacts the survey design and its interpretation.

Table III-2 distinguishes two alternative target populations: (1) Stream and river based and (2) HUC-based. The HUC-based target population is a subset of the stream and river based target population since HUC pour points are a subset of all possible locations on the stream and river network. The HUC-based target population was used because of uncertainties associated with county-level atrazine use estimates and because, at the time, the framework was not available to compute WARP scores for all stream and river locations within the corn/sorghum use areas (see Section IV.A for some potential future approaches). Consequently, rather than defining the target population as watersheds defined by all locations on stream and river network, the target population is defined in terms of HUCs where it is feasible to compute WARP scores for the 5,860 HUCs that intersect counties with atrazine use >0.25 lb ai/county acre. This is Stratum B for the HUC target population in Table III-2. This stratum was then split into two additional strata based on the WARP scores. Stratum B WARP > 80 Percentile includes the set of 1,172 HUCs in areas where corn and sorghum are grown that were predicted by the USGS WARP model to be the 20% most vulnerable watersheds to atrazine out of the 5,860 watersheds. This stratum is further split into the those HUCs predicted by USGS WARP model to be between the 80th and 95th percentile (874 HUCs) and those above the 95th percentile (298 HUCs).

Because the intent of the monitoring study was to focus on the most vulnerable watersheds, Stratum A and Stratum B WARP 0-80 Percentile are explicitly excluded from the survey design. HUCs in these two strata are not included in the atrazine monitoring program.

Table III-2 Target Population and Survey Design Stratification

Survey Design Strata	Stream and River Target Population	Hydrologic Unit (HUC-10) Target Population
Stratum A	All streams and rivers in HUC watersheds that do not intersect counties with atrazine use >0.25 lb atrazine/county acre	All HUC watersheds that do not intersect counties with atrazine use >0.25 lb atrazine/county acre
Stratum B	All streams and rivers in HUC watersheds that intersect counties with atrazine use >0.25 lb atrazine/county acre	All HUC watersheds that intersect counties with atrazine use >0.25 lb atrazine/county acre (5,860 HUCs)
Stratum B WARP 0-80 Percentile	All streams and rivers in Stratum B with WARP scores less than or equal to 80th percentile of all WARP scores in Stratum B	All HUC watersheds in Stratum B with WARP scores less than or equal to 80th percentile of all WARP Scores in Stratum B (4,688 HUCs)
Stratum B WARP > 80 Percentile	All streams and rivers in Stratum B with WARP scores greater than 80th percentile of all WARP scores in Stratum B	All HUC watersheds in Stratum B with WARP scores greater than 80th percentile of all WARP Scores in Stratum B (1,172 HUCs)
Stratum B WARP (2,4]		All HUC watersheds in Stratum B WARP >80 with WARP scores between 2 and 4 (874 HUCs)
Stratum B WARP (4,14]		All HUC watersheds in Stratum B WARP >80 with WARP scores > 4 (298 HUCs)

(2) Survey Design

The probability-based survey design is stratified based on the categories described for the HUC-10 target population. Stratum A and stratum "B WARP 0-80 Percentile" were not sampled. Only Stratum "B WARP (2,4]" and stratum "B WARP (4,14]" were sampled. Given the available resources and the desire to focus the sampling on HUCs in areas where corn and sorghum are grown that are the *most vulnerable* to exposures to atrazine, samples were selected only from HUCs within the top 20% of USGS WARP scores. That is the sampling units (i.e. the units actually sampled) were the HUCs, with the sampling frame (i.e. the list of sampling units) being a GIS coverage of the centroids of each of the HUCs.

Within each of the two strata sampled, the HUCs were selected with probability proportional to the value of atrazine use estimated for the HUC from the county-level use data. Consequently, HUCs with higher estimated atrazine use were more likely to be selected than those with lower estimated use within each stratum. The rationale was to focus sampling in HUCs more likely to result in an exceedance of the LOC.

(3) Sample Size And Analysis Weights

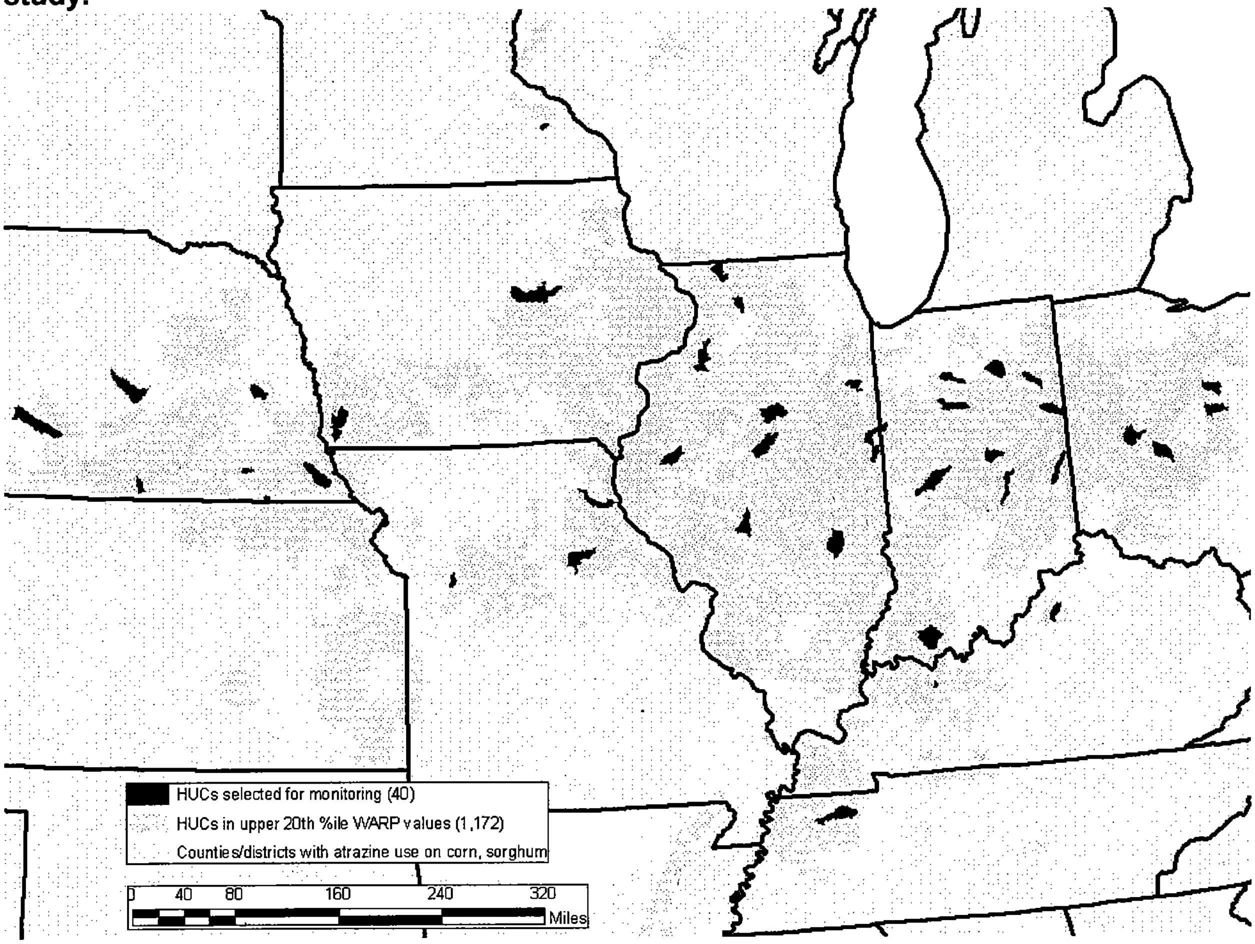
The total sample size was 40 HUCs with 20 allocated to each of the two strata WARP (2,4] and WARP (4,14]. In addition, 5 additional HUCs were selected in each stratum to be used as backup replacement HUCs in the event that one or more of the original 20 HUCs could not be monitored due to field operation limitations.

One stratum, where N_1=874, represents "moderately high" WARP scores of (2,4]. The other stratum represents watersheds with the overall highest WARP scores, which fall in the range of (4, 14] where N_2=298. Since the survey design includes stratification and unequal probability of selection proportional to atrazine use (kg/km^2), the statistical analyses must incorporate this information through the use of weights associated with each HUC. The weights are inversely proportional to the probability of inclusion; therefore, each of the selected watersheds in the WARP (2,4] stratum (N_1=874) represent 20 to 93 watersheds, where a HUC with higher atrazine use would represent fewer HUCs and a HUC with lower atrazine use would represent more HUCs (since more HUCs have lower atrazine use than high atrazine use within the stratum. Similarly, in the WARP (4,14] stratum (N_2=298) the selected watersheds represent approximately 9 to 38 watersheds.

The survey design selection also incorporated a process that ensures that every potential sample selection would be spatially-balanced. That is, the algorithm guarantees that the HUCs will always be spatially representative over the extent of the population of 1,172 watersheds. The method is termed a generalized random tessellation stratified (GRTS) design (Stevens and Olsen, 2004; Stevens and Olsen, 1999). The GRTS method was developed as part of the USEPA Office of Research and Development (ORD) Environmental Mapping and Assessment Program (EMAP) (McDonald et al, 2002) and has been used extensively by EPA and many state programs. Actual selection of HUCs was completed using the spsurvey library (ARM 2007) developed by EMAP for use with the R Statistical Software program (R Development Core Team, 2006).

Figure III-3 shows the location of the 1,172 HUC-10s and the subset of 40 HUC-10s that were actually selected and monitored.

Figure III-3 Location of the 40 watersheds (red) sampled for the atrazine eco-monitoring study.



(4) Sampled Population

The survey design selected 40 HUCs to be sampled (Table III-3). Each of the selected HUCs was evaluated to determine if it was feasible to locate and maintain a stream monitoring site within the HUC. In seven of the initial 40 HUCs a suitable stream sampling site could not be determined (4 from WARP (2,4] stratum and 3 from WARP (4,14] stratum). Following procedures for replacing HUCs for GRTS sampling these were replaced by other HUCs within each stratum. Although only 40 HUC-10s were monitored, the actual sample size is 47 with missing data for the 7 non-sampleable HUCs. It is critical that the seven non-monitored HUCs be included since they represent the collection of HUCs within the 1,172 HUCs where it would not have been possible to locate and maintain a monitoring site. Unless additional assumptions are made it is not possible to know whether the 40 monitored HUCs are representative of this collection of non-monitored HUCs. One potential assumption would be that this collection is "missing at random" and hence 40 monitored HUCs would represent all 1,172 HUCs. Note that the number of HUCs in this collection can, and will, be estimated.

Table III-3 Watersheds selected for monitoring using the GRTS approach.

Site	Watershed_Name	HUC11 Code	Stratum WARP	Years Monitored	Auto-samples
IA-01	Wolf Creek	07080205090	(2,4]	2004-05	
IA-02	Nishnabotana River	10240002080	(2,4]	2004-05	2004-05
IL-01	Pecatonica River	07090003140	(2,4]	2004-05	
IL-02	Pine Creek	07090005050	(2,4]	2004-05	
IL-03	Spring Creek	07090007050	(4,14]	2005-07[1]	
IL-04	Iroquois River	07120002160	(2,4]	2005-07[1]	
IL-05	Panther Creek	07130004040	(2,4]	2004-05	
IL-06	Sugar Creek West Fork	07130009060	(2,4]	2004-05	2004-05
IL-07	Grindstone Creek	07130010060	(2,4]	2004-05	
IL-08	Horse Creek	07130007060	(4,14]	2005-07[1]	2005-06
IL-09	Muddy Creek, Illinois	05120112070	(4,14]	2004-05	
IL-NS		07140202090	(2,4]	Not sampled	
IN-01	Mill Creek	05120106070	(2,4]	2004-05	
IN-02	Eel River	05120104040	(2,4]	2004-05	
IN-03	Eightmile Creek	05120101110	(4,14]	2005-06	
IN-04	Rock Creek	05120105020	(4,14]	2004-06	
IN-05	Limber Lost Creek	05120101050	(4,14]	2004-06	
IN-06	Vermilion River, North Fork	05120109090	(4,14]	2005-07[1]	2005-07
IN-07	White River	05120201070	(4,14]	2005-06	
IN-08	Whitewater, Nolans Fork	05080003030	(4,14]	2005-06	
IN-09	Raccoon Creek	05120108160	(4,14]	2005-06	2005-06
IN-10	Brandywine Creek	05120204040	(4,14]	2005-06	
IN-11	Little Pigeon Creek	00514020114	(2,4]	2005-07[1]	2005-07
IN-NS1		05120111170	(2,4]	Not sampled	
IN-NS2		05120111090	(4,14]	Not sampled	
KY-01	Brashears Creek	05140102090	(4,14]	2005-06	
KY-02	Twomile Creek	05110005130	(4,14]	2005-06	
KY-NS		05110004110	(2,4]	Not sampled	
LA_NS		01114020891	(4,14]	Not sampled	
MN-01	Whitewater North Fork	07040003110	(2,4]	2005-06	2005-06
MO-01	South Fabius River	07110003040	(2,4]	2004-07[1]	2004-07
MO-02	Youngs Creek	07110006030	(4,14]	2004-07[1]	
MO-03	Little Sni-a-Bar Creek	10300101130	(2,4]	2004-06	2006
MO-NS		10240011060	(2,4]	Not sampled	
NE-01	Wahoo Creek	10200203090	(2,4]	2004-05	
NE-02	Middle Loup River	10210003080	(2,4]	2005-06	
NE-03	Platte River	10200101040	(2,4]	2004-05	
NE-04	Big Blue River, Upper Gage	10270202060	(4,14]	2005-06	2006
NE-05	Muddy Creek, NE	10240008081	(4,14]	2005-06	2006

Site	Watershed_Name	HUC11 Code	Stratum WARP	Years Monitored	Auto-samples
NE-06	Crooked Creek	10250016081	(2,4]	2004-06	2004-06
NE-07	Big Blue River, Lower Gage	10270205011	(4,14]	2005-06	
NE-NS		10270203060	(4,14]	Not sampled	
OH-01	Kokosing River	05040003020	(2,4]	2004-05	
OH-02	Licking River, North Fork	05040006010	(4,14]	2005-07 [1]	
OH-03	Mad River	05080001160	(2,4]	2004-05	2004-05
OH-04	Deer Creek	05060002020	(4,14]	2005-06	
TN-01	Obion Middle Fork	00801020303	(4,14]	2005-06	

1 – Monitoring data for 2007 are still undergoing QA/QC and are not included in this assessment.

(5) Monitoring Question

The monitoring question initially posed was "To what extent are waters exceeding effects-based thresholds for atrazine? The extent of exceedances will be quantified in terms of X% of watersheds having flowing water bodies that exceed the trigger with Y% confidence." The actual monitoring question that can be answered by the survey design is "How many (%) HUCs in corn and sorghum growing regions in the United States where predicted exposure to atrazine is greatest are estimated to have atrazine concentrations that exceed the LOC in at least one sub-watershed?" The latter phase "in at least one sub-watershed" is necessary since only one potential monitoring site on the stream and river network within the HUC was monitored. The next section describes the process for selecting monitoring sites within a HUC.

c) Selection Of Monitoring Site Within The Watershed

Williams et al (2004a) details the criteria used to select monitoring sites within the targeted watersheds (described in Section III.B.1.b). The criteria for selecting stream segments for monitoring focused on stream segments relevant to study goals, e.g., sub-watersheds with higher row-crop densities (and, thus, higher likelihood of atrazine use) and sub-watersheds with minimal urban influences. The selection process also avoided sub-watersheds that may be subject to major annual variation in atrazine load as a result of crop rotation or highly "flashy" hydrology which may minimize longer atrazine exposures.

Syngenta identified stream segments with maximum drainage areas that would

- exclude major river stems running through the interbasin HUC10/11 watersheds,
- avoid larger streams/rivers (5th and 6th order) within larger HUCs, and
- allow for a sufficient watershed size to minimize the likelihood of monitoring data distortion due to annual crop rotation changes.

The following criteria were used to identify eligible stream segments using GIS data and tools:

- Minimum drainage area of 9 square miles

- Maximum drainage area of no more than one-half of the HUC11 watershed, unless total watershed area is less than 50 square miles. In such instances, tributaries of larger streams will be manually identified
- Percent flow accumulation under urban land use is less than 10%
- Percent flow accumulation under cropland is in the upper 50th percentile

Syngenta randomly numbered all stream segments that met the criteria for field evaluation. Beginning with the most downstream point of the first randomly-ordered segment and working upstream, the field crew looked for a suitable sampling site. The field crews verified that corn and/or sorghum agriculture was present and that the streams were accessible for monitoring. Conditions that would exclude a stream segment included areas with few acres in corn and sorghum, a prevalence of herbicide-tolerant corn or use of herbicides other than atrazine, point sources such as pesticide distributors, or other anomalies. If no suitable location was found for the first segment, the process was repeated for the next randomly selected segment until a suitable site was located.

2. Sampling/Monitoring Design

Williams et al (2004a) and Hampton et al (2007a) provide details of the monitoring design and conduct. Half (20) of the monitoring sties were sampled in 2004-05 and the remaining 20 sites were sampled in 2005-06 (Table III-2). Each site was sampled for at least two years. Monitoring extended into a third year for some sites in which atrazine concentrations exceeded the LOC in one or more years, elevated levels of atrazine below the LOC occurred in lower-than-normal rainfall years, or low flow conditions affected sample collection.

Sampling began in early April, before planting, and continued for approximately 120 days after an estimated 50% of the local corn acres were planted (Hampton et al, 2007a). The sampling period typically ran from April through August at most sites.

At every site, water samples were collected every 4 days during sampling period. In addition, flow-triggered automatic samplers were installed at 10 of the sites to provide a comparison between the 4-day grab samples and autosamples. The automatic samplers were triggered to start and stop at specified changes in stream flow, determined specifically for each site (Hampton et al, 2007a). In addition, all sites were instrumented to measure stream flow and to collect weather data (e.g., meteorological conditions, rainfall, soil moisture).

All water samples were analyzed for atrazine using immuno-assay (limit of detection of 0.05 ug/L), with detections confirmed using gas chromatography/mass spectrometry (GC/MS). After May 2, 2005, all samples were analyzed using liquid chromatography/ mass spectrometry/mass spectrometry (LC/MS/MS) (Hampton et al, 2007a).

C. Monitoring Results

Hampton et al (2007a) and Volz et al (2007) provide results of the monitoring study. This section provides the US EPA's analysis of the data.

1. Atrazine Chemographs

Appendix 2 provides a summary of the atrazine monitoring data by site and year. It includes yearly frequencies of detection as well as peak and rolling-average concentrations over various time periods. The frequency of detection across all sites and years ranged from a maximum of 100% to a minimum of 11%. The maximum concentration detected during the study was 208.8 µg/L from the IN-11 site in 2005. The mean annual concentrations ranged from a maximum of 9.5 µg/Ll from the MO-01 site in 2004 to a low of 0.1 µg/L for the NE-06 site in 2006, while the median values ranged from 4.2 µg/L for the MO-02 site in 2004 to 0.08 µg/L for the OH-03 site in 2005. For all 40 sites, peak concentrations ranged from 0.13 to 208.76 µg/L, 14-day average concentrations from 0.1 to 80 µg/L, 30-day average concentrations from 0.1 to 45 µg/L, 60-day average concentrations from 0.1 to 26 µg/L, and 90-day average concentrations from 0.1 to 18 µg/L.

Because of the nature of the LOC, the atrazine chemographs might be more appropriately summarized by evaluating the chemograph shape – the magnitude and duration of exposure – rather than considering a statistical or distributional summary of monitoring results. Appendix 3 provides a graphical summary of the individual chemographs in relation to rainfall events and time of planting. Table III-4 summarizes the chemograph patterns for atrazine peaks of greater than 1 µg/L. Most of the sites had multiple atrazine peaks (defined as detections greater than 1 µg/L), but these were generally of short duration, usually no more than 1 to 3 sample points (Table III-4, Appendix 3). The exceptions are MO-01 and MO-02, both of which had extended periods of elevated atrazine concentrations. Forty of the site-years had atrazine peaks greater than10 µg/L; 25 had peaks greater than 20 µg/L; and 10 had peaks greater than 50 µg/L, with 4 of those peaks associated with the same monitoring site (MO-01).

Table III-4 Summary of chemograph shapes, numbers and magnitudes of atrazine peaks for the 40 monitoring sites

Site	Year	Chemograph Shape		# Peaks			Max. Peak (µg/L)	Range in consecutive days >1 µg/L[2]
		Peaks >1 µg/L	Pattern [1]	10-20 µg/L	20-50 µg/L	>50 µg/L		
IA-01	2004	2	M-L	1			10.0	8-12
IA-01	2005	2	L-L				1.2	4
IA-02	2004	5	L-L-L-L-L				1.8	4-16
IA-02	2005	2	L-L				5.5	4-12
IL-01	2004	4	L-M-L-L	1			13.2	4-16
IL-01	2005	0					0.0	na
IL-02	2004	3	L-L-L				4.9	4-12
IL-02	2005	1	L				2.9	12
IL-03	2005	1	L				5.6	4
IL-03	2006	1	L				2.5	4

Site	Year	Chemograph Shape		# Peaks			Max. Peak (µg/L)	Range in consecutive days >1 µg/L[2]
		Peaks >1 µg/L	Pattern [1]	10-20 µg/L	20-50 µg/L	>50 µg/L		
IL-04	2005	1	L				2.8	12
IL-04	2006	4	M-L-L-L	1			11.5	4-12
IL-05	2004	3	L-L-H		1		22.1	4
IL-05	2005	1	L				1.8	4
IL-06	2004	3	L-L-L				2.2	4-8
IL-06	2005	0					0.0	na
IL-07	2004	3	L-H-L		1		21.8	4-12
IL-07	2005	2	L-L				2.3	1-8
IL-08	2005	3	L-L-L				5.6	4-20
IL-08	2006	2	H-M	1	1		33.1	8
IL-09	2004	4	M-M-M-L	3			13.3	4-20
IL-09	2005	2	M-L	1			16.0	8-12
IN-01	2004	3	L-L-L				8.6	8-24
IN-01	2005	2	L-L				4.4	4-12
IN-02	2004	5	L-L-L-L-L				9.3	12-20
IN-02	2005	3	L-H-L		1		20.3	4-12
IN-03	2005	3	L-L-L				7.6	8-12
IN-03	2006	6	M-L-L-L-L-L	1			16.9	4-12
IN-04	2004	3	VH-L-L			1	78.1	4-8
IN-04	2005	3	L-L-L				8.7	4-8
IN-04	2006	3	M-L-L	1			10.2	4-8
IN-05	2004	4	L-H-H-L		2		28.9	4-12
IN-05	2005	3+	M-L-M	2			17.3	8-36
IN-05	2006	4	L-H-H-L		2		41.0	4-12
IN-06	2005	2	L-L				7.2	4-8
IN-06	2006	5	L-L-L-L-L				9.4	8-20
IN-07	2005	3	H-M-L	1			22.6	4-11
IN-07	2006	3	M-L-L	1			10.5	4-16
IN-08	2005	4	L-H-L-L		1		21.1	4-8
IN-08	2006	5	L-H-H-L-L		2		20.7	4-12
IN-09	2005	4	L-L-L-L				9.4	4-12
IN-09	2006	2	L-L				8.3	4-8
IN-10	2005	3	M-L-L	1			12.4	4-20
IN-10	2006	3	M-M-L	2			16.4	4-12
IN-11	2005	1	VH			1	208.0	24
IN-11	2006	3	L-L-L				9.8	4-12
KY-01	2005	2	L-L				2.2	12-20
KY-01	2006	3	L-H-L		1		22.4	4
KY-02	2005	5	L-M-M-L-L	2			19.3	8-12
KY-02	2006	2	M-L	1			14.3	8-12
MN-01	2005	1	L				5.9	16
MN-01	2006	0					0.0	na
MO-01	2004	4	VH-VH-M-L	1		2	66.0	12-24
MO-01	2005	3	H-VH-H		2	1	182.0	24-32
MO-01	2006	3	VH-L-L			1	82.8	8-32
MO-02	2004	5	H-VH-H-L-L		2	1	54.0	20-24
MO-02	2005	5	M-M-H-L-L	2	1		28.1	12-76

Site	Year	Chemograph Shape		# Peaks			Max. Peak (µg/L)	Range in consecutive days >1 µg/L[2]
		Peaks >1 µg/L	Pattern [1]	10-20 µg/L	20-50 µg/L	>50 µg/L		
MO-02	2006	3	H-L-L		1		43.2	8-60
MO-03	2004	2	L-VH			1	59.0	13-79
MO-03	2005	4	L-M-L-L	1			12.3	20-56
MO-03	2006	1	L				3.9	52
NE-01	2004	2	L-M	1			19.3	16-36
NE-01	2005	3	L-M-M	2			16.7	8-16
NE-02	2005	5	M-H-M-M-L	3	1		20.7	8-12
NE-02	2006	2	VH-L			1	82.0	4-16
NE-03	2004	3	L-L-L				2.3	4-8
NE-03	2005	2	L-M	1			11.3	4
NE-04	2005	3	H-L-L		1		49.9	4-60 [3]
NE-04	2006	1	L				4.1	28
NE-05	2005	3	L-H-H		2		49.9	8-44 [3]
NE-05	2006	1	L				6.8	52
NE-06	2004	5	L-L-L-L-L				7.8	4-8
NE-06	2005	2	M-H	1	1		33.1	8-12
NE-06	2006	0					0.0	na
NE-07	2005	3	L-M-VH	1		1	112.2	8-24 [3]
NE-07	2006	1	L				1.9	37
OH-01	2004	3	M-M-L	2			18.3	8-12
OH-01	2005	3	L-L-L				3.0	4
OH-02	2005	4	M-L-L-L	1			18.2	8-24
OH-02	2006	2	L-M	1			14.0	8-20
OH-03	2004	4	M-M-H-L	2	1		21.5	8-20
OH-03	2005	2	L-L				8.2	4-39
OH-04	2005	4	H-L-L-L		1		20.2	4-16
OH-04	2006	2	L-L				6.3	4
TN-01	2005	5	L-L-L-L-L				7.6	8-20
TN-01	2006	4	L-L-L-M	1			10.7	4-8

1 – Pattern refers to the relative size of the peak in sequence. L = 1-10 ug/l; M = 10-20 ug/l; H = 20-50 ug/l; VH = >50 ug/l

2 – the range in consecutive days >1 ug/l is based on 4-day sample intervals, except where autosample data were available. For the 4-day samples, the measured concentration applied to a 4-day period.

3 – the span of consecutive days with concentrations >1 ug/L for NE-04, NE-05, and NE-07 in 2005 include sample gaps (see text for discussion).

2. Analyzing Atrazine Chemographs: LOC Exceedances

Ultimately, the site chemographs must be interpreted against the LOC, i.e., relating the magnitude and duration of atrazine concentrations to results of the microcosm/mesocosm studies using CASM. Table III-5 summarizes results of the CASM analysis for the site-year chemographs. Each site/year of data was expanded to a 365 day time series. Preliminary data interpolation used a stair-step method where the grab sample concentration was extended (imputed) to the subsequent 3 days between sampling events. Samples prior to the first sample date were given the same concentration as the first sample date from that year, and a similar approach was taken for the dates after the last sampling event. Sample results from each date that were reported as a non-detection were conservatively assigned an assumed value of the detection limit. Because of the low concentrations, this assumption did not impact the LOC determination. Finally, dates where no sample was collected or analyzed were assumed to be equal to the nearest previous sample with a result. This final assumption resulted in significant uncertainty for three sites in Nebraska, where dry or low-flow conditions resulted in fewer samples being collected. It is not clear how much the lack of samples are due to dry stream/no flow conditions and how much are due to low flow with stream bed morphologies that precluded the collection of samples. The uncertainties arising from the approach the Agency took in extrapolating concentrations across periods when no samples are taken are addressed in Section III.E.2.

Table III-5 Summary of monitoring results and LOC exceedances for the 40 watersheds.

Site	Year	Max. concentration (µg/L)				%SSI Dev.	Mult. Factor	LOC Status
		Peak	14-day	30-day	60-day			
IA-01	2004	10.0	3.7	2.1	1.2	0.3	12.1	Below LOC 2 or more years
	2005	1.2	0.5	0.3	0.3	0.0	13.2	
IA-02	2004	1.8	1.1	0.8	0.6	0.4	12.2	Below LOC 2 or more years
	2005	5.5	2.1	1.4	0.8	0.3	14.1	
IL-01	2004	13.2	6.6	4.1	2.5	0.8	5.5	Below LOC 2 or more years
	2005	0.6	0.3	0.3	0.3	0.0	7.2	
IL-02	2004	4.9	2.9	2.3	1.5	0.5	8.6	Below LOC 2 or more years
	2005	2.9	1.8	1.1	0.6	0.2	8.5	
IL-03	2005	5.6	1.8	1.0	0.6	0.1	23.1	Below LOC 2 or more years
	2006	2.5	0.9	0.5	0.3	0.1	18.4	
IL-04	2005	2.8	1.4	0.8	0.5	0.1	16.9	Below LOC 2 or more years
	2006	11.5	3.4	1.8	1.8	0.6	7.5	
IL-05	2004	22.1	7.2	3.6	2.0	0.7	7.9	Below LOC 2 or more years
	2005	1.8	0.7	0.4	0.3	0.1	19.1	
IL-06	2004	2.2	1.1	0.7	0.5	0.3	15.3	Below LOC 2 or more years
	2005	0.2	0.2	0.2	0.2	0.0	13.3	
IL-07	2004	21.8	7.0	4.2	2.4	0.9	6.6	Below LOC 2 or more years
	2005	2.3	0.9	0.6	0.5	0.1	14.3	
IL-08	2005	5.6	4.4	2.8	1.8	1.1	3.6	Below LOC 2 or more years
	2006	33.1	11.0	8.1	4.4	1.9	2.9	
IL-09	2004	13.2	8.1	6.3	4.6	1.4	2.9	Below LOC 2 or more years
	2005	16.0	6.2	3.4	2.3	1.0	3.2	
IN-01	2004	8.6	4.0	3.5	2.4	0.7	5.9	Below LOC 2 or more years
	2005	4.4	1.4	1.0	0.7	0.3	5.5	
IN-02	2004	9.3	6.3	4.5	2.8	0.8	4.6	Below LOC 2 or more years
	2005	20.3	6.3	4.3	3.0	1.0	4.5	
IN-03	2005	7.6	4.3	3.3	2.3	0.7	5.1	Below LOC 2 or more years
	2006	16.9	10.6	6.2	3.9	1.3	3.7	
IN-04	2004	78.1	23.8	12.0	6.4	1.7	2.7	Below LOC 2 or more years
	2005	8.8	3.6	2.1	1.4	0.4	7.2	

Site	Year	Max. concentration (µg/L)				%SSI Dev.	Mult. Factor	LOC Status
		Peak	14-day	30-day	60-day			
	2006	10.2	5.6	3.7	2.2	0.6	6.0	
IN-05	2004	28.9	14.9	11.9	7.0	2.2	2.2	Below LOC 2 or more years
	2005	17.3	7.8	4.5	4.1	1.5	2.8	
	2006	41.3	17.9	13.1	7.4	2.4	2.2	
IN-06	2005	7.2	2.9	1.8	1.0	0.4	11.5	Below LOC 2 or more years
	2006	9.4	4.0	2.7	1.9	0.9	5.4	
IN-07	2005	22.6	9.6	6.4	3.9	0.6	7.6	Below LOC 2 or more years
	2006	10.5	5.4	3.6	2.0	0.6	7.4	
IN-08	2005	21.1	6.9	4.9	2.8	1.0	5.5	Below LOC 2 or more years
	2006	20.7	8.9	7.7	4.4	1.5	3.8	
IN-09	2005	9.4	3.7	2.4	1.7	1.2	4.2	Below LOC 2 or more years
	2006	8.3	3.0	1.8	1.2	0.6	7.1	
IN-10	2005	12.4	6.1	4.0	2.8	0.9	4.8	Below LOC 2 or more years
	2006	16.4	7.5	6.3	3.6	1.2	4.4	
IN-11	2005	208.8	65.1	31.5	16.2	**5.6**	0.7	Exceeds LOC in 1 year
	2006	9.8	5.9	3.3	1.9	1.3	3.5	
KY-01	2005	2.2	1.5	1.2	0.9	0.3	14.2	Below LOC 2 or more years
	2006	22.4	6.9	3.6	1.9	0.7	8.5	
KY-02	2005	19.3	8.7	7.1	4.5	1.7	2.0	Exposures within 2x of LOC in 1 year
	2006	14.3	4.7	3.9	2.3	0.6	3.9	
MN-01	2005	5.8	2.6	1.4	0.8	1.2	3.8	Below LOC 2 or more years
	2006	0.2	0.2	0.1	0.1	0.0	20.4	
MO-01	2004	65.9	39.6	28.6	19.4	**4.4**	0.9	Exceeds LOC in 2 or more years
	2005	182.8	78.1	42.5	25.7	**6.8**	0.5	
	2006	82.8	48.2	31.6	17.5	**4.4**	0.9	
MO-02	2004	53.8	33.0	25.9	16.8	**4.7**	0.8	Exceeds LOC in 2 or more years
	2005	28.1	18.7	14.6	11.5	**5.2**	0.8	
	2006	43.2	34.7	27.4	15.4	**4.5**	0.8	
MO-03	2004	59.0	23.3	13.1	8.1	3.0	1.3	Exposures within 2x of LOC in 2 years
	2005	12.3	8.7	6.9	5.5	1.9	2.0	
	2006	3.9	2.3	1.9	1.5	1.0	4.8	
NE-01	2004	19.2	13.0	7.5	4.3	1.3	3.8	Below LOC 2 or more years
	2005	16.7	6.6	5.6	3.6	1.2	4.4	
NE-02	2005	20.7	11.4	10.7	6.3	2.0	2.4	Below LOC 2 or more years
	2006	82.0	28.6	14.1	7.3	1.8	2.3	
NE-03	2004	2.3	1.1	1.0	0.6	0.1	19.0	Below LOC 2 or more years
	2005	11.9	3.7	2.1	1.2	0.3	10.0	
NE-04	2005	36.0	36.0	27.3	17.4	**4.5**	0.8	Low flow/ exceeds 1 year
	2006	4.1	4.1	3.1	1.7	2.1	2.1	
NE-05	2005	49.9	23.8	19.9	16.5	**4.6**	0.8	Low flow/

Site	Year	Max. concentration (μg/L)				%SSI Dev.	Mult. Factor	LOC Status
		Peak	14-day	30-day	60-day			
	2006	6.8	6.8	6.8	5.1	0.8	4.5	exceeds 1 year
NE-06	2004	7.7	2.8	2.1	1.7	0.5	7.3	Below LOC 2 or more years
	2005	33.1	20.6	11.4	6.0	1.9	2.8	
	2006	0.1	0.1	0.1	0.1	0.0	20.5	
NE-07	2005	112.2	80.0	45.2	22.7	**5.2**	0.7	Low flow/ exceeds 1 year
	2006	na	na	na	na	0.6	8.5	
OH-01	2004	18.3	8.8	5.7	3.2	1.0	5.3	Below LOC 2 or more years
	2005	3.0	1.0	0.9	0.6	0.2	12.0	
OH-02	2005	18.1	7.1	4.0	2.9	1.0	5.1	Below LOC 2 or more years
	2006	14.0	5.9	5.2	2.9	0.8	5.3	
OH-03	2004	21.5	9.1	7.3	4.5	1.4	3.9	Below LOC 2 or more years
	2005	8.2	3.0	1.6	0.9	0.5	11.5	
OH-04	2005	20.2	8.0	4.7	2.7	1.0	5.5	Below LOC 2 or more years
	2006	6.3	2.6	1.7	1.0	0.3	12.9	
TN-01	2005	7.6	5.6	4.0	2.9	1.0	3.9	Below LOC 2 or more years
	2006	10.7	3.6	2.4	2.0	0.7	3.5	

The level of concern is triggered when the Steinhaus Similarity Index (SSI) exceeds 4 percent. Only two sites – MO-01 and MO-02 exceeded the 4% SSI trigger in multiple years. Those sites exceeded in all three years of monitoring. IN-11 exceeded the 4% SSI in 2005 but not in 2006. Monitoring continued at this site in 2007, but the results are not available at this time. Three sites in Nebraska – NE-04, NE-05, and NE-07 – exceeded the 4% SSI in one year (2005), but not in subsequent years when there was sufficient flow to allow for sampling on a 4-day interval. The chemographs associated with the LOC exceedances in these sites include periods in which no samples were taken because of low stream flow (Hampton et al, 2007a). Two sites – KY-02 and MO-03 did not exceed the 4% SSI trigger but had exposures that were within a factor of 2 of exceeding the trigger based on the multiplication factor. Because of uncertainties identified in the way the model may underestimate the effects of short-duration high exposures and in the extent to which the sample frequencies may capture peak concentrations, these sites are flagged as uncertain. These conditions are grouped separately in the statistical assessment below.

D. Percentage Of Watersheds Exceeding The LOC Threshold

1. Statistical Analysis Based On GRTS

a) Methods

This monitoring study was specifically designed to answer the question, "How many watersheds in corn and sorghum growing regions in the United States where predicted exposure to atrazine is greatest are estimated to have atrazine concentrations that exceed the LOC in at least one subwatershed?" This section explains how the statistical analysis performed directly corresponds with the survey design that was used, in order to accurately address the question.

The primary objective of the analysis was to determine how many watersheds out of the 1,172 are estimated to fall within each of three basic categories: 1) considered an excluded site 2) are not likely to contain a water body with atrazine concentrations that exceed the LOC, and 3) are likely to contain a water body with atrazine concentrations that exceed the LOC. The analysis provides the estimated proportion (expressed as a percent) of watersheds as well as the number of watersheds, along with 95% confidence intervals for each.

This monitoring study required 47 watersheds be visited in order to successfully attain an overall sample size of n=40 (i.e. 7 sites had to be excluded because of logistical constraints to sampling). Although it may seem intuitive to completely disregard these 7 excluded sites and only focus on the 40 in which monitoring was actually performed, doing so would result in the loss of key information describing the characteristics of the watersheds within the population and potentially result in a bias in the estimates. Therefore, in order to accurately represent the status of the population of 1,172 watersheds, the estimated number of excluded sites in the population is calculated, where n=24 for stratum (2,4], and n=23 for stratum (4,14], totaling an overall n=47.

Proportion (expressed as a percent) and unit estimates are calculated using the Horvitz-Thompson ratio estimator (Horvitz and Thompson, 1952). For each stratum, the numerator of the ratio is calculated by summing the design weights for each sample response within a category and then dividing by the sum of the design weights over the sample size for the stratum. The number of watersheds for a response category is then estimated simply by multiplying the estimated proportion of watersheds by the number of watersheds within that stratum. Estimates and standard errors are then calculated for all strata combined by weighting each stratum by its respective population size, with N1=874 and N2=298 representing approximately 75 and 25 percent, respectively, of the population of 1,172.

Variance estimates are calculated using the local mean variance (Stevens and Olsen, 2003), which utilizes the x- and y-coordinates for each watershed, and confidence intervals are calculated using a Normal distribution multiplier value of 1.96, multiplied by the standard error. Simulation studies reported by Stevens and Olsen (2003) have shown that this variance estimator performs better than the Horvitz-Thompson variance estimator.

b) Assumptions

The following assumptions drive the accuracy of the estimates presented in the results.

1) The 1172 HUCs accurately represent the 20% most vulnerable watersheds within the true population.
2) All other HUCs within the United States are assumed not to exceed the LOC.

3) If the monitored site within each HUC shows an exceedance, then any other similar site within that HUC would have exceeded the LOC if it had been selected to be monitored.
4) The atrazine chemograph reported for each site is independent of whether that site was sampled during the period of 2004-2005 or from 2005-2006. This validates the data being grouped together and generalized as a single 2004-2006 sampling period.
5) The true atrazine chemographs that occurred throughout the sampling period were in fact captured by the data.
6) Data responses have been correctly categorized.

c) Results

The use of the phrase "based upon this data" at the beginning of each statement refers to the fact that the estimates and their confidence intervals are completely dependent upon the sample size of data used, the circumstances under which the data was collected, and the way that the data was manipulated and/or used prior to the calculation of the estimates themselves. A level of concern (LOC) exceedance is based on CASM SSI % deviation calculation for each sub-watershed.

2. Population Estimates

Population estimates have been generated for 47 HUCs representing the 1172 watersheds. These estimates have been broken into four categories:

(1) Excluded sites - 7 HUCs
(2) Sites that did not exceed the LOC in either year - 32 HUCs
(3) Sites that exceed the LOC in multiple years - 2 HUCs
(4) Sites that exceed the LOC in one year with additional monitoring pending – 1 HUC
(5) Sites where the interpretation is uncertain - 5 HUCs

This last category includes one site where the LOC was exceeded 1 year and a third year of data is pending, three sites in Nebraska where low/no flow conditions limited sample collection, and two sites where application of an uncertainty bound based on model sensitivity analysis (see Section II) suggests that exceedances could occur. The following sections summarize the population estimates for each category separately however the Agency is only certain about exceedances of the LOC for the two sites with more than one year of exceedances. All other categories are subject to interpretation based on the uncertainty analysis discussed in Section II (model sensitivity) and Section III (monitoring data uncertainty).

a) Excluded Sites

Based upon the data, an estimated 255 (22%) HUCs out of the population of 1172 HUCs during 2004-2006 would have had to be "excluded," whereby monitoring activities could not have been successfully performed (Table III-6). The 95% confidence interval for the estimate is from 119 to 390 HUCs (i.e. 10%-33%). No inference is possible whether these HUC-10s would have had one or more subwatersheds with LOC exceedances, without making additional assumptions. The fact that a monitoring site could not be located within these HUCs may result in having different characteristics with respect to atrazine chemographs than HUCs where a monitoring site could be located.

b) Sites That Did Not Exceet the LOC

Out of the 47 HUC-10s in the sample, 32 of the 40 monitored sub-watersheds within the HUC-10s reported atrazine concentrations resulting in an assessment that they were below the level of concern. Based upon the data, it is estimated that 669 HUC-10s (57% of 1172) would have atrazine concentrations resulting in an assessment that they were below the established level of concern. The 95% confidence intervals for the estimates are 47-67% in terms of percents and 551-787 in terms of HUC-10s.

c) Sites That Exceeded the LOC in At Least 2 Years

Two watersheds (MO 01 and MO 02) have experienced exposures that exceed the LOC in two or more years (LOC Exceeds 2YR). The LOC exceeds 2YR category includes an estimated 101 (9% of 1172) HUCs that would contain at least one sub-watershed having atrazine concentrations resulting in an exceedance of the designated level of concern in at least 2 years, with 95% confidence limits of 0 and 218 HUCs, or 0% to 19% of 1172 HUCs. These are sites that triggered follow-up mitigation actions as a result of 2 years of LOC exceedances.

d) Sites That Exceeded the LOC in 1 Year

One watershed (IN-11) exceeded the LOC in one year of monitoring but not in a second year. The LOC exceeds 1YR category includes an estimated 46 (4% of 1172) HUCs that would contain at least one sub-watershed having atrazine concentrations resulting in an exceedance of the designated level of concern in 1 of 2 monitoring years, with 95% confidence limits of 0 and 125 HUCs, or 0% to 11% of 1172 HUCs. Monitoring has been extended for a third year at this site.

e) Uncertain Sites

Two categories of watersheds are considered uncertain in the interpretation of the LOC exceedance for the years that were monitored: 1) Sites in which samples were not taken during low flow but exceeded the LOC in one year based on extrapolated monitoring (Low Flow Exceeds), and 2) Sites with exposures below the 4% SSI but within 2 times of exceeding (LOC within 2X). These estimates are shown in Table III-6. These categories are uncertain and final determination of whether they should be considered as exceeding the LOC will depend on the outcome of this SAP meeting. The population estimates are simply provided to give context to the estimates.

The Low Flow Exceeds category includes an estimated 34 (3% of 1172) HUCs that would contain at least one sub-watershed having atrazine concentrations resulting in an exceedance of the designated level of concern due to low flow conditions, with 95% confidence limits of 15 and 54 HUCs, or 1% to 5% of 1172 HUCs.

The LOC within 2X category includes an estimated 67 (6% of 1172) HUCs that would contain at least one sub-watershed having atrazine concentrations that are within 2X of an exceedance of the designated level of concern, with 95% confidence limits of 0 and 154 HUCs, or 0% to 13% of 1172 HUCs.

Table III-6 Population Estimates for the 1,172 Vulnerable Watersheds Based on the 40 Monitoring Sites

Category	Fre-quency	Estimated Population Percent	95% Lower Confidence Bound	95% Upper Confidence Bound	Estimated Number of Watersheds	95% Lower Confidence Bound	95% Upper Confidence Bound
Excluded	7	22%	10%	33%	255	120	390
LOC Below	32	57%	47%	67%	669	551	787
LOC Exceeds 2YR	2	9%	0%	19%	101	0	218
LOC Exceeds 1YR	1	4%	0%	11%	46	0	125
Low Flow Exceeds	3	3%	1%	5%	34	15	54
LOC within 2X	2	6%	0%	13%	67	0	154
Total	47	100%			1172		

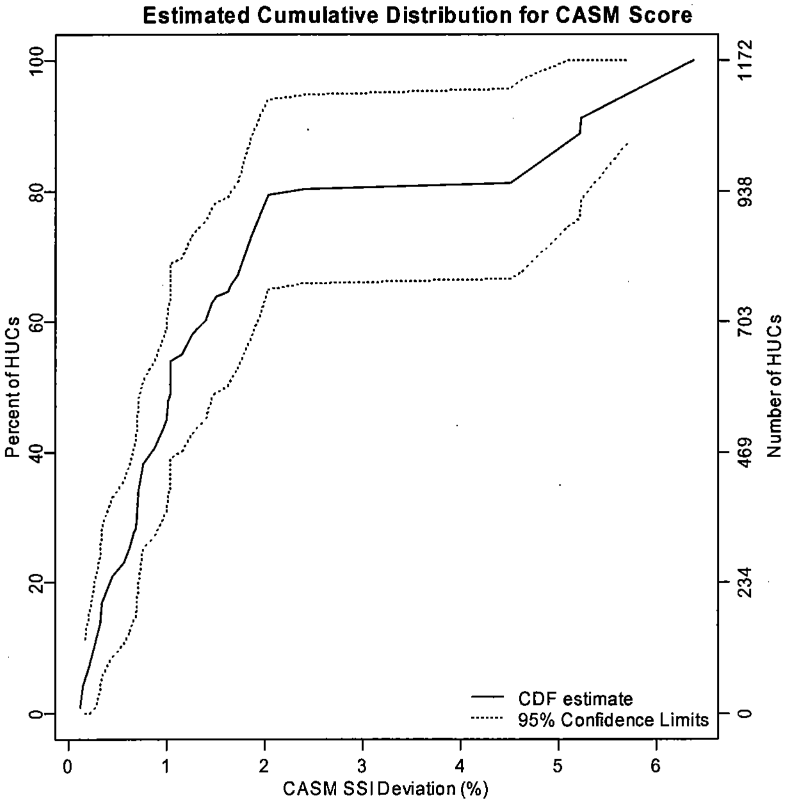
Previously, the question was raised about what assumptions could be made about the seven HUCs initially selected that could not be monitored. One assumption is that they are missing at random, i.e., that the HUCs that could not be monitored have the same atrazine chemograph characteristics as HUCs that could be monitored. Table III-7 summarizes population estimates for HUCs exceeding the LOC when this assumption is made. Typically, the estimates under this assumption are 1-2% greater for LOC exceedances while the estimated number of HUCs that are below the LOC exceedance changes from 57% to 73% (669 to 855 HUCs).

Table III-7 Population Estimates Assuming Non-Monitored HUCs Missing at Random

Category	Fre-quency	Estimated Population Percent	95% Lower Confidence Bound	95% Upper Confidence Bound	Estimated Number of Watersheds	95% Lower Confidence Bound	95% Upper Confidence Bound
LOC Below	32	73%	59%	87%	855	695	1016
LOC Exceeds 2YR	2	11%	0%	24%	130	0	283
LOC Exceeds 1YR	1	5%	0%	13%	61	0	150
Low Flow Exceeds	3	4%	2%	5%	40	19	61
LOC within 2X	2	7%	0%	17%	86	0	199
Total	40	100%			1172		

Another way to summarize the population estimates is to estimate the cumulative distribution for CASM SSI deviation (%) scores. Figure III-4 shows the estimated cumulative distribution and 95% confidence limits. The flat portion of the plot between approximately 2 and 4 is potentially indicative that two populations of HUC-10s may exist with respect to CASM scores.

Figure III-4 Estimated Cumulative Distribution for CASM Score.



f) Reliability of WARP estimates for HUCs and Sub-watersheds

The WARP predictions for the sampled HUCs closely correlated (r= 0.874) with those predicted for the monitored sub-watersheds within the selected HUCs (Figure III-5). Sub-watershed WARP scores tend to be greater than those predicted for HUCs (Figure III-6). Given that the data was collected at the sub-watershed level, WARP predictions for sub-watershed, rather than HUCs will be used in subsequent plot comparisons.

Figure III-5 Comparing WARP scores for HUC-based watersheds vs. sub-watersheds

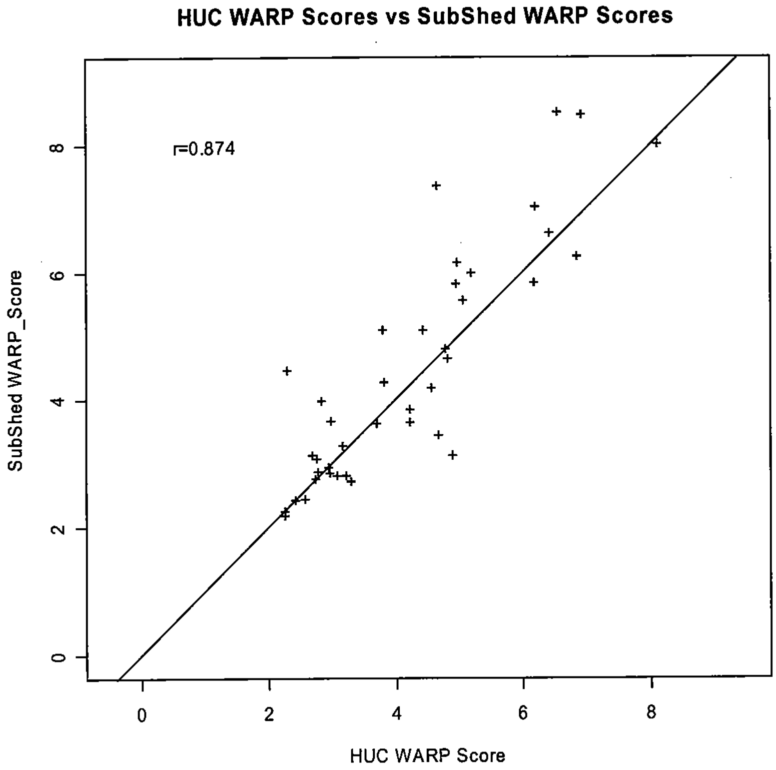
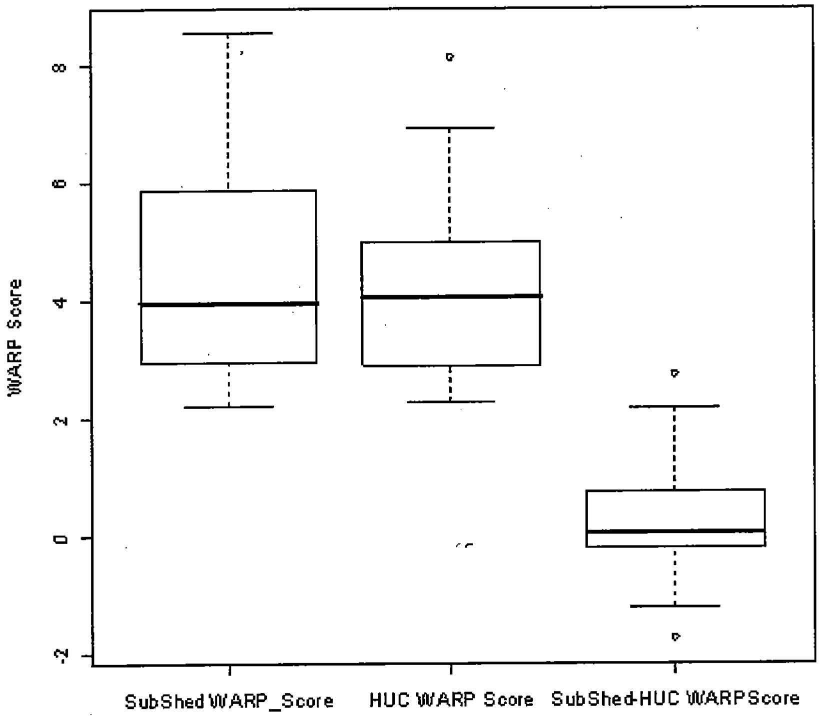


Figure III-6 Comparison of WARP scores for sub-watershed and HUCs



The monitoring results indicate that WARP is not able to successfully distinguish "moderately high" vulnerability from "high to very high" vulnerability predictions. If WARP were in fact able to distinguish between the two, we would expect to see a positive relationship between CASM SSI deviations and WARP scores (Figure III-7). It might also be expected that all WARP predictions between (2,4] would have values falling in Quadrant 4, indicating that they also received a low CASM score. Likewise, it would be expected that all WARP predictions with values greater than 4 would appear in Quadrant 2, having CASM scores greater than 4%. It is notable for these for sub-watersheds that no CASM scores occur between approximately 2 and 4. It is yet to be determined whether or not the 6 points with CASM SSI scores >4% share a common factor that could potentially be added to the WARP model in order to improve prediction capabilities within the most vulnerable sites. For CASM scores less than or equal to 2%, however, an overall direct linear relationship can be seen in WARP model, although some discrepancies appear to be present around 2%. A similar plot is shown in Figure III-8, plotting WARP scores against the maximum 14-day rolling average across year per site.

Figure III-7 Illustrating WARP's capabilities to accurately predict moderately high vs. high vulnerability to atrazine by relating it to resulting CASM scores.

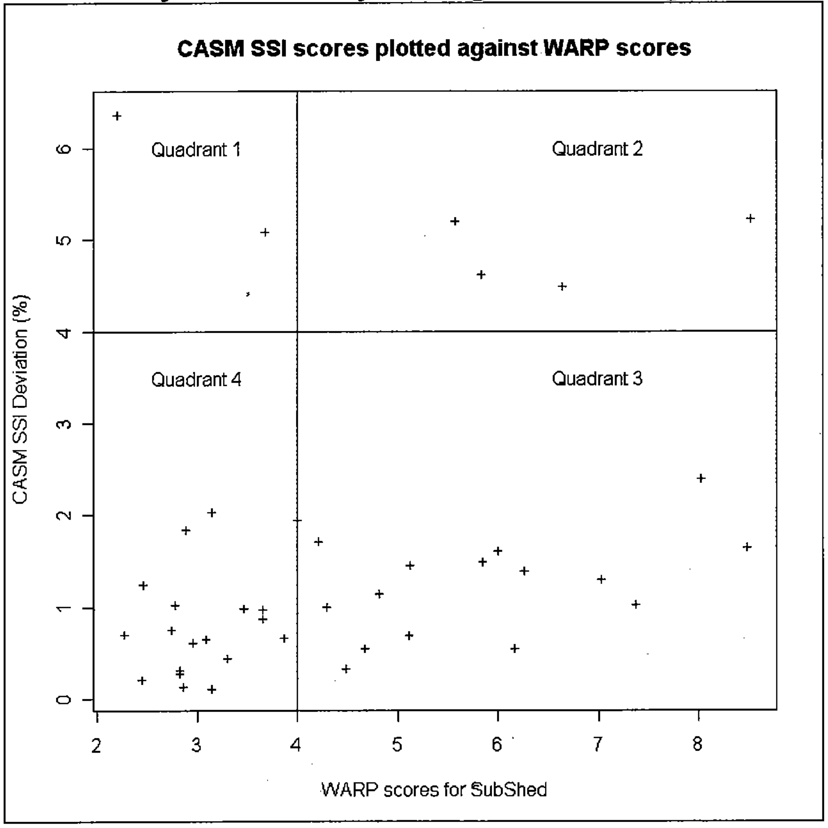
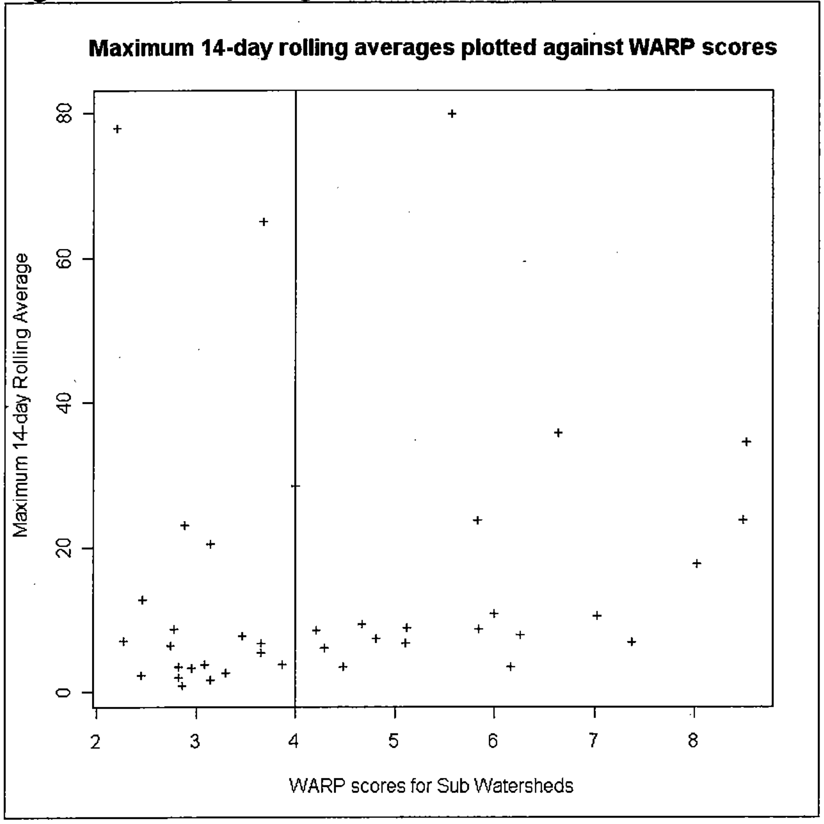


Figure III-8 Comparing how well WARP predicts maximum 14 day rolling averages



The WARP predictions in this analysis were used as a surrogate for the %SSI to identify vulnerable watersheds that were likely to exceed LOC when the study was designed. This analysis asked the question "What evidence does the monitoring results give to indicates that WARP was a reasonable surrogate for SSI and consequently that the study focused on the appropriate set of watersheds?" Unfortunately the only data available for comparison is the 40 monitored watersheds which are at the upper end of WARP predictions. At this upper end, the Agency sees no evidence of a relationship. Potentially this suggests that WARP may be a "weak" surrogate for %SSI. The analysis is limited because %SSI is not available for any watersheds below the 80th percentile. A relationship may exist but is not evident at the upper end of the plot.

g) Comparison of Alternative WARP estimates for HUCs

WARP model predictions depend on the values of the input variables. The initial WARP estimates used to define vulnerable watersheds used atrazine use data averaged for the years 1998 to 2002 and did not include Dunne overland flow as a variable (WARPDOFZ). Subsequently, Syngenta calculated two updated WARP predictions (WARP and WARP_NewUse) where WARP used same atrazine use data as WARPDOFZ and WARP_NewUse used atrazine use data updated for 2001 to 2003 (Hampton et al, 2007b). The US EPA used atrazine data from 1999 to 2001 in its original watershed vulnerability assessment (WARP_EFED_NoPrecip) and considered a version of the WARP model that included May-June Precipitation as one of the predictive parameters (WARP_EFED_Precip). The question is whether these alternatives would identify the same set of vulnerable watersheds. The various WARP estimates are listed in Table III-8.

Table III-8 Atrazine Use Data and Model Inputs Used for Alternative WARP Estimates

WARP Estimate	Atrazine Use Data	WARP Model Parameters (1)
WARPDOFZ	1998-2002	U, R, K, A
WARP	1998-2002	U, R, K, A, D
WARP_NewUse	2001-2003	U, R, K, A, D
WARP_EFED_NoPrecip	1999-2001	U, R, K, A, D
WARP_EFED_Precip	1999-2001	U, R, K, A, D, P

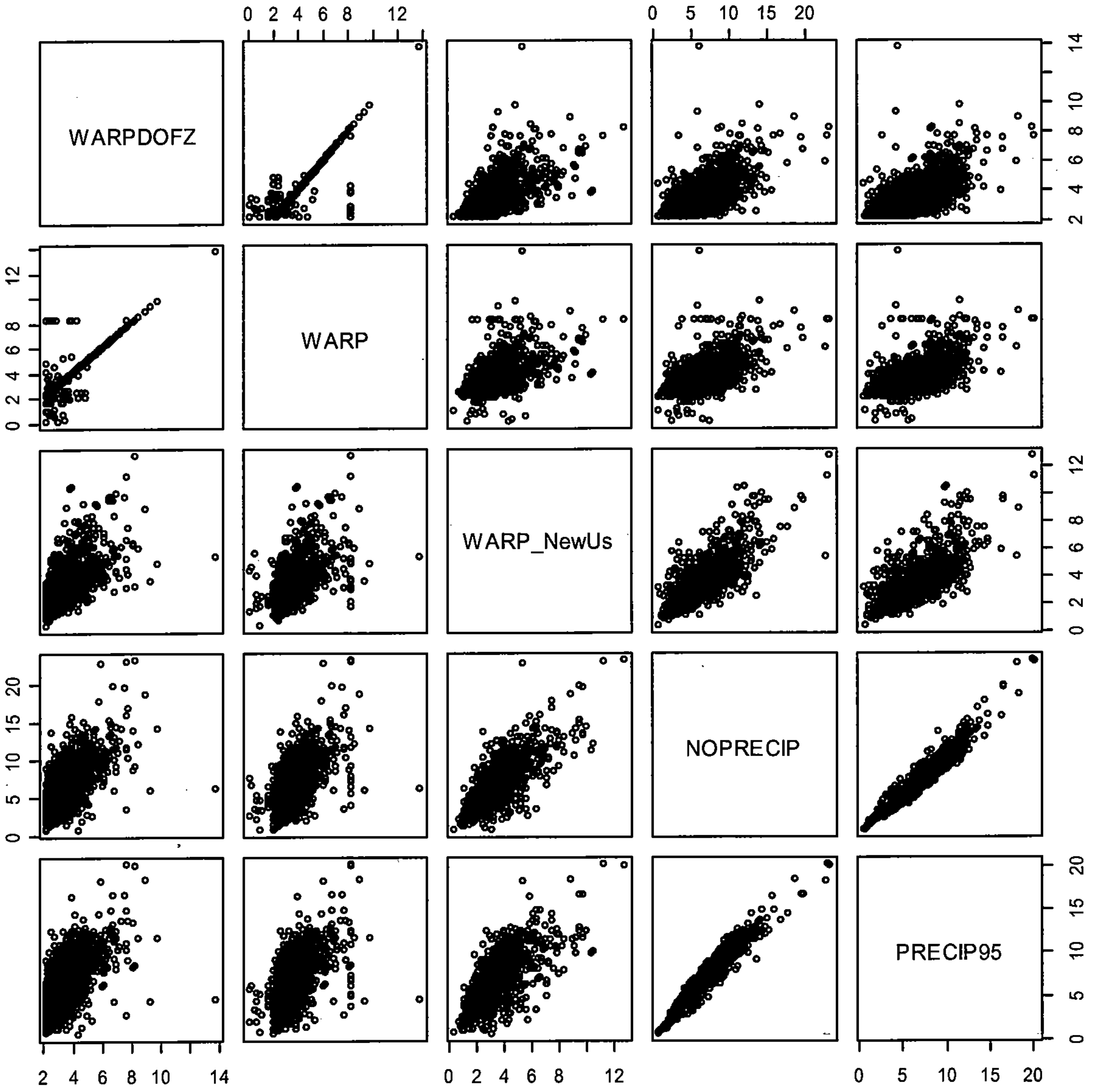
1 U = Use Intensity; R = R Factor; K = K Factor; A = Watershed Area; D = Dunne Overland Flow; P = May-June Precipitation

Table III-9 gives the correlations for the five WARP predictions while Figure III-9 shows the relationship for the 1172 vulnerable HUCs identified by WARPDOFZ. In general correlations are higher when the same atrazine use data is used.

Table III-9 Correlations of Alternative WARP Predictions for 1172 vulnerable HUCs

	WARPDOFZ	WARP	WARP_NewUs	NOPRECIP	PRECIP95
WARPDOFZ	1	0.895	0.616	0.620	0.583
WARP	0.895	1	0.563	0.597	0.564
WARP_NewU	0.616	0.563	1	0.777	0.704
NOPRECIP	0.620	0.597	0.777	1	0.965
PRECIP95	0.583	0.564	0.704	0.965	1

Figure III-9 Scatterplots of Alternative WARP Predictions for 1172 vulnerable HUCs



The above comparison is based only on the 1172 vulnerable HUCs. To determine whether the five alternatives would identify the same top 20% vulnerable HUCs requires the comparison to be made on the 5860 HUCs with high atrazine use. This information is available for all alternatives, although only the actual 1172 WARP predictions are available for WARPDOFZ. First, the correlations for the five WARP predictions based on 5860 HUCs are stronger, as would be expected, than when only the 1172 HUCs are considered (Table III-10). Note the correlations with WARPDOFZ are the same since only the 1172 HUCs are available for it.

Table III-10 Correlations of Alternative WARP Predictions for 5860 High Atrazine Use HUCs

	WARPDOFZ	WARP	WARP_NewUse	NOPRECIP	PRECIP95
WARPDOFZ	1	0.895	0.616	0.620	0.583
WARP	0.895	1	0.824	0.818	0.811
WARP_NewUse	0.616	0.824	1	0.777	0.704
NOPRECIP	0.620	0.818	0.919	1	0.986
PRECIP95	0.583	0.811	0.900	0.986	1

The top 20% of the WARP predictions were identified for each alternative assuming 5860 HUCs. Then all HUCs that were common across all alternatives were identified (Top20_All) and all HUCs that were in the top 20% for at least one alternative were identified (Top20_Any). Across the alternatives, 819 HUCs are identified by all alternatives and 1585 are in the top 20% for at least one alternative. Table III-11 compares how the alternatives classify vulnerability of HUCs compared to the initial classification based on WARPDOFZ. Each small table would have no HUCs in the off diagonals of the table similar to the WARPDOFZ first table. Each of the four new alternatives classifies from 87 to 218 HUCs as being in the top 20th percentile compared to the original WARPDOFZ classification. Note that since NOPRECIP and PRECIP WARP predictions were available for all 9510 HUCs where atrazine was used, 34 and 41 of the top 20th percentile HUCs occurred outside the high atrazine use study region.

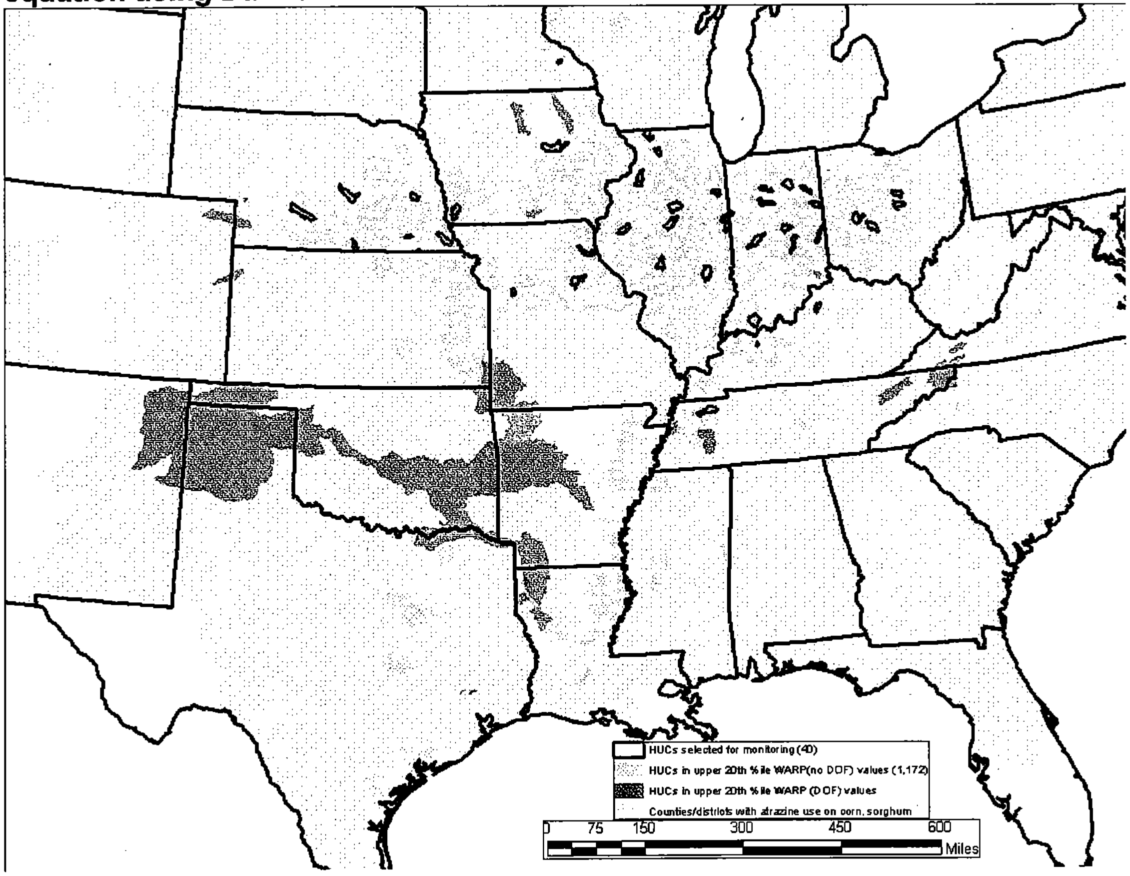
Table III-11 Comparison of HUCs in Top 20% WARP Predictions

Alternative WARP Prediction Vulnerable HUCs	**WARPDOFZ Vulnerable HUCs**				**Total**
	<80%	**80-95%**	**>95%**	**Outside 5860 HUCs**	
WARPDOFZ					
<80%	4688	0	0		4688
80-95%	0	874	0		874
>95%	0	0	298		298
Total	4688	874	298		5860
WARP					
<80%	4601	87	2		4690
80-95%	71	774	28		873
>95%	16	13	268		297
Total	4688	874	298		5860
WARP_NewUse					
<80%	4518	172	1		4691
80-95%	166	572	134		872
>95%	4	130	163		297
Total	4688	874	298		5860
NOPRECIP					
<80%	4501	225	14	3599	8339
80-95%	178	537	115	43	873
>95%	9	112	169	8	298

Alternative WARP Prediction Vulnerable HUCs	WARPDOFZ Vulnerable HUCs				Total
	<80%	80-95%	>95%	Outside 5860 HUCs	
Total	4688	874	298	3650	9510
PRECIP					
<80%	4470	235	17	3616	8338
80-95%	210	520	119	27	876
>95%	8	119	162	7	296
Total	4688	874	298	3650	9510

The Agency then looked at the spatial distribution of the vulnerable watersheds identified by the different WARP estimates. Figure III-10 compares the locations of the 1,172 vulnerable watersheds identified using WARPDOFZ (WARP estimates with Dunne Overland Flow set to 0) and the watersheds identified using WARP with Dunne Overland Flow included. The green areas show where the HUCs overlap; watersheds in yellow are in the original 1172 but not in the revised WARP set; and watersheds in blue are in the revised group only.

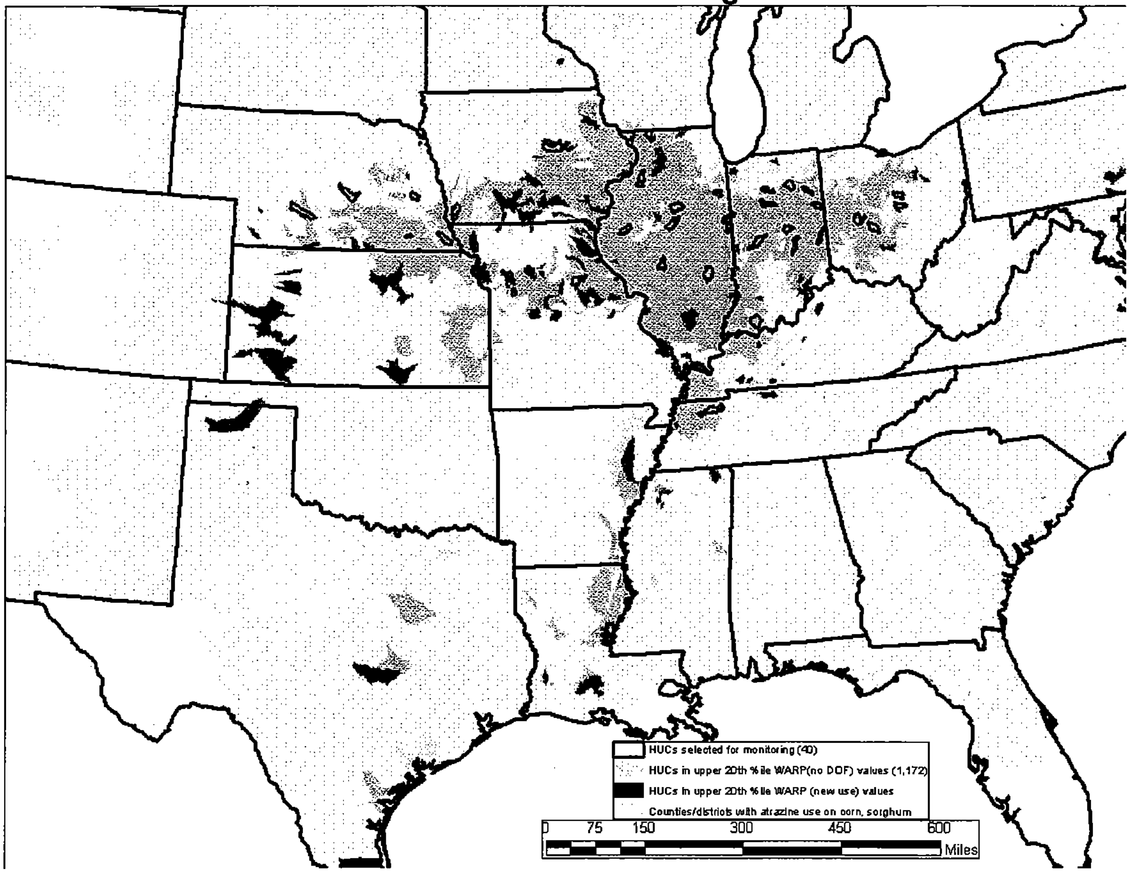
Figure III-10 Comparison of the spatial distribution of the original vulnerable watersheds used to select the monitoring sites with watersheds identified with the full WARP equation using Dunne Overland Flow.



The extensive blue area is misleading because it includes larger HUC-8 watersheds where no HUC-10 watersheds were available for TX, OK, or AR. All 40 of the watersheds selected for monitoring are included in both sets of vulnerable watersheds. That does not preclude the possibilty that the GRTS process would possibly have selected a different suite of watersheds based on the revised WARP group.

Figure III-11 contrasts the locations of the original 1172 HUCs selected with WARPDOFZ (yellow) with the upper 20th %ile set of HUCs that would have been identified using the newer atrazine use (WARP_NewUse), shown in red. The orange represents the areas of overlap. In this case, 3 of the monitoring sites would not have been in the most vulnerable tier with the new use data (1 in MN, 1 in KY, 1 in NE).

Figure III-11 Comparison of original vulnerable watersheds identified using 1998-2002 use data with vulnerable watersheds identified using 2001-03 use data.



E. Sensitivity / Uncertainty Analyses

This section focuses on factors that might impact how the results could be interpreted or how future monitoring studies and data could be used to assess the impacts of atrazine on aquatic communities.

1. Weather

One of the assumptions of the population estimates (Section III.D) is that the chemographs are independent of the year of sampling. Sources of variability in monitoring data collected over multiple years include:

- variability in weather patterns, particularly extreme events
- timing of rainfall in relation to application period
- amount of flow in the water body prior to runoff events
- stark differences in rainfall amounts, timing, and intensity that make comparisons among sites or among years at the same site difficult.

In the 2003 IRED addendum (US EPA, 2003b), the Agency specified that monitoring might be extended for a third year at a site if either of the following occurred:

- atrazine concentrations in water triggered an LOC exceedance in any of the sampling years, or
- unusual meteorological conditions (e.g., high or low rainfall) occurred during the monitoring period.

The US EPA analyzed the rainfall data two ways (see Appendix 3):

(1) Rainfall totals by month were compared against historical totals, with special emphasis placed on rainfall amounts from April to June, which is considered the principal atrazine use period and coincides with the bulk of the analytical sampling;

(2) Daily precipitation data was plotted against the monitoring data and overlaid the planting season for a more detailed evaluation.

In the first analysis, the site-specific precipitation data were summed by month and compared with historical monthly totals. A site year with precipitation less than the 25th percentile for one or more of the critical months is considered below normal precipitation and the results from that year would be considered not representative of a normal, or above normal climatic conditions. Site years where data was between the 25 percentile and the 75th percentile were considered normal, and above the 75th percentile were considered above normal.

In general, more sites had months with lower-than-normal than higher-than-normal precipitation. In particular, 2005 was a low rainfall year (based on the monthly rainfall comparisons for the Apr-Aug sampling period) for a number of sampling locations, including nine sites in Illinois, three in Indiana (IN-02, -06, -11), two in Ohio (OH-02, -03), and one each in Kentucky (KY-02) and Minnesota (MN-01). Such rainfall discrepancies may make it difficult to draw definitive conclusions regarding the relative vulnerabilities of the water bodies to atrazine runoff.

However, lower-than-normal precipitation during the likely application months does not necessarily mean that atrazine concentrations will be correspondingly low. The timing of the precipitation is critical. If precipitation is low in the time leading up to planting, then low-flow conditions may exist in the streams and a rainfall event after application could result in high concentrations because the relative amount of dilution (runoff water into stream water) would be lower than in a "normal" rainfall year with "normal" stream flow. The high concentration (208 ppb) at IN-11 in 2005 is an example of this. In 2006, when monthly rainfall totals at IN-11 were higher than normal, measured atrazine concentrations were much lower than in 2005.

A comparison of total precipitation against yearly or monthly averages may not be a sufficient assessment of the potential for high atrazine concentrations to occur in water body without an additional evaluation of the timing of rainfall events and of stream flow at the time of the runoff event. The US EPA has requested that Syngenta continue monitoring for a third year in IL-03, IL-04, IL-08, IN-06, IN-11, MO-01, MO-02, and OH-02, collecting data on stream flow as well as rainfall during the monitoring period.

2. Flow rates / Low flow sites

a) Low Flow Sites

Sampling frequency is a critical issue for understanding uncertainty in monitoring data and by extension the interpretation of the SSI scores from CASM. Although robust in both number of samples and geographic diversity the AEMP data does include years where samples could not be collected at some sites. Of particular interest were sites monitored in Nebraska. Three of the seven sites in Nebraska experienced a higher frequency of missed samples compared to other sites both within Nebraska and across the entire AEMP geographic range. According to the registrant (Hampton, et al, 2007) three sites in Nebraska – NE-04, NE-05, and NE-07 – experienced low to no-flow conditions that resulted in significant number of missed grab samples in 2005.

Because of the missing samples, Syngenta did not use CASM to evaluate the three NE sites (Hampton, 2007a), suggesting that a dry stream would experience "significant stressors" other than atrazine runoff. They implied that these low- to no-flow events would make exposure to atrazine irrelevant because the stressors on aquatic communities due to low flow conditions are significant and would overwhelm these communities (Hampton et al, 2007a, Hampton et al, 2007b).

The issue raises several important questions. First, if sites exhibit low- or no-flow conditions such as those which may have been encountered in the three Nebraska sites, does this preclude the analysis of these data for evaluating aquatic community impacts? Meyer et al (2007) have demonstrated that headwater streams, including both low flow and intermittent streams, can have significant biodiversity. They note that these types of streams are critical to the integrity of the entire river network (Meyer, et al 2007). Given this, the Agency believes the question which should be asked is whether the type of streams represented by the three Nebraska sites with missing samples due to low/no flow conditions can be evaluated in the context of the microcosm and mesocosm studies that are the foundation of the LOC (4% SSI response from CASM).

The second question is, if the microcosm/mesocosm studies are representative of low/no flow sites (intermittent streams), what is the impact of missing samples on interpreting CASM output? If sites have a "significant" number of missing samples, is it appropriate to use these data in CASM? A logical follow up question would be that if it is inappropriate to use sites with missing data, then how many samples must be missing to exclude the data from use?

Finally, the Agency evaluated a series of landscape and watershed metrics for any obvious explanations for the uniqueness of the three Nebraska sites. These three sites with low flow conditions are in southeastern Nebraska while other sites in western Nebraska did not experience similar conditions. Metrics evaluated included flow information (both from AEMP and USGS Gages), stream order, precipitation, base flow conditions, recharge potential, soils, geology, irrigation use, and presence of tile drains. Generally, there does not appear to be an obvious explanation from any of these metrics accounting for why these three sites should have experienced conditions unique from the other 37 sites and, in particular, the other four sites in Nebraska and nearby areas of Iowa and Missouri. Interestingly, it did become apparent during this evaluation that sites exceeding the LOC tended to be lower flow sites.

Given this uncertainty the Agency decided to conduct stair step interpolation for the three sites and run each chemograph through CASM. The sites exceeded the CASM LOC, principally due to the fact that several of the sample concentrations were high and interpolation using the stair step approach extended these exposures well beyond the standard 4 day gap, possibly overestimating the importance of individual sample results. For now, the three Nebraska sites are grouped separately in the population estimates (see Section III.D) in order to evaluate what these sites would represent if they were considered to be exceeding. Given the uncertainty in the appropriateness of the use of these data, these population estimates could be useful for determining how many sites might be expected to experience similar conditions whether they be interpreted as simply low/no flow or exceeding the LOC.

b) Flow Measured at the Monitoring Sites

Stream flow was the most obvious factor to compare between the monitoring sites.Flow data for each year was summarized for each site by calculating the annual average flow rate for each site by year (Table III-12).

Table III-12 Summary of annual average flow rate for the 40 monitoring sites by year.

Site	2004 flow (cfs)	2005 flow (cfs)	2006 flow (cfs)
IA 01	50.20	69.95	37.70
IA 02	20.81	21.09	97.78
IL 01	102.25	15.05	
IL 02	71.71	56.08	
IL 03		46.34	37.70
IL 04		21.45	97.78
IL 05	102.89	83.12	
IL 06	30.02	20.49	
IL 07	29.71	20.82	
IL 08		146.39	125.51

Site	2004 flow (cfs)	2005 flow (cfs)	2006 flow (cfs)
IL 09	32.95	27.57	
IN 01	63.86	145.85	
IN 02	30.57	14.22	
IN 03		19.49	36.36
IN 04	42.96	14.77	12.55
IN 05	8.28	7.22	9.26
IN 06		132.89	213.52
IN 07		199.77	202.98
IN 08		27.60	42.37
IN 09		56.13	79.52
IN 10		15.23	29.35
IN 11		11.43	36.79
KY 01		6.55	14.30
KY 02		46.46	63.70
MN 01		28.33	16.46
MO 01	2.73	3.13	2.30
MO 02	28.30	25.86	29.69
MO 03	85.10	69.73	24.78
NE 01	42.85	57.50	
NE 02		84.83	37.90
NE 03	2.73	4.82	
NE 04		**9.50**	**6.59**
NE 05		**35.22**	**22.35**
NE 06	3.62	1.04	4.40
NE 07		**15.37**	**8.56**
OH 01	34.63	26.97	
OH 02		27.41	36.24
OH 03	21.14	21.42	
OH 04		192.55	208.70
TN 01		17.22	11.97

In addition, the 86 years of flow data were ranked relative to each other (Table VII-3 in Appendix 2**Error! Reference source not found.**). The three NE sites did not have the lowest average flow: NE-04 in 2005 had the 15th lowest flow out of 86 site years, NE-07 in 2005 was 24th, and NE-05 was 51st. Interestingly, three of the five lowest flow site years were the three sample years forMO-01, which exceeded the LOC each year.

Figure III-12 through Figure III-15 plot atrazine concentrations against measured stream flow for NE-04, NE-05, NE-07, and MO-01 in 2005 to illustrate the relationship between atrazine concentrations and flow conditions. In these figures the missing samples are shown as 0. While Figure III-12 and Figure III-15 suggest a relationship between atrazine concentrations and flow events, even it is a delayed response, the relationship is not as evident in Figure III-13 and Figure III-14. One possible explanation is that atrazine concentrations may be higher in some low-flow streams because there is less receiving waters to dilute the atrazine load in runoff waters. It is also possible that some unexplained feature of streambed morphology could influence the ability to collect samples.

Figure III-12 Atrazine concentrations and measured stream flow, NE-04, 2005

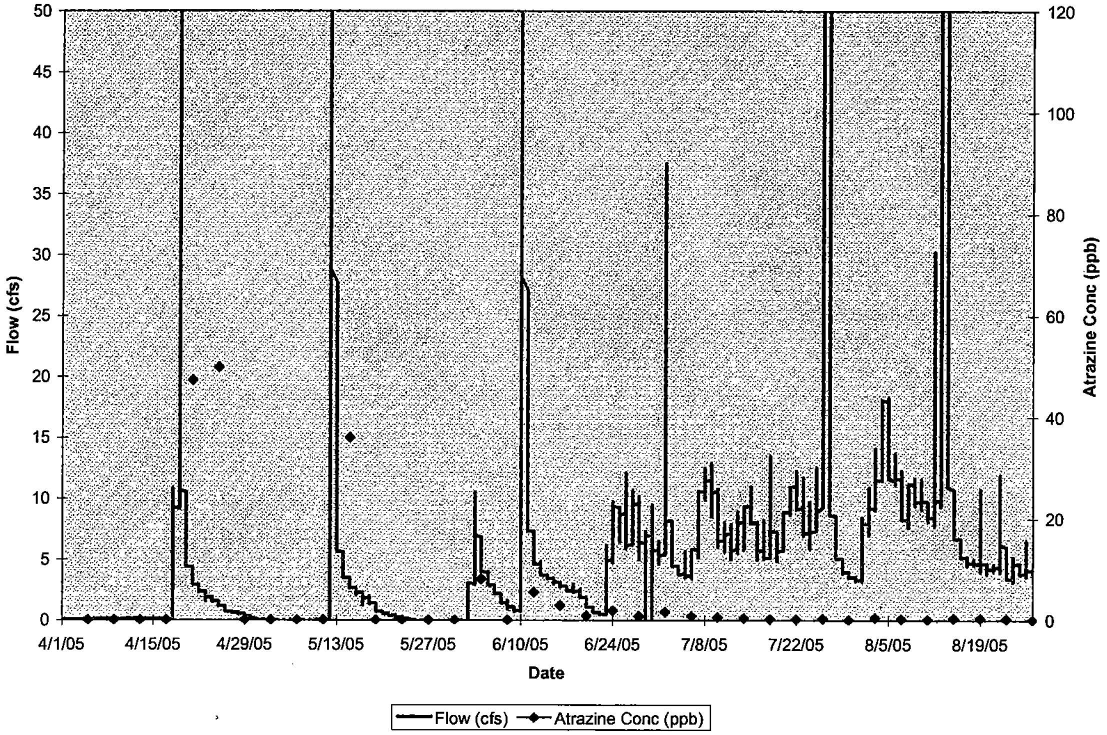


Figure III-13 Atrazine concentrations and measured stream flow, NE-05, 2005

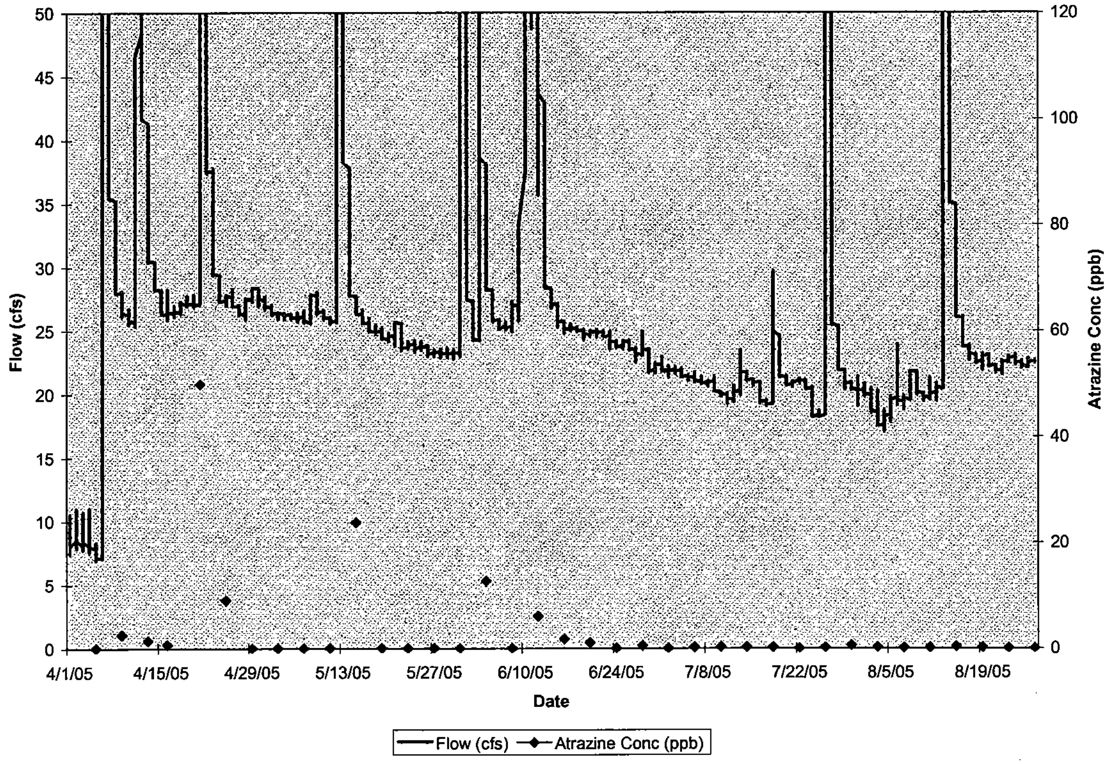


Figure III-14 Atrazine concentrations and measured stream flow, NE-07, 2005

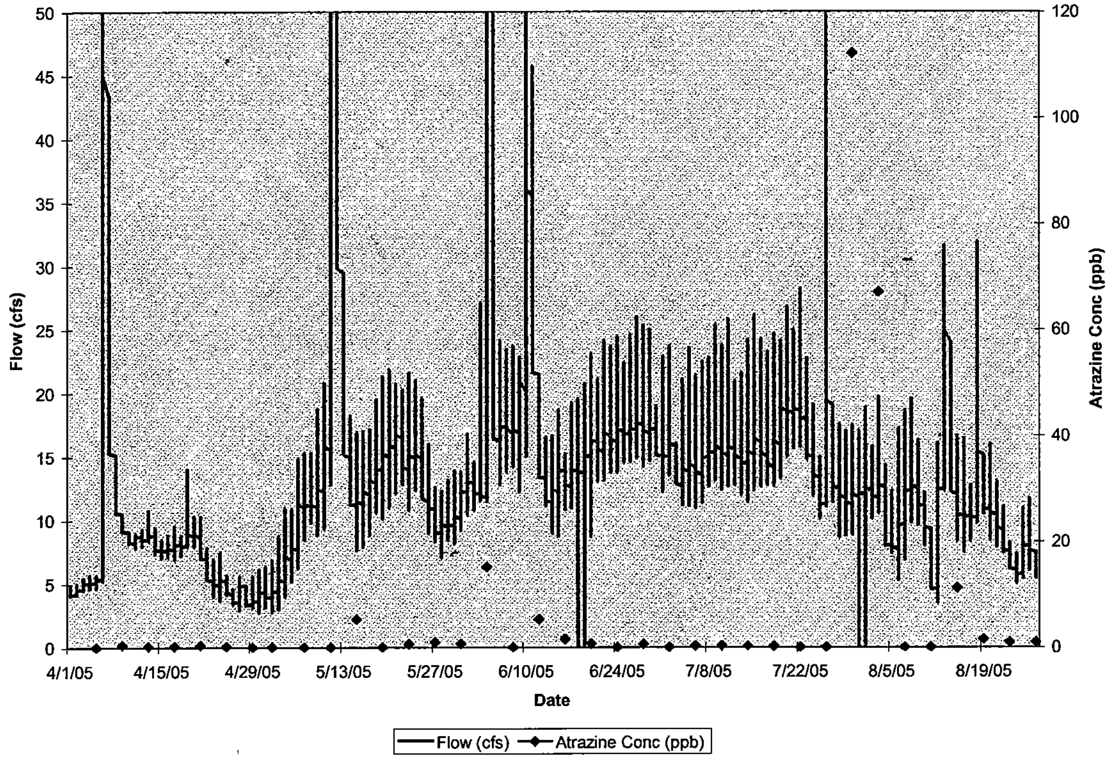
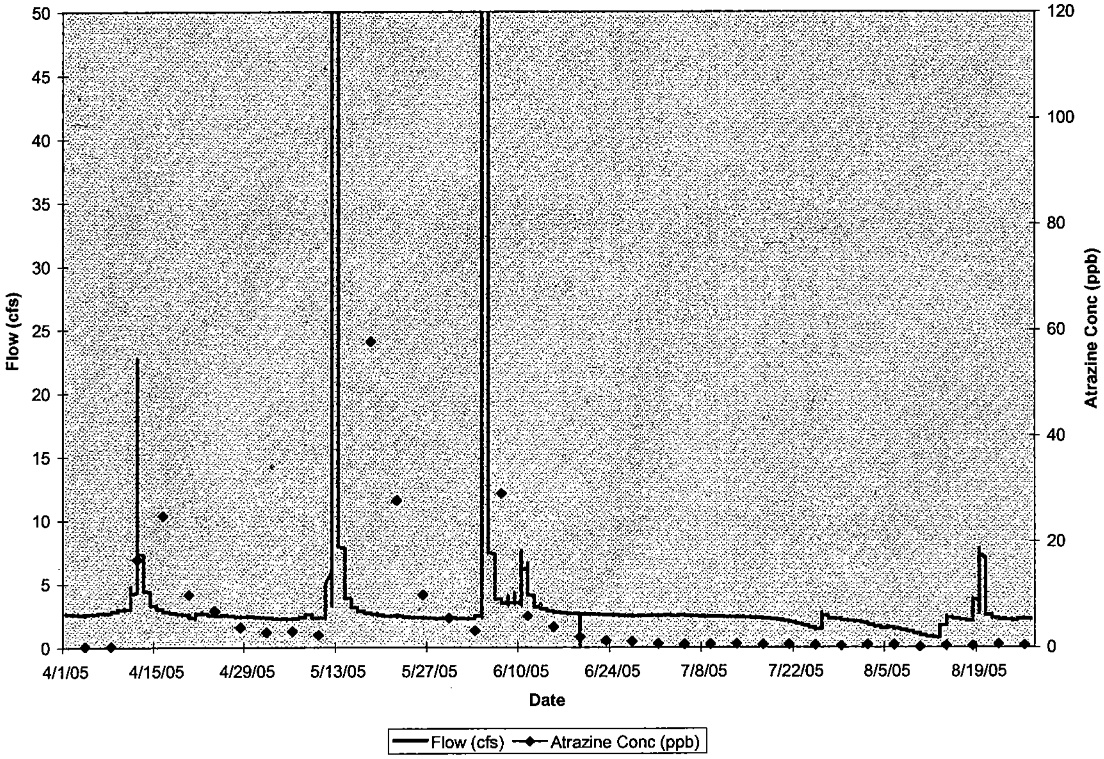


Figure III-15 Atrazine concentrations and measured stream flow, MO-01, 2005



3. Sampling Frequency / Auto-samples

The AEMP data set represents a robust and targeted monitoring data set available for atrazine with 4-day grab samples augmented with more frequent flow triggered auto-samples. The AEMP site averaged 36 samples per year for 37 of the 40 sites with an average of 17 samples per year for the three sites (NE-04, NE-05, and NE-07) that experienced more missing samples than the others. On average, this equates to roughly 7 samples per month during the sample season (generally from April to September) while the sites with missing samples averaged 3 samples per month during the sample season. The AEMP has been input into CASM in order to determine whether community level effects can be expected given the duration and magnitude of atrazine exposures in each chemograph. Even with the robust nature of this data, CASM requires a complete 365 day chemograph for estimating effects levels. Thus each AEMP chemograph is augmented by interpolation between sample events and extrapolation to estimate atrazine concentrations prior to the first sample and after the last sample.

Sampling frequency is a critical component of uncertainty analysis for this evaluation because atrazine exposure and interpretation of potential community responses relative to the microcosm and mesocosm studies is driven by the magnitude and duration of exposure. In this construct the means of "filling in" (e.g. interpolation or imputation) missing data is critical and thus the more data that is missing (e.g. less frequent sampling) the greater uncertainty there will be in determining if the LOC has been exceeded based on increasing uncertainty in the magnitude *and* duration of atrazine exposure. Thus an understanding of the inherent uncertainty in the AEMP data is critical to evaluating the risk conclusions drawn from CASM. Sensitivity analysis of the CASM model informed model uncertainty, however, this analysis did not address the potential uncertainty in the AEMP data. Understanding uncertainty associated with the AEMP data due to interpolation, missing samples, and less frequent sampling is critical and can assist in interpreting uncertainty in the model estimates and the amount of conservativeness of overall risk conclusions. Also, a better understanding of how these factors might influence model output for the AEMP data can inform how other monitoring data not collected as part of the AEMP might, or might not be reasonably interpreted when run in CASM

For the AEMP, the method chosen to interpolate or impute a 'missing' value is the stair step approach whereby a concentration at a given sampling event is carried forward across the four day window to the next sampling date. Estimating atrazine concentrations pre- and post-sampling occurs by extrapolation of the first sample backwards to the beginning of the year and the last sample forward to the end of the year except where a chemograph represents a second or third year at a site, in which case the last sample result is carried beyond the end of the year to the first sampling event of the following year. Thus even though this represents a robust data set, there is uncertainty associated with the means of estimating the chemographs to obtain a 365 day profile.

The impact of the infilling process was evaluated to determine how important the assumptions used to infill are on CASM output (e.g. risk conclusions for each site). First, sampling frequency was evaluated by simulating a less frequent sampling design using the AEMP data. The ramifications of this are then compared with selected sites within the AEMP where sampling frequency was less (e.g. the three Nebraska sites with low flow conditions and missing data) and how missing samples or less robust data might influence uncertainty. Second, an alternative approach to assessing uncertainty in different sampling frequencies was considered. Third, alternative approaches to infilling are considered in the context of uncertainty.

a) Evaluation of Sampling Frequency Using AEMP Data

As noted in the analysis of the three Nebraska sites there will clearly be instances where less robust monitoring data can be encountered. The following evaluations were completed to determine how important sampling frequency is in the use of the CASM model relative to AEMP data, to determine if uncertainty with missing samples can be characterized, and by extension if monitoring data that is less robust can and/or should be evaluated using CASM.

The CASM model uses 365 day chemographs as the exposure profile input and thus even for the robust AEMP data some level of interpolation, or infilling of missing data points, is required. The method chosen for interpolation in CASM is a stair-step approach by which each sample result is carried forward across the un-sampled days until the next sample result is reached. The infilling then proceeds across the profile until the last sample is reached. How dates prior to the first sample event and after the final sample event in a given year are imputed raises an issue of uncertainty. In their analysis, Syngenta assumed that all days prior to the first event and after the last event were 0. The Agency's approach is predicated on an assumption (supported by other data sets such as the Heidelberg College data; Volz et al, 2007) that there will be quantifiable exposure year round including these early and late time frames. Thus, the Agency has estimated the last days of the 365 day profile with the results from the last day sampled. For the days prior to the first sample we have estimated using two methods. First, if no sampling has occurred in the previous year, the result of the first sample date was assigned to every day extending backwards to January 1. If a previous year's sampling has occurred, the last value from the previous year is carried forward to the first date of the following year. Comparison of rolling average estimation and CASM risk conclusions indicate that the Agency's approach increases the atrazine exposure compared to that used by the registrant and increases the overall exposure profile slightly but does not change the ultimate conclusion for the AEMP sites (the same sites are identified to exceed the LOC using both approaches).

The second issue associated with interpretation of the AEMP data in CASM is interpolation between sampling events and the sampling frequency of individual chemographs. CASM requires a 365 day profile and will "interpolate" between sampling events where data is lacking. Options in CASM for interpolation include linear and stair-step interpolation between sampling events. In both instances, there is a question of whether peak concentrations are being missed by 4 day grab samples and what impact potentially missed pulses of atrazine exposure might be having on model output based on a magnitude and duration of exposure.

In order to test the importance of sampling frequency the Agency conducted an analysis where data from one of the AEMP sites was reduced to a 12-day grab sample profile. First, the first sampling date was intentionally skewed to miss the peak concentration from the 4 day grab sample data. Then an alternative 12 day profile was created which included the peak concentration. 14-day, 30-day, 60-day, and 90-day rolling average concentrations for each of the three profiles were then calculated.

Comparisons for 2004 chemograph for IN-04 show a wide range in peak and average concentrations depending on the length and timing of sampling events (Table III-13). Missing the peak concentration of 78 ppb resulted in much lower longer-term average concentrations than those found with the 4-day grab samples while hitting the peak concentration resulted in higher longer-term average concentrations. This analysis suggests that sampling frequency and when the samples are collected can have a significant impact on how the results are interpreted. In this case, neither of the alternative 12 day grab sample profiles exceeded the LOC although the 12 day profile that captured the peak was 3.8% compared to the 4% LOC and was well within the 2x multiplication factor uncertainty bound for CASM.

Table III-13 Comparison of estimated atrazine concentrations between 4-day and 12-day grab samples, IN-04, 2004

	Atrazine concentration (ug/L) and CASM SSI% for various average periods							
	Peak	**14-da**	**21-da**	**30-da**	**60-da**	**90-da**	**Annual Avg.**	**SSI%**
4-day grab samples w/stair step interpolation	78.08	23.81	16.33	12.05	6.35	4.37	1.20	1.7
12-day grab samples w/peak EEC missed	2.26	2.04	1.60	1.48	1.06	0.88	0.34	0.3
12-day grab samples w/peak EEC captured	78.08	**67.38**	45.97	**33.20**	17.29	11.68	3.03	3.8

b) Auto Sample Results

In addition to 4-day grab samples, 13 sites were instrumented with auto-samplers. The auto-samplers were installed to collect 8-hour composite samples triggered by increased flow events within a stream site. A total of 25 site years of data was collected using the auto samplers. These data were used to augment the 4-day grab time series to investigate the impact of grab samples on uncertainty in the CASM runs using 4-day samples. Both the 4-day grab sample chemographs and the chemograph created from 4-day grab samples augmented with autosample results were interpolated/extrapolated to create 365 day profiles.

In order to conduct this analysis the 4-day time series was compared with the auto-sample results for each site-year of data and the auto-sample results were added to the time series. For days with more than one auto-sample result the highest value from that day was used as though that value was the grab sample for that day. The auto-sample results were compared against the 4-day grab samples and where an auto-sample event occurred on the same day as a 4-day grab sample the highest of the two sample types was used in the distribution. If the auto-sample event occurred on a day when no 4-day grab sample was collected then the auto-sample result was placed in the time series on the day it was collected. Data interpolation then proceeded as with the 4-day samples with the exception being that if there were un-sampled days after an auto-sample event these days were assumed to have the same value as the auto-sample result. In essence, the auto-sample results were used to fill exposure gaps between the 4-day grabs and then used as part of the stair-step interpolation process in the same manner as the 4-day grab sample interpolation.

In order to test the robustness of the 4 day samples an analysis was conducted whereby various rolling average concentrations (Table III-14) were calculated for each site by year for the 4 day grab samples augmented with auto-samples (the 4 day grab sample rolling averages and SSI% were summarized previously in Table III-5.

Table III-14 4-day Grab Samples Augmented with Auto Samples - Rolling Averages (ppb)

		Maximum atrazine concentration, ug/L (ppb) over averaging periods of						
Site	Year	Peak	14 days	21 days	30 days	60 days	90 days	365 days
IA 02	2004	5.37	2.41	1.83	1.84	1.26	0.92	0.17
IA 02	2005	5.53	2.14	1.53	1.39	0.85	0.63	0.58
IL 06	2004	5.26	1.07	0.92	0.74	0.53	0.42	0.19
IL 06	2005	0.23	0.15	0.14	0.13	0.12	0.11	0.09
IL 08	2005	24.67	9.22	7.11	5.82	3.53	2.61	0.55
IL 08	2006	50.70	11.74	8.06	10.06	5.54	3.78	0.84
IN 06	2005	7.23	3.85	2.93	2.31	1.22	0.88	0.24
IN 06	2006	24.30	5.73	4.79	3.87	2.39	1.79	0.47
IN 09	2005	34.49	8.81	6.08	5.40	3.45	2.46	0.40
IN 09	2006	13.80	4.27	3.13	2.85	1.93	1.37	0.31
IN 11	2005	237.50	65.13	44.41	31.51	16.18	11.32	3.80
IN 11	2006	15.89	5.90	4.36	3.34	1.92	1.37	0.83
MN 01	2005	15.03	5.10	3.62	2.61	1.41	1.04	0.33
MN 01	2006	0.22	0.16	0.14	0.13	0.12	0.11	0.10
MO 01	2004	65.94	28.83	21.92	22.08	15.43	11.10	3.20
MO 01	2005	182.75	78.06	54.19	45.66	26.98	19.18	4.98
MO 01	2006	106.00	45.11	39.06	30.20	17.01	11.69	3.09
MO 03	2006	20.31	5.00	3.82	3.12	2.10	1.68	0.86
NE 04	2006	125.00	21.08	14.10	13.98	8.00	5.47	1.45
NE 05	2006	6.76	5.29	4.49	3.94	3.18	2.22	0.63
NE 06	2004	10.99	3.08	2.75	2.20	1.70	1.56	0.45
NE 06	2005	36.13	19.29	13.01	10.85	5.79	3.95	1.05
NE 06	2006	0.13	0.11	0.11	0.10	0.10	0.10	0.10
OH 03	2004	21.50	8.14	7.60	6.97	4.25	2.86	0.74
OH 03	2005	15.84	4.06	2.78	2.43	1.29	0.90	0.28

Once the chemographs were augmented with auto-sample results and interpolated/extrapolated to a 365 day profile using the stair-step approach each data set was input into CASM where a SSI% and multiplication factor (MF) was estimated. The SSI% and MF for the auto-sample augmented chemographs were then compared with the original chemograph SSI% and MF to understand what influence the incorporation of continuous auto-sample results into the profile had on model behavior (Table III-15). While none of the auto-sample augmented profiles exceeded the 4% SSI LOC (except where the original chemograph exceeded) the overall influence on model response was an average 64% increase in SSI% and a 18% decrease in MF across all sites with auto-samplers.

Table III-15 Percent Difference Between Grab Averages and Auto Sample Adjusted Averages using CASM SSI%

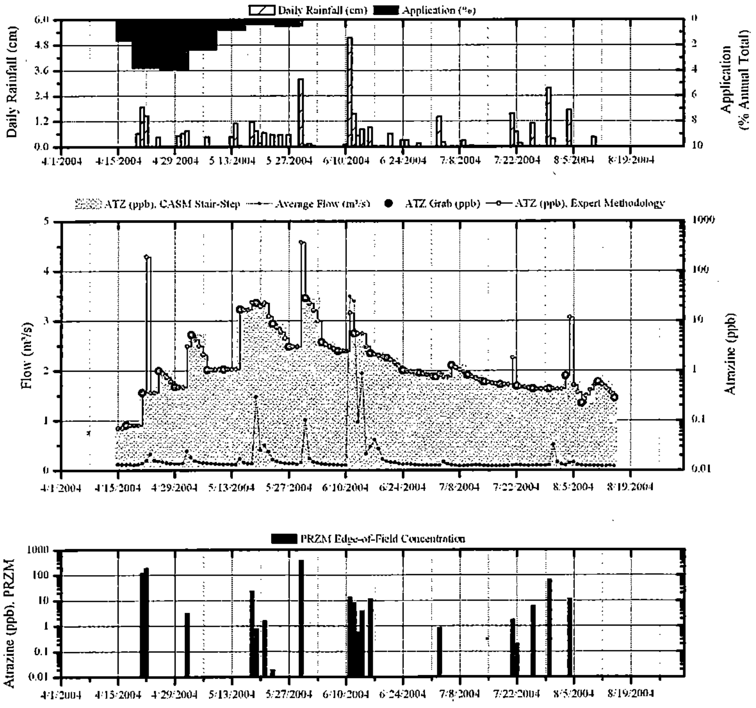
Site Name	Auto Sampled Sites		Four Day Sites		Percent Difference	
	AD365	MF	AD365	MF	AD365	MF
IA02 2004	0.35	12.22	0.14	18.75	150	-35
IA02 2005	0.33	14.06	0.28	16.13	18	-13
IL06 2004	0.27	15.25	0.14	21.00	93	-27
IL06 2005	0.00	13.32	0.00	27.16	0	-51
IL08 2005	1.13	3.63	0.61	5.70	85	-36
IL08 2006	1.91	2.87	1.62	3.72	18	-23
IN06 2005	0.37	11.47	0.28	14.45	32	-21
IN06 2006	0.87	5.44	0.68	6.50	28	-16
IN09 2005	1.19	4.16	0.56	7.72	113	-46
IN09 2006	0.64	7.09	0.43	9.80	49	-28
IN11 2005	5.64	0.71	5.09	0.78	11	-9
IN11 2006	1.32	3.50	0.53	7.81	149	-55
MN01 2006	0.00	20.40	0.00	20.40	0	0
MN01 2005	1.15	3.84	0.22	13.75	423	-72
MO01 2004	4.44	0.85	5.04	0.70	-12	22
MO01 2005	6.80	0.53	6.31	0.57	8	-7
MO01 2006	4.43	0.87	4.48	0.84	-1	3
MO03 2006	0.96	4.78	0.78	5.41	23	-12
NE04 2006	2.14	2.10	0.44	7.97	386	-74
NE05 2006	0.78	4.54	1.05	2.77	-26	64
NE06 2004	0.54	7.31	0.53	7.13	2	3
NE06 2005	1.94	2.85	2.04	2.75	-5	4
NE06 2006	0.00	20.49	0.00	20.49	0	0
NE07 2006	0.55	8.46	na	na	na	na
OH03 2004	1.41	3.91	1.46	3.66	-3	7
OH03 2005	0.54	11.47	0.36	15.38	50	-25
				Average	64	-18

In general, overall rolling average concentrations increased across all sites and the overall change in CASM SSI% was 64% across all sites. The analysis indicates that incorporation of continuous sampling is likely to increase the overall exposure profile vis. the profile presented by grab samples, and that use of less frequent [grab] samples is likely to underestimate exposure. However, none of the revised chemographs exceeded the LOC (4% SSI) except for sites already above the LOC (e.g. MO 01).

c) Syngenta PRZM Augmentation

In Snyder et al (2007) Syngenta presented additional analysis on the importance of data interpolation. This analysis involved augmentation of the 4-day grab sample profile using the Pesticide Root Zone Model (PRZM) (Carsel et al, 1998) to predict edge of field concentrations with site-specific climate data and application information. Predicted peak concentrations were matched to 4-day grab sample results to establish dilution and dissipation factors. The remaining PRZM concentrations not corresponding with 4-day grab samples were then "augmented" to the time series profile. Syngenta completed this analysis for all 40 sites and years monitored (80 site years in all) available at the time of Snyder (2007). Each PRZM augmented chemograph was then run through CASM to generate rolling average concentrations for 14-day, 30-day, 60-day, and 90-day durations as well as calculated SSI%. More detail on the methodology and assumptions employed in this evaluation are presented in Snyder (2007). A graphical representation of how the analysis was performed is presented in Figure III-16.

Figure III-16 Graphical Representation of PRZM Augmentation of a 4-Day Grab Sample Time series (taken from Syngenta Presentation Titled "Atrazine Ecological Monitoring Program review" dated December 14, 2006)



Additional analysis of this evaluation was conducted by the Agency and consisted of comparing the rolling average concentrations and SSI% from the original un-adjusted chemographs and the PRZM augmented chemographs. The SSI% are presented for completeness but not used for further analysis because the SSI% were created using a different version of CASM than currently being evaluated and because the majority of the 80 chemographs remained unchanged at 0% SSI (24 or 30% of all site years) or increased but the original SSI% was 0 (36 or 45% of all site years) and no percent difference could be calculated. For all 80 chemographs the percent change in rolling average concentrations and SSI% (where values greater than 0 were available for both original and augmented chemographs) were calculated. The PRZM augmented rolling average concentrations and SSI% is presented in Table VII-4 in Appendix 2 while the percent change from the original rolling average and SSI is summarized Table III-16. The original rolling average and SSI% are presented in Table III-5.

Table III-16 Summary of Percent Differences Between Original Rolling Average Concentrations and SSI% and revised Rolling Average Concentrations (ppb) and SSI% for PRZM Augmented Chemographs from Snyder, et al (2007)

		% Difference in the				
Site	Year	14-day rolling average	30-day rolling average	60-day rolling average	90-day rolling average	SSI%
IA 01	2004	180	273	323	284	a
IA 01	2005	842	767	587	387	b
IA 02	2004	604	535	485	402	a
IA 02	2005	100	135	235	210	a
IL 01	2004	22	43	56	48	b
IL 01	2005	940	1180	1320	900	a
IL 02	2004	367	251	252	235	a
IL 02	2005	32	9	23	62	b
IL 03	2005	384	437	368	443	a
IL 03	2006	287	292	273	435	a
IL 04	2005	103	163	122	113	b
IL 04	2006	105	222	166	144	a
IL 05	2004	66	153	173	182	43
IL05	2005	459	430	267	300	b
IL 06	2004	524	763	652	560	a
IL 06	2005	1095	1040	710	460	a
IL 07	2004	78	120	129	122	a
IL 07	2005	653	610	302	348	a
IL 08	2005	61	94	137	129	a
IL 08	2006	58	40	50	78	140
IL 09	2004	54	75	72	70	a
IL 09	2005	16	57	61	95	600
IN 01	2004	232	158	223	217	a
IN 01	2005	226	220	281	276	a
IN 02	2004	32	60	65	55	a
IN 02	2005	-7	-8	-3	1	b
IN 03	2005	-2	-1	0	11	b
IN 03	2006	7	22	66	64	a
IN 04	2004	26	49	68	64	24
IN 04	2005	388	338	443	437	a
IN 04	2006	101	80	83	78	a
IN 05	2004	2	5	17	20	-44
IN 05	2005	2	25	-3	15	a
IN 05	2006	-31	-19	-6	-1	-68
IN 06	2005	19	18	12	27	b
IN 06	2006	24	27	15	31	b
IN 07	2005	-29	-16	-8	-4	-69
IN 07	2006	65	57	121	121	a

Site	Year	% Difference in the				
		14-day rolling average	30-day rolling average	60-day rolling average	90-day rolling average	SSI%
IN 08	2005	0	0	0	10	b
IN 08	2006	25	19	25	37	a
IN 09	2005	213	184	245	225	a
IN 09	2006	63	70	89	107	b
IN 10	2005	-1	30	43	40	b
IN 10	2006	49	42	42	49	a
IN 11	2005	-30	-29	-23	-21	-15
IN 11	2006	24	58	71	66	b
MO 01	2004	-29	-24	-14	-14	-15
MO 01	2005	-16	-13	-10	-33	-41
MO 01	2006	-8	-2	10	10	-5
MO 02	2004	-5	-1	1	2	-2
MO 02	2005	5	17	25	21	144
MO 02	2006	-13	-8	0	-2	-4
MO 03	2004	-18	-12	-6	-4	-6
MO 03	2005	20	24	21	18	b
MO 03	2006	125	69	44	80	b
NE 01	2004	3	4	3	6	b
NE 01	2005	26	30	42	40	a
NE 02	2005	-5	-9	-1	0	a
NE 02	2006	-2	13	14	14	6
NE 03	2004	557	301	227	220	a
NE 03	2005	5	12	21	19	b
NE 06	2004	92	49	67	44	a
NE 06	2005	-29	-19	-16	-16	-71
NE 06	2006	1440	1310	640	420	a
KY 01	2005	25	27	21	33	b
KY 01	2006	7	38	67	79	-71
KY 02	2005	23	17	17	16	a
KY 02	2006	60	82	87	82	b
MN 01	2005	97	172	186	185	a
MN 01	2006	1170	1460	950	770	a
OH 01	2004	-9	6	16	19	b
OH 01	2005	108	86	130	82	b
OH 02	2005	8	13	50	74	300
OH 02	2006	23	26	44	43	b
OH 03	2004	-1	5	45	41	a
OH 03	2005	42	115	102	105	a
OH 04	2005	-2	35	83	107	1600
OH 04	2006	123	171	230	233	a
TN 01	2005	-12	-6	5	5	b
TN 01	2006	1	11	-8	1	b

a – 0% SSI in both original and augmented chemographs

b – 0% SSI in original chemograph

Finally, the percent differences were ranked and percentile generated for each duration and the SSI% separately. In addition, a single percentile distribution was created for all four rolling averages. The result of this analysis is presented in Table III-17.

Table III-17 Percentile of Ranked Distribution of Percent Differences from Table III-16

	14-day rolling average	30-day rolling average	60-day rolling average	90-day rolling average	SSI%[1]	All rolling averages
average	151	162	145	132	122	148
median	26	42	61	66	-4	49
99th	1224	1340	1024	796	1410	1280
95th	842	767	640	443	650	653
90th	524	437	368	402	330	436
75th	108	163	186	185	67	171
50th	26	42	61	66	-4	49
25th	1	11	15	18	-42	10
10th	-12	-8	-3	0	-69	-6
5th	-29	-16	-8	-4	-71	-15
1st	-31	-25	-17	-24	-71	-29

1 – SSI% percent difference distributions are suspect due to limited number of suitable data.

This overall analysis suggests that augmentation of the original 4-day grab sample chemograph using a modified PRZM approach can increase thresholds by roughly 50% at the median and as much as 150% for the average. This analysis is consistent with the comparison of grab sample only chemographs versus grab sample augmented with autosample results chemographs that suggests that 4 day grab sample profiles by themselves are likely to miss peak exposures and thus underestimate overall exposure. This does not suggest that all sites will increase by this amount using this type of approach to augment a time series but it does provide context to the uncertainty in using a stair step interpolation method for the 4-day grab samples.

d) Evaluation of Alternate Sampling Frequency Strategies

Application of the CASM model beyond the AEMP will be highly influenced by the type of sample program implemented as well as type of streams being assessed. Setting aside stream type which is addressed elsewhere, the analysis presented above clearly suggests that sample programs less robust than the AEMP are likely to miss peak concentrations and may result in an under-estimation of exposure. Many monitoring programs are being conducted for the implementation of TMDL programs and for the evaluation of the establishment of aquatic life criteria. It is highly unlikely that these sample designs will include the level of monitoring captured in the AEMP.

One possible solution to the uncertainty associated with differing sample frequencies may be found in the work of Crawford (2004). Crawford (2004) used a robust data set of 10 years of atrazine data collected by Heidelberg College Water Quality Laboratory (WQL) from four streams in Ohio was linearly interpolated to provide a synthetic chemograph of hourly observations. Crawford (2004) conducted a Monte Carlo assessment using the Heidelberg data to approximate different sampling strategies ranging from a limited sampling consisting of one sample per quarter to a more robust program of 10 samples per month. The probabilistic assessment ran 1,000 iterations and error distributions based on percent difference between computed and actual mean, 90th, 95th, and 99th percentile concentrations. As expected, the analysis shows that as sampling frequency increases the difference between actual and sampled values decreases. A summary of the various monitoring programs evaluated by Crawford (2004) and the +/- differences at the 10th and 90th percentiles are presented in Table III-18 and Table III-19.

Table III-18 Sampling frequency strategies used by Crawford (2004)

Abbreviation[1]	**Samples per Year**	**Samples per Month during Runoff Period**
Q	4	1
W7	7	1
W10	10	2
M	12	1
W14	14	2
W22	22	4
M2	24	2
W46[2]	**46**	**10**
M4	48	4
M10	120	10

1 – Detailed descriptions of sample strategies may be found in Crawford, 2004
2 – Sample strategy W46 most closely matches AEMP

Table III-19 Error Distribution for Various Sample Strategies of Crawford (2004) for Different Concentration Profiles

		Mean Concentration		**90th % Concentration**		**95th % Concentration**		**99th % Concentration**	
Site	**Method**	**10th %**	**90th %**	**10th %**	**90th %**	**10th %**	**90th %**	**10th %**	**90th %**
Honey Creek	Q	-77.18	98.70	-79.54	213.79	-91.46	48.56	-97.72	-36.24
	W7	-48.70	66.14	-70.15	65.97	-54.91	215.90	-84.40	0.12
	W10	-37.47	49.94	-36.07	42.27	-49.99	40.44	-74.46	14.50
	M	-49.68	69.82	-59.79	35.26	-50.32	214.69	-84.96	3.60
	W14	-38.71	35.94	-35.26	34.61	-50.16	33.22	-74.70	10.83
	W22	-21.74	20.06	-19.90	28.96	-30.36	21.97	-48.23	69.39
	M2	-38.80	47.36	-35.60	39.11	-50.12	33.49	-74.33	29.90
	W46	**-9.02**	**10.85**	**-13.16**	**10.43**	**-17.01**	**19.05**	**-32.34**	**7.61**
	M4	-23.29	15.22	-15.77	27.96	-28.89	19.00	-52.02	58.51
	M10	-12.82	7.34	-12.66	15.33	-14.31	18.32	-41.83	6.31
Maumee River	Q	-68.50	83.64	-76.56	105.18	-86.91	22.96	-93.66	-16.57
	W7	-29.16	26.37	-59.24	48.51	-33.64	52.33	-69.42	-0.69
	W10	-14.73	26.17	-31.84	26.35	-37.52	11.80	-43.41	5.09

		Mean Concentration		90th % Concentration		95th % Concentration		99th % Concentration	
Site	**Method**	**10th %**	**90th %**	**10th %**	**90th %**	**10th %**	**90th %**	**10th %**	**90th %**
	M	-27.13	26.67	-56.22	15.50	-31.51	63.34	-62.37	0.41
	W14	-17.66	16.70	-32.15	15.26	-36.16	8.66	-43.57	4.59
	W22	-9.18	8.72	-16.64	25.50	-17.12	9.12	-22.01	15.55
	M2	-17.55	17.23	-29.31	19.41	-38.95	12.69	-43.20	7.37
	W46	**-3.42**	**6.30**	**-7.41**	**5.77**	**-8.18**	**6.37**	**-18.27**	**2.75**
	M4	-7.33	6.56	-14.23	29.85	-14.12	8.31	-22.66	16.60
	M10	-2.99	1.30	-8.99	4.47	-6.51	6.40	-18.72	2.75
Rock Creek	Q	-79.62	138.39	-82.18	327.73	-92.57	71.38	-97.59	-38.85
	W7	-59.24	65.53	-72.11	176.81	-61.16	198.07	-87.08	-10.84
	W10	-41.47	44.17	-48.40	66.81	-56.96	48.68	-73.12	17.40
	M	-58.29	84.30	-68.55	70.73	-63.04	249.73	-89.30	4.42
	W14	-42.95	32.08	-41.81	45.60	-59.16	41.70	-73.23	6.54
	W22	-28.33	28.20	-27.45	41.90	-31.46	39.77	-54.50	66.09
	M2	-44.46	47.89	-38.90	60.55	-58.63	54.55	-72.53	33.67
	W46	**-11.35**	**13.34**	**-18.34**	**17.04**	**-18.20**	**20.10**	**-29.03**	**9.24**
	M4	-27.61	20.80	-26.37	34.03	-34.32	42.30	-55.79	58.42
	M10	-6.20	13.20	-5.64	17.09	-16.44	30.79	-32.79	5.09
Sandusky River	Q	-73.39	104.09	-78.24	173.84	-89.14	38.23	-95.61	-27.29
	W7	-44.29	54.28	-68.72	63.49	-46.41	94.62	-80.06	3.32
	W10	-26.11	34.14	-44.31	78.33	-47.57	31.43	-52.67	12.70
	M	-40.06	44.07	-64.72	33.93	-43.37	110.12	-76.09	3.76
	W14	-27.50	25.15	-44.05	40.15	-47.26	26.84	-54.63	10.40
	W22	-15.51	18.96	-17.63	41.40	-23.50	30.03	-34.11	31.54
	M2	-28.93	26.86	-39.14	44.16	-48.33	30.17	-53.83	15.93
	W46	**-6.10**	**10.70**	**-8.57**	**13.21**	**-10.93**	**16.72**	**-21.08**	**9.50**
	M4	-15.34	15.12	-17.87	41.97	-21.32	30.19	-33.32	28.75
	M10	-6.99	6.45	-8.54	12.56	-9.10	20.99	-22.11	11.39

The data and analysis in Crawford (2004) were evaluated with two objectives. First, can the error estimates provide additional information on the uncertainty associated with a sampling frequency comparable to the AEMP relative to a continuous 365 day exposure profile (e.g. an analysis similar to the grab versus autosample analysis above)? In this case, it is assumed that sampling strategy W46 from Crawford (2004) is the closest approximation of the AEMP. It is then assumed that the error estimate for this strategy at the 99th percentile concentration can provide context to the autosample analysis above. In essence the Heidelberg data approximates the autosample augmented profile described above. The error estimates for W46 at the 99th percentile range from 18 to 32%. This comparison is limited because the autosample analysis above includes interpolation between events while the Crawford (2004) data does not estimate the intermittent peak concentration.

In the summary above the potential for underestimation of exposure in a sampling design such as W46 can vary by as much as 30% depending on target concentration (e.g. 99th percentile of the yearly distribution) keeping in mind that the error estimate represents the uncertainty in the ability of a sampling strategy to capture a certain percentile of a 365 day time series. This analysis suggests that it may be possible to estimate how likely a given sampling strategy will capture a given target exposure. Interestingly, the error estimates for W46 are similar to the estimated uncertainty seen when comparing 4-day grab sample chemograph with autosample augmented chemographs.

An additional value in the Crawford (2004) data is the ability to compare uncertainty in different sampling frequencies (e.g. monitoring other than the AEMP). As an example of how this approach might work the following table (Table III-20) was created to show the difference in error estimates for the various sampling strategies for the annual mean concentration relative to W46. The W46 sampling strategy evaluated by Crawford (2004) best represents the AEMP and thus could form the foundation for comparison. It should be noted that the error estimates provided below do not include the influence of interpolation/extrapolation used on the AEMP. Thus the analysis is useful for comparing uncertainty in raw data (e.g. data that has not been interpolated to a 365 day profile) from sampling scheme similar to the AEMP with other less frequent sample strategies that could potentially be input in CASM. This table provides a clearer picture of the trend summarized above suggesting that as sampling frequency decreases the error differential increases. In this example, it could be interpreted that a sampling strategy approximated by the monthly sampling strategy (i.e. method M below) would be expected to under-predict exposures relative to W46 by 40%.

It is suggested that the different error distributions surrounding the various sampling strategies will allow for an estimation of the uncertainty in less robust data. For example, the percent difference for one watershed (Sandusky River) in Crawford (2004) for the annual time weighted mean concentration when sampling 10 times per month ranged from -13% at the 5th percentile up to roughly +7% at the 95th percentile while quarterly sampling yielded a range of -77% to 152%. Additionally, it should be possible to provide uncertainty bounds on less robust monitoring data based on the differences seen in the Crawford data. It is speculated that these data can allow for an uncertainty factor to be put in place which, when monitoring yields exposure duration profiles within a certain bound of the LOC established by CASM, would be similar to the MF approach based on the model sensitivity presented in Section II.

Table III-20 Variability of estimated concentrations based on different sample frequencies (Crawford, 2004)

Sample Site Name	Sample Method Code			% Difference from W46	
		p10	p90	p10	p90
Honey Creek	Q	-77.18	98.70	-68	88
Honey Creek	W7	-48.70	66.14	-40	55
Honey Creek	W10	-37.47	49.94	-28	39

	Sample Method			% Difference from W46	
Sample Site Name	Code	p10	p90	p10	p90
Honey Creek	M	-49.68	69.82	-41	59
Honey Creek	W14	-38.71	35.94	-30	25
Honey Creek	W22	-21.74	20.06	-13	9
Honey Creek	M2	-38.80	47.36	-30	37
Honey Creek	W46	-9.02	10.85	0	0
Honey Creek	M4	-23.29	15.22	-14	4
Honey Creek	M10	-12.82	7.34	-4	-4
Maumee River	Q	-68.50	83.64	-65	77
Maumee River	W7	-29.16	26.37	-26	20
Maumee River	W10	-14.73	26.17	-11	20
Maumee River	M	-27.13	26.67	-24	20
Maumee River	W14	-17.66	16.70	-14	10
Maumee River	W22	-9.18	8.72	-6	2
Maumee River	M2	-17.55	17.23	-14	11
Maumee River	W46	-3.42	6.30	0	0
Maumee River	M4	-7.33	6.56	-4	0
Maumee River	M10	-2.99	1.30	0	-5
Rock Creek	Q	-79.62	138.39	-68	125
Rock Creek	W7	-59.24	65.53	-48	52
Rock Creek	W10	-41.47	44.17	-30	31
Rock Creek	M	-58.29	84.30	-47	71
Rock Creek	W14	-42.95	32.08	-32	19
Rock Creek	W22	-28.33	28.20	-17	15
Rock Creek	M2	-44.46	47.89	-33	35
Rock Creek	W46	-11.35	13.34	0	0
Rock Creek	M4	-27.61	20.80	-16	7
Rock Creek	M10	-6.20	13.20	5	0
Sandusky River	Q	-73.39	104.09	-67	93
Sandusky River	W7	-44.29	54.28	-38	44
Sandusky River	W10	-26.11	34.14	-20	23
Sandusky River	M	-40.06	44.07	-34	33
Sandusky River	W14	-27.50	25.15	-21	14
Sandusky River	W22	-15.51	18.96	-9	8
Sandusky River	M2	-28.93	26.86	-23	16
Sandusky River	W46	-6.10	10.70	0	0
Sandusky River	M4	-15.34	15.12	-9	4
Sandusky River	M10	-6.99	6.45	-1	-4

At this point, this analysis is not proposed specifically as a metric for others implementing lower frequency sampling to use but as an outline of a potential approach.

Additional tools for interpolation of daily concentrations from temporal monitoring may include kriging, conditional simulation (stochastic sequential simulation), and time series interpolation techniques (Deutsch and Journel, 1998; Isaaks and Srivastava, 1989). As Crawford (2004) suggests, use of these tools requires an analysis of data stationarity (constant mean and variance) and development of correlation functions using semi-variagrams and correlograms. None of these approaches have been evaluated as an alternative to the stair step method of interpolation at this time.

e) Conclusions

The AEMP represents one of the most robust and targeted monitoring data sets for atrazine submitted to the Agency. However, no large-scale monitoring can provide continuous exposure data and the analysis above suggests that there is still uncertainty with even a robust data set such as the AEMP. The comparison of sampling frequency results suggests that sampling design is critical to incorporation of a chemograph (i.e. monitoring data profile) into the LOC evaluation. Monitoring programs that are less robust than AEMP will have greater uncertainty in capturing maximum peak and even some longer-term exposures. Analysis of grab versus auto sample results suggest that auto-samplers provide an excellent choice for replacing or augmenting a grab sample program but resources may limit this approach. The auto sample analysis conducted above suggests that some uncertainty is expected even with a robust data set like the AEMP but the analysis also suggests that this type of uncertainty can be quantified. In addition, Syngenta has evaluated an approach of augmenting monitoring data with PRZM estimates that also suggests that even data as robust as the AEMP can underestimate continuous exposure. Finally, the analysis of sampling frequency using the data from Crawford (2004) suggests that error bounds on a sampling design may be appropriate for less robust monitoring data. This could be a key element to allowing application of uncertainty criteria to monitoring results.

F. SAP Charge Questions on the Atrazine Monitoring Results

(1) The monitoring program used a tool (WARP) designed to assess the vulnerability of watersheds and stream segments to (1) identify watersheds within the corn/sorghum growing region that are likely to be most vulnerable to atrazine exposure and, (2) select sampling sites within the watersheds that are likely to be more susceptible to atrazine runoff.

  - Please comment on the use of WARP predictions for hydrologic units (HUC 10/11) to restrict the survey design to those HUCs in the upper 20^{th} percentile and then (1) to stratify by WARP predictions between 80^{th} – 95th percentiles and above 95^{th} percentile and (2) to select HUCs with probability proportional to higher atrazine use rates.
  - Comment on the use of survey design population estimation approach for estimating the number (and %) of HUCs that may have LOC exceedances.

(2) Once the vulnerable HUC 10/11 watersheds were selected for monitoring, specific monitoring sites were selected within each watershed using criteria that

were designed to maximize the potential for selecting the streams most vulnerable to atrazine exposure. However, with only a single point monitored per watershed, estimates of within-HUC variability for detections of atrazine could not be calculated. The resulting population estimates reflect variability across watersheds but not within the monitored watersheds. Please comment on this approach and identify and discuss any alternative approaches to extend the results of the monitoring sites.

(3) Three monitoring sites in NE experienced low- or no-flow conditions that precluded sampling. While Hampton et al. (2007a) suggest that these sites with intermittent or low flow are already stressed by other factors, Meyer et al. (2007) indicate that such aquatic communities are rich in diversity. The Agency has generated statistics for these three sites as a separate stratum, however the meaning of these separate population estimates is uncertain.

- Please comment on whether the Agency should consider the low flow sites and/or intermittent streams as a part of the population estimates or treat them separately.
- Please comment on whether the aquatic systems and exposure conditions of the existing microcosm and mesocosm studies adequately represent these low flow and/or intermittent stream communities. If not, how could EPA determine an LOC for low flow conditions?

(4) The monitoring study sampled for atrazine concentrations at 4-day intervals to characterize the atrazine chemograph in these low-order Midwestern streams. The CASM_Atrazine model used these chemographs with a stair-step interpolation between samples dates to relate atrazine exposures in the streams to microcosm/mesocosm studies in order to determine whether the exposures triggered LOC thresholds.

- What other approaches for interpolation should be considered? Given the concentration-duration endpoint, how frequently must sampling occur to appropriately capture the magnitude and durations of exposure associated with atrazine?
- Sensitivity analysis of CASM_Atrazine model inputs suggests that some uncertainty bound on model results is appropriate. The Agency used a 2x multiplication factor from the model sensitivity analysis to estimate uncertainty in model output. The sample frequency analysis indicates that there is uncertainty associated with monitoring data that may not be accounted for by the model uncertainty factor of 2x. Given the importance of sample frequency and interpolation, please comment on whether consideration should be given to placing additional uncertainty bounds on monitoring data to account for uncertainty in the ability of the sampling strategy to capture the magnitude and duration of atrazine exposures. Please provide any suggestions for how to proceed with this approach.

IV. Approaches To Address The Question "Where Are The Waters That Are Exceeding Effects-Based Atrazine Thresholds?"

A. From Watersheds To Waterbodies

The monitoring study design was based on a watershed vulnerability assessment. As noted earlier, it addresses the question regarding how many vulnerable watersheds in corn and sorghum growing regions in the United States exceed the LOC for atrazine in at least one of its subwatersheds. However, ultimately, the value in the results of the study is in identifying water bodies (stream miles) where atrazine concentrations exceed the LOC. While the initial results of the study indicate that, for example, 9% (0 to 19%, based on a 95th percent confidence bound) of the HUC-10 watersheds in this vulnerable tier had streams that triggered the LOC for primary producers in multiple years, that does not necessarily imply that all of the flowing waters in those watersheds exceed the LOC. The results imply that conditions exist within those HUC-10 watersheds that trigger an LOC in at least some of the waters.

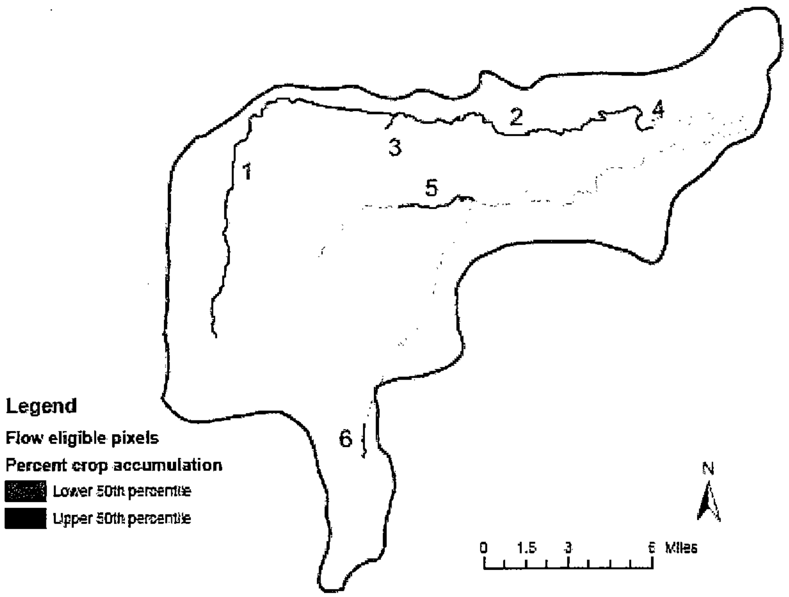
Since watershed-based approaches make sense for addressing nonpoint sources of impact, that is where the follow-up actions should be focused. Part of the follow-up action specified in the atrazine IRED addendum was to identify other areas in the larger HUC-10 watershed that might have similar conditions and concerns. This work is ongoing and includes more detailed watershed study, discussions with local soil and water quality experts, and additional monitoring.

The US EPA is exploring several options for addressing the question, "How many stream miles/kilometers exceed the established LOC?" These options are briefly summarized here and will be explored in more detail in a future SAP. For now, the Agency is seeking feedback and recommendations from the SAP on these or other viable options.

A first approach to identifying stream segments within the HUC-10 watersheds that exceed the LOC for atrazine would be to map out the stream segments that met the initial selection criteria for monitoring site locations (described in Section III.B.1.c) and assume that, as a first cut, this represents the extent of stream segments that similarly exceed the LOC.

Figure IV-1 (taken from Harbourt et al, 2004) shows the extent of stream segments that met the sample selection criteria with a breakdown of stream segment miles that met the criteria.

Figure IV-1 Extent of stream segments in the MO-02 HUC that met the sample selection criteria (from Harbourt et al, 2004).



Name	Segment	Upstream Drainage Area (mi^2)	Downstream Drainage Area (mi^2)	Downstream Percent crop accumulation	Length (mi)
Youngs Creek	1	9.9	48.6	44.2	15.1
Youngs Creek	2	60.8	87.4	44.0	12.9
Youngs Creek	3	10.7	12.2	47.7	0.7
Youngs Creek	4	87.7	87.7	44.0	0.03
Youngs Creek	5	25.7	30.2	46.5	3.2
Youngs Creek	6	9.1	10.3	44.9	1.3

This approach has several limitations:

- The stream segments were generated using digital elevation models (Harbourt et al, 2004) and, thus, may not exactly correspond to actual streams in the watershed. In addition, such an approach will be dependent not only on the source of the data, but also on the scale.
- This approach assumes that the specific criteria used for site selection are valid predictors of atrazine loading in streams within a larger HUC-10 watershed.
- Limiting the focus to stream segments that meet the criteria fails to address the extent to which atrazine loads that exceed the LOC continue downstream at concentrations sufficient to exceed the LOC. It also assumes that concentrations upstream of the identified segments are less than those that would trigger the LOC.
- Localized subwatershed characteristics are assumed to be captured by the watershed-scale WARP vulnerability assessment approach.

The limitation regarding the synthetic nature of the stream segments and data source/scale issues can be addressed by using a consistent hydrography database.

Since the initiation of this atrazine monitoring study, an improved version of the National Hydrography Dataset (NHD), called NHDPlus, has been released (HSC, 2006). NHDPlus includes an increased set of value-added attributes and tools that allow for better catchment characterization, stream network and flow evaluations, and user-added capabilities (HSC, 2006). The US EPA plans to take advantage of the catchment characteristics, flow network capabilities, and tool development options to

- Link the USGS WARP model to the NHDPlus stream segments and map WARP values to stream segments (thus the vulnerability approach could be applied ot the NHDPlus stream segments)
- Accumulate and map stream catchment characteristics, such as land use, to the stream segments
- Evaluate subwatershed characteristics that may have an impact on atrazine loading and identify stream segments with characteristics similar to those monitored in the atrazine study (this is addressed in more detail in the following section).

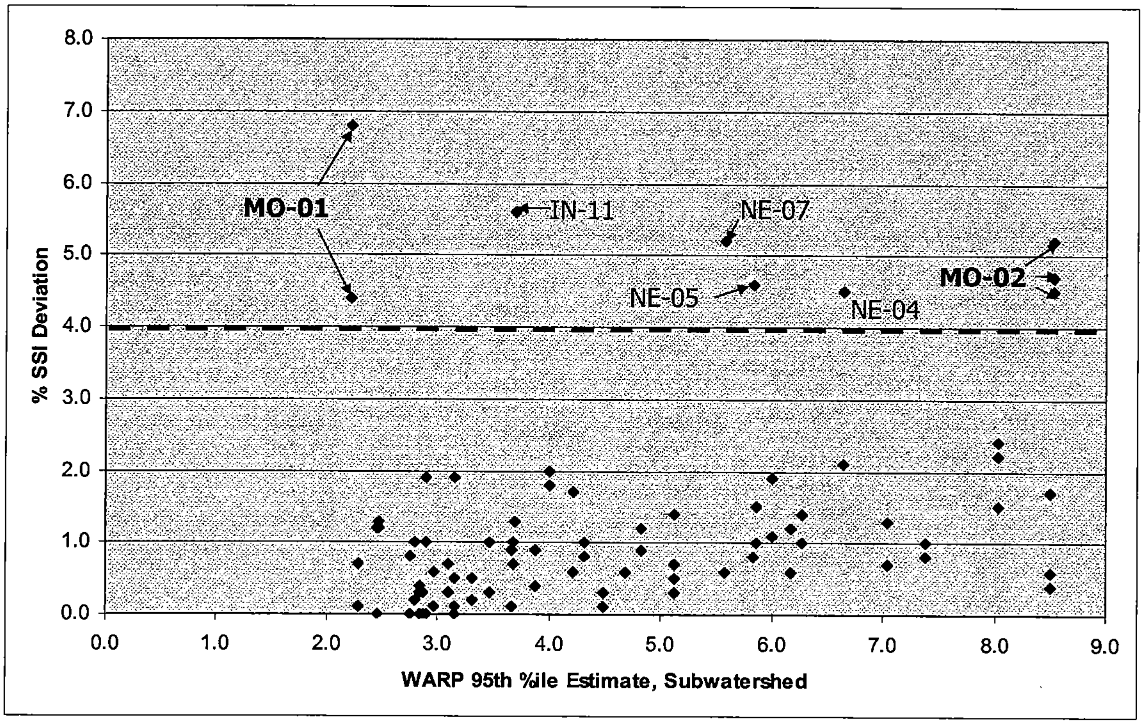
B. From The 40 Sampled Watersheds To The Larger Population Of Vulnerable Watersheds

A challenge in addressing the third objective of the monitoring study – identifying areas where higher atrazine exposures are likely to occur – is to determine whether the watersheds that exceeded the LOC in multiple years are randomly distributed within the 1,172 vulnerable watersheds or represent a unique subset of conditions that may be applied to other areas. This section presents two approaches the Agency is taking to address this question.

1. Evaluation of WARP Parameters

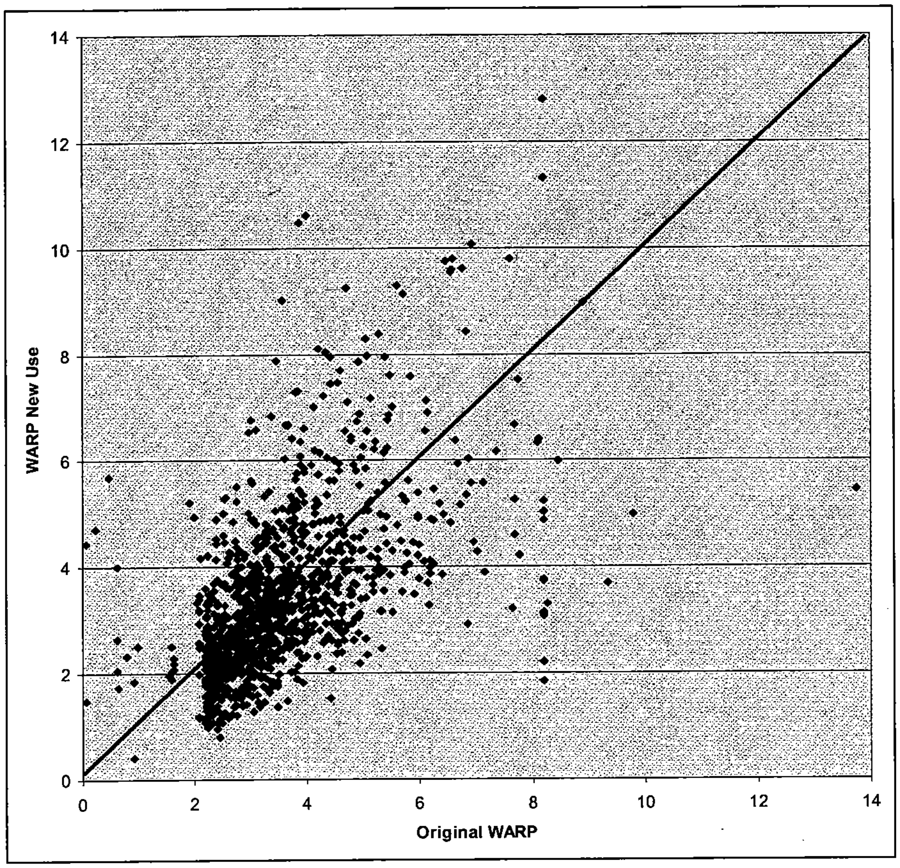
A plot of the WARP values estimated for the most vulnerable 1,172 HUC-10 watersheds against the percent changes in the Steinhaus Similarity Index (Figure IV-2) shows that the estimated 95th percentile atrazine concentration from WARP does not distinguish between the 10 site years that exceeded the LOC and the remaining 76 site years that fell below the 4% SSI deviation. In fact, the only two sites (MO-01 and MO-02) that exceeded the LOC in multiple years of monitoring represented the high and low end of WARP values. As noted in Section III.D.2, no apparent trend was seen between WARP values and %SSI for the 40 monitored watersheds. However, the relationship may not be evident because only the upper end of the plot (the watersheds represent the upper 80th percentile of watersheds) is available.

Figure IV-2 Comparison of WARP values to %SSI deviation for the 1,172 vulnerable watersheds (sites exceeding the 4% LOC trigger are labeled)



The WARP estimates used for the watershed vulnerability assessment represent an average of atrazine use over the years 1998 through 2002 while the monitoring data represent more recent atrazine usage (for the years 2004 through 2006). A plot of WARP based on 1998-2002 usage data and WARP estimates based on more recent usage data (2001-2003) shows a fair bit of scatter around the 1-to-1 line (Figure IV-3).

Figure IV-3 Comparison of original WARP values based on 1998-2002 use data with new WARP values based on 2001-2003 use data



The variations in WARP estimates based on changes in usage data could be expected because atrazine use is the major explanatory factor in the regression models, accounting for 53 to 64 percent of the variability in the monitoring data used for WARP development (Crawford, 2004). The results illustrate the importance of atrazine use as a factor affecting the vulnerability of water bodies to atrazine exposure. Changes in use patterns both locally and at a larger watershed scale, could be expected to result the variations in the WARP vulnerability estimates seen here.

The Agency plans to explore the use of the WARP model with atrazine use zeroed out to evaluate the intrinsic watershed vulnerability independent of use. In addititi0n, coupling the WARP parameters with updated atrazine use intensities using the NHDPlus might provide a useful means of identifying potential vulnerable areas based on both current use and on projections of changing use (for instance, increasing acreage planted in corn because of demands for ethanol). This tool, coupled with the results of the monitoring study, could serve as a useful tool to identify areas to target future monitoring efforts for atrazine.

2. Evaluation Of Other Soil- And Hydrology-Related Parameters

Results of the monitoring program suggest that the chemographs that triggered the LOC had relatively high concentrations with a prolonged period of elevated exposures (see

MO-01 and MO-01 in Appendix 2). In their preliminary evaluation of these two Missouri sites that triggered the LOC in multiple years, Syngenta noted that the prolonged periods of elevated exposure might be attributable to the presence of 'claypan' soils in the region. This was supported by additional research conducted by the USDA in the Central Claypan Major Land Resource Area (MLRA), where the watersheds are located (Blanchard and Lerch, 2000; Lerch and Blanchard, 2003).

The US EPA is exploring the potential for the presence of a shallow restrictive layer, such as but not limited to the claypan soils in the Central Claypan MLRA, to be a driving factor that results in high atrazine loads to water bodies for prolonged periods of time. The impact of such drainage-restrictive layers is two-fold:

- A shallow depth to a drainage-restrictive layer reduces the water storage capacity of the soil. During rainfall events, the soil overlying the restrictive layer becomes saturated quickly, increasing the frequency and volume of runoff events in comparison to deeper soils with no restrictive layer in otherwise similar conditions. If the rainfall occurs after atrazine has been applied to the field, the runoff could include sufficient quantities of atrazine in the runoff to result in high concentrations.
- Subsurface drainage laterally over the restrictive layer would result in a delayed baseflow, contributing additional loadings of atrazine over time, prolonging the exposure period in the receiving water bodies

Syngenta proposes that the MO-01 and MO-02 are unique because of their location in the Central Claypan MLRA and, as such, should be treated as a separate stratum. The US EPA believes that MO-01 and MO-02 potentially represent conditions where a shallow restrictive layer may result in atrazine exposures that exceed the LOC. To test this, the Agency plans to compare the extent, type, and depth of drainage-restrictive layers in these 2 watersheds with the other 38 monitored watersheds to determine whether distinctions are present. Where distinctions between the watersheds are found, the US EPA plans to identify other areas where conditions similar to those found in MO-01 and MO-02 may exist.

The USDA NRCS defines a restrictive layer as a "nearly continuous layer that has one or more physical, chemical, or thermal properties that significantly reduce the movement of water and air through the soil or that otherwise provide an unfavorable root environment. Cemented layers, dense layers, frozen layers, abrupt or stratified layers, strongly contrasting textures, and dispersed layers are examples of soil layers that are restrictions." (USDA NRCS, 2007).

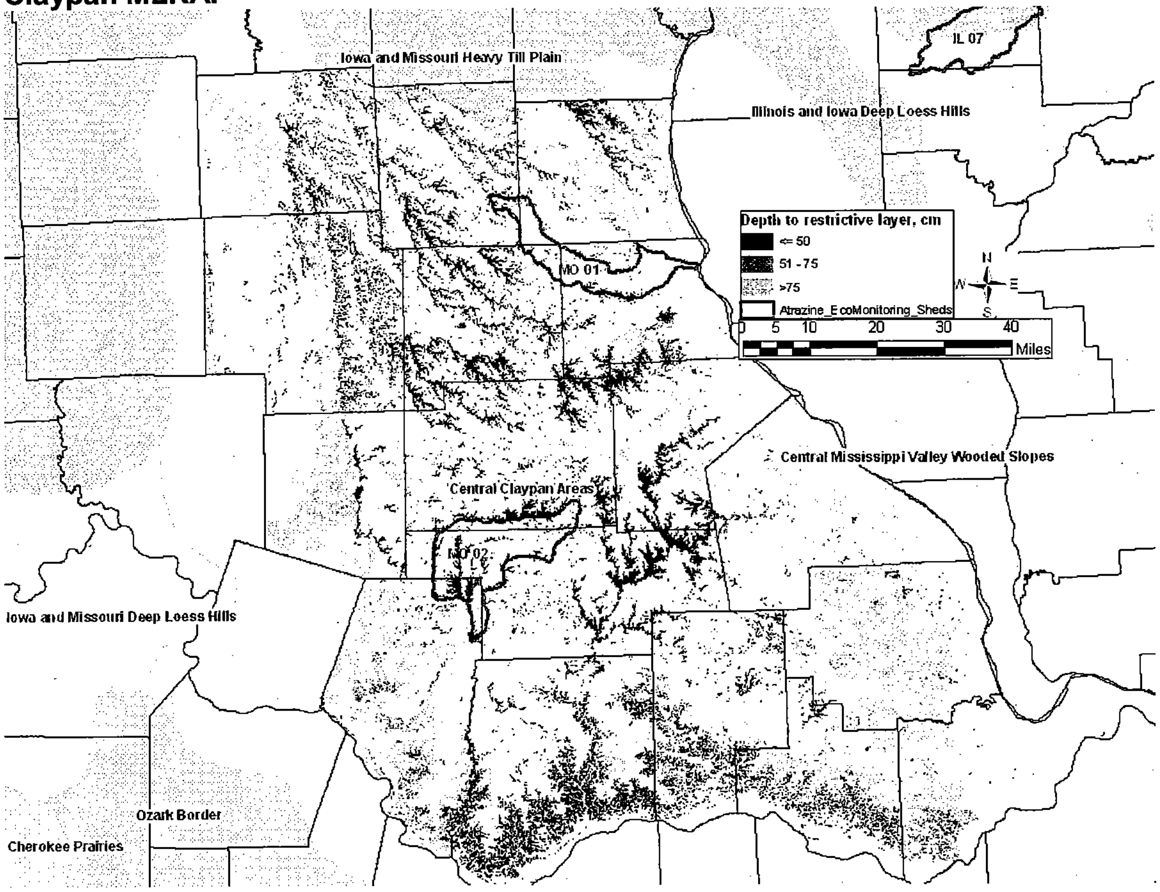
A number of specific restrictive layers are defined by the USDA NRCS. The Agency is evaluating county-level spatial soil survey data (SSURGO) to determine the extent, type, and depth of the following kinds of layers that can restrict water movement vertically through the soil profile:

- Abrupt textural change
- Strongly contrasting textural stratification

- Dense material
- Duripan/ Fragipan
- Cemented horizon
- Petroferric/ Petrocalcic/ Petrogypsic/ Placic
- Plinthite/ Ortstein
- Bedrock (lithic or paralithic)

A preliminary evaluation of SSURGO data in the Claypan MLRA indicate that soils with an abrupt textural change located at shallow depths (<50 cm below the surface) are more predominant in and around MO-01 and MO-02 than in the other monitoring sites (Figure IV-4). Other drainage restrictive layers, particularly dense material, bedrock, and fragipans, are found in some of the other monitoring sites, but are typically deeper than what occurs in and around MO-01 and MO-02. Figure IV-4 illustrates that the soil factors that may influence atrazine loadings to receiving water bodies are likely to be distinguishable at subwatershed scales. Additional distinctions, such as the extent of shallow restrictive layers under cropland, will also be considered.

Figure IV-4 Depth to restrictive soil layers in MO-01 and MO-02, located in the Central Claypan MLRA.



In addition to the depth to restrictive layer, the US EPA plans to use SSURGO data to evaluate the relative percentage of hydrologic soil groups (particularly D or C and D soils combined), soil drainage classes (somewhat poorly and poorly drained soils), low hydraulic conductivity soils, and soils with a high surface runoff potential. A preliminary evaluation of SSURGO data for the counties that intersect the monitoring sites shows that not only are the MO-01 and MO-02 watersheds dominated by soils in the hydrologic soil group D class (Figure IV-5), but that the three Nebraska sites that exceeded the LOC in one year as a result of low flow conditions also had higher percentages of hydrologic group D soils than did the other four Nebraska sites or other monitored sites (Figure IV-6).

Figure IV-5 Distribution of Hydrologic Group C and D Soils in MO-01 and MO-02, located in the Central Claypan MLRA.

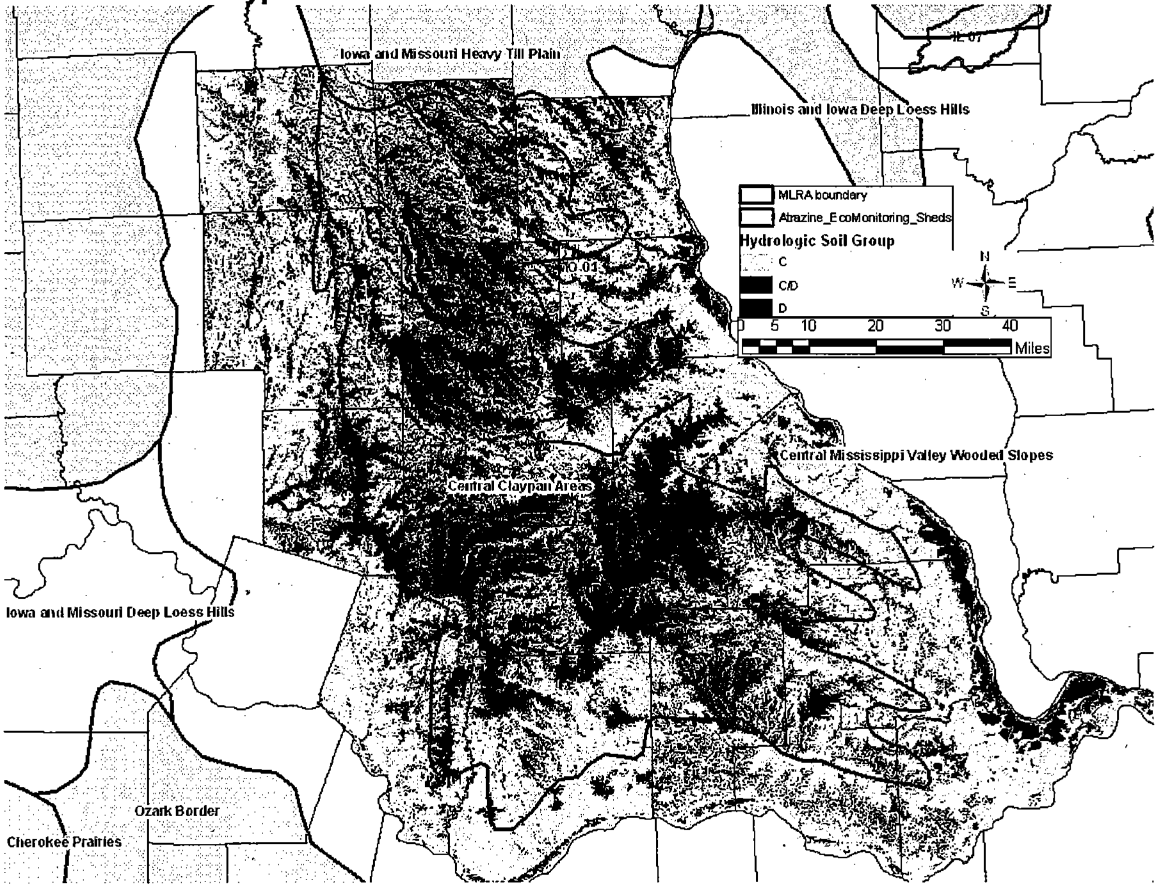
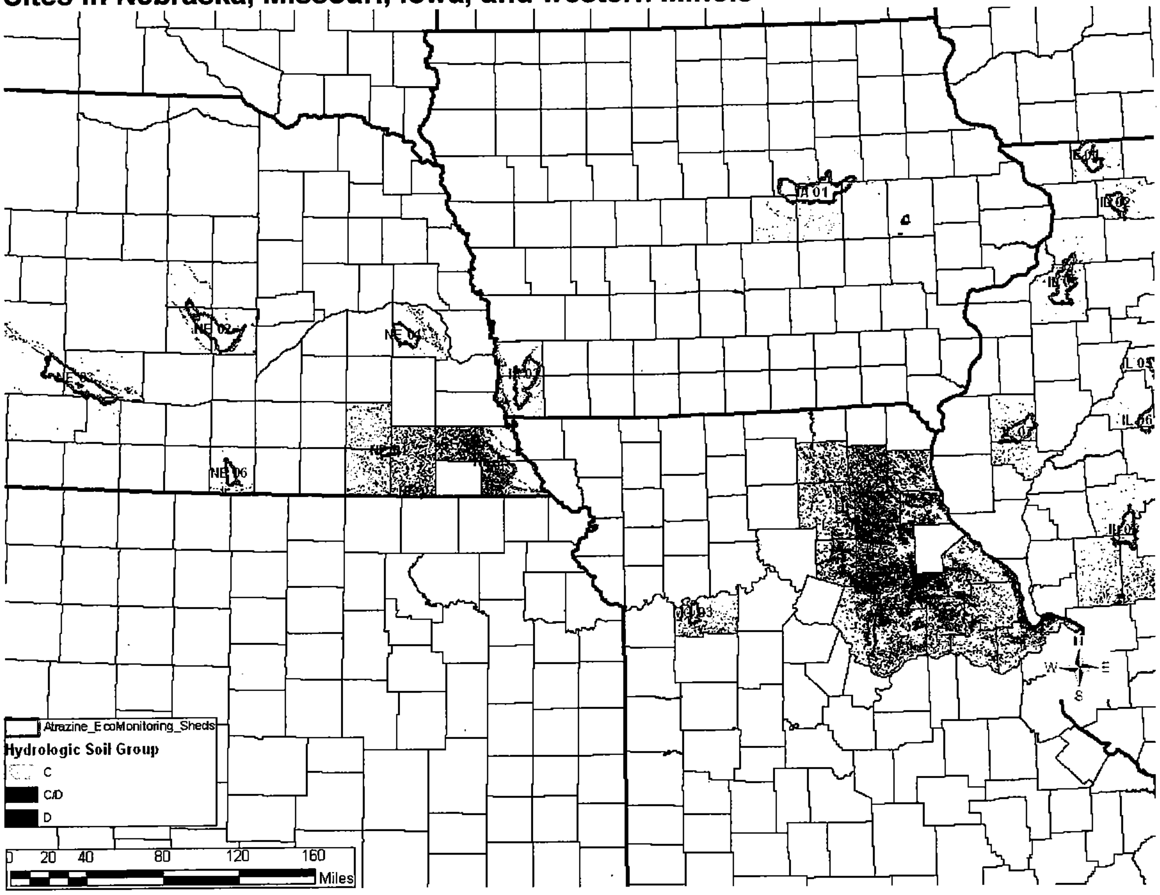


Figure IV-6 Distribution of Hydrologic Group C and D Soils in the Atrazine Monitoring Sites in Nebraska, Missouri, Iowa, and western Illinois



While the preliminary evaluations suggest that potential differences in soil and hydrology may exist between the two MO monitoring sites that exceeded the LOC in multiple years, as well as between the three NE monitoring sites that exceeded the LOC in one year as a result of low flow, more extensive comparisons will require a substantial amount of data processing and analysis. The US EPA plans a three step approach:

(1) Compare soil/hydrologic properties among the 40 monitored watersheds, both at the HUC-10 level and at the specific subwatershed level;
(2) Extend the soil/hydrologic analysis to the 1,172 watersheds the represented the most vulnerable tier of watersheds based on WARP
(3) Because the soil/hydrologic parameters being investigated were not explicitly part of the WARP parameters, further extend the evaluation to the larger extent of atrazine use, in particular, the 5,860 watersheds that intersected a county with atrazine use of greater than 0.25 lb ai/county acre

These approaches are data and resource intensive. While SSURGO data are now available for most of the counties in the US, they have to be processed and compiled from individual county coverages to state and regional coverages. Currently, the US EPA has only processed SSURGO for the counties that encompass each of the 40 watersheds included in the monitoring study. Before proceeding, the US EPA first intends to consult with this SAP on the feasibility of such an assessment and to solicit recommendations and suggestions on other parameters and/or approaches that might be useful in extending the results of the monitoring study beyond the 40 monitored watersheds in a manner that would be useful to the US EPA for identifying other water bodies exceeding the LOC.

C. SAP Charge Questions Relating to Identifying Where Atrazine Exceedances Are Likely to Occur

(1) While the monitoring study was based on a watershed vulnerability assessment, the ultimate value is in identifying water bodies where atrazine concentrations exceed the LOC. One approach is to use the updated version of the National Hydrography Database (NHDPlus) and apply the criteria used to select the monitoring locations to identify streams that appear to have the potential to exceed the LOC.

- Please comment on the strengths and weaknesses of the Agency's proposed approach for identifying streams within watersheds that exceeded the LOC.
- In what ways can the preliminary approach be improved?
- Please recommend alternative approaches, if any, that may be better suited to apply the watershed-based assessment to streams?

(2) In order to identify areas beyond the 40 study sites where higher atrazine exposures are likely to occur, the Agency must determine whether the watersheds that exceeded the LOC in multiple years are randomly distributed within the 1,172 vulnerable watersheds or represent a unique subset of conditions. If the latter and the conditions can be identified, monitoring could be focused only in watersheds where those conditions exist.The Agency has proposed evaluating WARP parameters and other sub-watershed soil and hydrologic properties to determine the extent to which the monitoring results can be used to identify other water bodies exceeding the LOC.

- To what extent can WARP be used to identify other watersheds of concern? Given the influence of atrazine use on vulnerability and exposure, please comment on whether the extrapolation should be limited to the original 1,172 watersheds or include a broader atrazine use area?
- Please comment on the soil and hydrology parameters the Agency is evaluating for extrapolation to vulnerable watersheds. What additional soil and hydrologic parameters should the Agency consider?
- What additional approaches to the identification of watersheds that may have atrazine levels that exceed the LOC should the Agency consider?

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VI. Appendix 1: Microcosm and Mesocosm Studies Used in CASM_Atrazine

Table VI-1 Micro- and mesocosm studies table with Brock scores and estimated average % change in community structure (Steinhaus similarity) of primary producers

No.	Duration (d)	Test Conc (µg/L)	Single / Constant / Multiple	Brock Effect Score	Reference(s)	Ecosystem	Results	Measurement Endpoint	Plant Group	Recovery	> or <	AVG % change in community structure (Steinhaus similarity) of primary producers
1	300	500	single	5	Carney 1983; Kettle et al. 1987; deNoyelles et al. 1989; deNoyelles et al. 1994	mesocoms, experimental ponds	*Decrease*	cover by emerged, floating and submerged aquatic plants	Macro	> 1 yr	>	48.4
2	300	20	single	5	Carney 1983; Kettle et al. 1987; deNoyelles et al. 1989; deNoyelles et al. 1994, deNoyelles & Kettle 1983, deNoyelles & Kettle 1980, Dewey 1986	mesocoms, experimental ponds	*Decrease*	cover by floating and submerged aquatic plants	Macro	> 1 yr		0.7
3	60	500	single	5	deNoyelles et al. 1982; Kettle 1982; deNoyelles et al. 1989	mesocoms, experimental ponds	*Decrease / Change*	^{14}C-uptake phytoplankton and biomass phytoplankton; all important phytoplankton species / species composition phytoplankton	Phyto	60 - > 63 d	>	40.6

No.	Dur-ation (d)	Test Conc (µg/L)	Single / Constant / Multiple	Brock Effect Score	Reference(s)	Ecosystem	Results	Measurement Endpoint	Plant Group	Recovery	> or <	AVG % change in community structure (Steinhaus similarity) of primary producers
4	300	100	single	5	deNoyelles et al. 1989 Carney 1983	mesocoms, experimental ponds	*Decrease*	cover by emerged and submerged aquatic plants	Macro	> 1 yr		18.0
5	300	200	single	5	deNoyelles et al. 1989 Carney 1983	mesocoms, experimental ponds	*Decrease*	cover by emerged and submerged aquatic plants	Macro	> 1 yr		48.4
6	56	50	single	5	Fairchild et al. 1994	mesocoms, experimental ponds (2)	*Change / No Effect*	*Chara* sp. replaces *Naja* sp. / total biomass aquatic plants	Macro	> 15 wks		8.9
7	60	80	multiple	5	Hamilton et al 1987	lake enclosure	*Decrease*	number. biomass, composition	Peri	49 d		14.9
8	60	140	multiple	5	Hamilton et al 1987	lake enclosure	*No Effect / Change*	numbers, biomass, Chl-a and C14 uptake / species composition	Peri	>56 d		15.4
9	73	143	multiple	5	Herman et al. 1986; Hamilton et al. 1988; Hamilton et al. 1989	lake enclosure	*Change*	species composition	Phyto	>294 d		40.6
10	73	143	multiple	5	Herman et al. 1986; Hamilton et al. 1988; Hamilton et al. 1989	lake enclosure	*Decrease / Change*	POC (slight), c14 uptake / species composition	Peri	90 d; 14 d; >294 d; >294 d		40.6

No.	Duration (d)	Test Conc (µg/L)	Single / Constant / Multiple	Brock Effect Score	Reference(s)	Ecosystem	Results	Measurement Endpoint	Plant Group	Recovery	> or <	AVG % change in community structure (Steinhaus similarity) of primary producers
11	63	182	constant	5	Jüttner et al. 1995	pond enclosures	*No Effect / Decrease*	rotifer / DO, conductivity (slight); algal species [Mallomonas sp (slight); Cryptomonas sp.]	Phyto	>63 d; 50 d; 35 d; 56 d		40.6
12	63	318	constant	5	Jüttner et al. 1995	pond enclosures	*Decrease*	DO (slight); conductivity (slight); rotifers (slight); algal species [Mallomonas sp (slight); Cryptomonas sp.]	Phyto	> 63 d; 50 d; 25 d; 35 d; >56 d;	>	40.6
13	60	500	single	5	Stay et al. 1985	microcosms, laboratory Taub	*Decrease*	DO, 14C-uptake, net primary production, respiration, 14C-uptake, Chl-a	Phyto	> 53 d	>	40.6
14	60	1000	single	5	Stay et al. 1985	microcosms, laboratory Taub	*Decrease*	DO, 14C-uptake, net primary production, respiration, 14C-uptake, Chl-a	Phyto	> 53 d	>	40.6
15	60	5000	single	5	Stay et al. 1985	microcosms, laboratory Taub	*Decrease*	DO, 14C-uptake, net primary production, respiration, 14C-uptake, Chl-a	Phyto	> 53 d	>	40.6

No.	Duration (d)	Test Conc (µg/L)	Single / Constant / Multiple	Brock Effect Score	Reference(s)	Ecosystem	Results	Measurement Endpoint	Plant Group	Recovery	> or <	AVG % change in community structure (Steinhaus similarity) of primary producers
16	21	10	single	4	Berard et al 1999 (1)	microcosm, lab stagnant	*Change*	Change in species composition & density	Phyto	?	<	0.4
17	7	100	single	4	Brockway et al. 1984	microcosms, lab stagnant	*Decrease*	Net O_2 production	Phyto	> 12 d		7.4
18	12	500	single	4	Brockway et al. 1984	microcosms, lab stagnant	*Decrease*	Net O_2 production	Phyto	> 12 d	>	16.4
19	12	5000	single	4	Brockway et al. 1984	microcosms, lab stagnant	*Decrease*	Net O_2 production	Phyto	> 12 d	>	16.4
20	28	15	constant	4	Carder and Hoagland 1998 (1)	artificial streams, continuous flow	*Decrease*	Algal community biovolume	Peri	> 28 d		0.4
21	28	150	constant	4	Carder and Hoagland 1998 (1)	artificial streams, continuous flow	*Decrease*	Algal community biovolume	Peri	> 28 d		25.5
22	27	15	constant	4	Detenback et al 1996	artificial flow-through swamp	*Decrease / Increase*	DO, metabolism of periphyton in bioassays / nutrients	Peri	?		0.4
23	27	25	constant	4	Detenback et al 1996	artificial flow-through swamp	*Decrease / Increase*	metabolism of periphyton in bioassays / nutrients	Peri	?		5.1
24	27	50	constant	4	Detenback et al 1996	artificial flow-through swamp	*Decrease / Increase*	metabolism of periphyton in bioassays / nutrients	Peri	?		6.0
25	27	75	constant	4	Detenback et al 1996	artificial flow-through swamp	*Decrease / Increase*	metabolism of periphyton in bioassays / nutrients	Peri	?		11.6

No.	Duration (d)	Test Conc (µg/L)	Single / Constant / Multiple	Brock Effect Score	Reference(s)	Ecosystem	Results	Measurement Endpoint	Plant Group	Recovery	> or <	AVG % change in community structure (Steinhaus similarity) of primary producers
26	14	100	constant	4	Hamala and Kollig 1985	microcosm, lab flowing	*Decrease / Change*	primary production, number of species, Chl-a and biomass of periphyton / species composition	Peri	pp 16-d; > 21 d		10.2
27	30	1000	single	4	Johnson 1986	microcosm, lab stagnant	*Decrease*	gross primary production; biomass;	Macro	>30 d	>	25.5
28	21	10	constant	4	Kosinski 1984; Kosinski and Merkle 1984	artificial streams, recirculating	*Decrease*	gross primary productivity; biovolume of periphyton on atrifical substrate	Peri	> 21 d	<	0.4
29	21	1000	constant	4	Kosinski 1984; Kosinski and Merkle 1984	artificial streams, recirculating	*Decrease*	gross primary productivity; biovolume of periphyton on atrifical substrate	Peri	> 21 d; 14 d	>	25.5
30	21	10000	constant	4	Kosinski 1984; Kosinski and Merkle 1984	artificial streams, recirculating	*Decrease*	gross primary productivity; biovolume of periphyton on atrifical substrate	Peri	> 21 d	>	25.5

No.	Duration (d)	Test Conc (µg/L)	Single / Constant / Multiple	Brock Effect Score	Reference(s)	Ecosystem	Results	Measurement Endpoint	Plant Group	Recovery	> or <	AVG % change in community structure (Steinhaus similarity) of primary producers
31	12	24	constant	4	Krieger et al. 1988	artificial streams, recirculating	*No effect / Decrease*	uptake of phosphorous, silicium and nitrogen by periphyton / Chl-a and biomass of periphyton	Peri	?		3.4
32	12	134	constant	4	Krieger et al. 1988	artificial streams, recirculating	*No effect / Decrease*	silicium uptake by periphyton / uptake of phosphorus and nitrate by periphyton (slight); Chl-a and biomass of pheriphyton	Peri	?		10.2
33	3	10000	single	4	Moorhead and Kosinski 1986	artificial streams, recirculating	*No Effect / Decrease*	conductivity, alkalinity, soluble reactive phosphorous, respiration, species compositionof periphyton (study probably too short) / pH, net primary production	Peri	7 d	>	6.8
34	21	337	constant	4	Pratt et al. 1988	microcosms, laboratory flowing	*Decrease*	DO, potassium, magnesium, calcium (slight), number of species, protien biomass and Chl-a protozoa	Peri	> 21 d		25.5

No.	Duration (d)	Test Conc (µg/L)	Single / Constant / Multiple	Brock Effect Score	Reference(s)	Ecosystem	Results	Measurement Endpoint	Plant Group	Recovery	> or <	AVG % change in community structure (Steinhaus similarity) of primary producers
35	42	200	single	4	Stay et al. 1989	microcosms, laboratory Leffler	*Decrease*	pH and primary production	Phyto	42 - >42 d		40.6
36	42	500	single	4	Stay et al. 1989	microcosms, laboratory Leffler	*Decrease*	pH and primary production	Phyto	> 42 d	>	40.6
37	42	1000	single	4	Stay et al. 1989	microcosms, laboratory Leffler	*Decrease*	pH and primary production	Phyto	> 42 d	>	40.6
38	42	5000	single	4	Stay et al. 1989	microcosms, laboratory Leffler	*Decrease*	pH and primary production	Phyto	> 42 d	>	40.6
39	70	50	constant	3	Brockway et al. 1984	microcosms, lab continuous flow	*Decrease / Increase*	Net O_2-production / Nitrate	Phyto	1 d		8.9
40	70	100	constant	3	Brockway et al. 1984	microcosms, lab continuous flow	*Decrease / Increase*	Net O_2-production / Nitrate	Phyto	1 d; 2 d		15.8
41	20	100	single	3	deNoyelles et al. 1989	mesocoms, experimental ponds	*Decrease*	^{14}C-uptake and biomass phytoplankton	Phyto	20 d		12.8
42	20	200	single	3	deNoyelles et al. 1989	mesocoms, experimental ponds	*Decrease*	^{14}C-uptake and biomass phytoplankton; biomass phytoplankton	Phyto	20 d		25.5
43	63	68	constant	3	Jüttner et al. 1995	pond enclosures	*No Effect / Decrease*	one algal species, rotifer / DO, conductivity (slight)	Phyto	?		14.9
44	21	100	constant	3	Kosinski 1984; Kosinski and Merkle 1984	artificial streams, recirculating	*No effect / Decrease*	biovolume of periphyton on artifical substrate; gross primary productivity	Peri	< 3 d		12.7

No.	Dur-ation (d)	Test Conc (µg/L)	Single / Constant / Multiple	Brock Effect Score	Reference(s)	Ecosystem	Results	Measurement Endpoint	Plant Group	Recovery	> or <	AVG % change in community structure (Steinhaus similarity) of primary producers
45	3	100	single	3	Moorhead and Kosinski 1986	artificial streams, recirculating	*No Effect / Decrease*	conductivity, alkalinity, soluble reactive phosphorous, respiration, species compositionof periphyton (study probably too short) / pH, net primary production	Peri	7 d		5.6
46	3	1000	single	3	Moorhead and Kosinski 1986	artificial streams, recirculating	*No Effect / Decrease*	conductivity, alkalinity, soluble reactive phosphorous, respiration, species compositionof periphyton (study probably too short) / pH, net primary production	Peri	7 d	>	6.8
47	60	60	single	3	Stay et al. 1985	microcosms, laboratory Taub	*Decrease*	DO, ^{14}C-uptake, net primary production, respiration / 14C-uptake, Chl-a	Phyto	20 - 27 d; 53 d		8.9

No.	Duration (d)	Test Conc (µg/L)	Single / Constant / Multiple	Brock Effect Score	Reference(s)	Ecosystem	Results	Measurement Endpoint	Plant Group	Recovery	> or <	AVG % change in community structure (Steinhaus similarity) of primary producers
48	60	100	single	3	Stay et al. 1985	microcosms, laboratory Taub	*Decrease*	DO, 14C-uptake, net primary production, respiration / 14C-uptake, Chl-a	Phyto	25 - 32 d; 53 d		15.8
49	60	200	single	3	Stay et al. 1985	microcosms, laboratory Taub	*Decrease*	DO, 14C-uptake, net primary production, respiration / 14C-uptake, Chl-a	Phyto	25 - 32 d; 53 d		40.6
50	42	100	single	3	Stay et al. 1989	microcosms, laboratory Leffler	*Decrease*	pH and primary production	Phyto	7 - >42 d		15.8
51	12	50	single	2	Brockway et al. 1984	microcosms, lab stagnant	*Decrease*	Net O_2-production (slight)	Phyto	> 12 d		4.2
52	7	20	single	2	deNoyelles et al. 1982; Kettle 1982; deNoyelles et al. 1989	mesocoms, experimental ponds	*Decrease / Change*	^{14}C-uptake and biomass phytoplankton / composition of phytoplankton species; increase in dinoflagellates	Phyto	7 d		0.1
53	30	10	single	2	Johnson 1986	microcosm, lab stagnant	*Decrease*	gross primary production (slight)	Macro	7 d		0.4
54	30	100	single	2	Johnson 1986	microcosm, lab stagnant	*Decrease*	gross primary production (slight)	Macro	7 d		12.8
55	63	22	constant	2	Jüttner et al. 1995	pond enclosures	*No Effect / Decrease*	one algal species / DO, pH, conductivity (slight)	Phyto	?		0.5
56	63	10	constant	2	Jüttner et al. 1995	pond enclosures	*No Effect / Decrease*	one algal species / DO, pH, conductivity (slight)	Phyto	?	<	0.5

No.	Duration (d)	Test Conc (µg/L)	Single / Constant / Multiple	Brock Effect Score	Reference(s)	Ecosystem	Results	Measurement Endpoint	Plant Group	Recovery	> or <	AVG % change in community structure (Steinhaus similarity) of primary producers
57	14	1.89		2	Lakshminarayana et al 1992	stream, adjacent to agri tile drainage	*Decrease*	number of species and cell numbers (during low flow)	phyto	150 d	<	0.1
58	18	1		2	Lampert et al 1989	lake enclosure	*Decrease*	primary production	phyto	14 d	<	0.1
59	21	32	constant	2	Pratt et al. 1988	microcosms, laboratory flowing	*No Effect / Decrease*	potassium, protein biomass, Chl-a of Protozoa / DO, magnesium, calcium (slight)	Peri	> 21 d		5.2
60	21	110	constant	2	Pratt et al. 1988	microcosms, laboratory flowing	*No Effect / Decrease*	potassium, calcium, number of species, protien biomass, Chl-a of Protozoa / DO, magnesium, (slight)	Peri	> 21 d		12.7
61	42	20	single	2	Stay et al. 1989	microcosms, laboratory Leffler	*Decrease*	primary production (slight)	Phyto	1-10 d		0.5
62	35	5	constant	2	van den Brink et al. 1995	microcosms, laboratory	*Decrease*	photosynthetic activity, as indicated by higher conductivity and alkalinity, and lower Do and pH	Phyto	NA	<	0.4
63	7	0.5	single	1	Brockway et al. 1984	microcosms, lab stagnant	*No effect*	Net O_2 production	Phyto	NA	<	0.1
64	7	5	single	1	Brockway et al. 1984	microcosms, lab stagnant	*No effect*	Net O_2 production	Phyto	NA	<	0.1
65	70	0.5	constant	1	Brockway et al. 1984	microcosms, lab continuous flow	*No effect*	Net O_2 production	Phyto	NA	<	0.1

No.	Dur-ation (d)	Test Conc (µg/L)	Single / Constant / Multiple	Brock Effect Score	Reference(s)	Ecosystem	Results	Measurement Endpoint	Plant Group	Recovery	> or <	AVG % change in community structure (Steinhaus similarity) of primary producers
66	70	5	constant	1	Brockway et al. 1984	microcosms, lab continuous flow	*No effect*	Net O_2-production / Nitrate	Phyto	NA	<	0.1
67	14	5 (3)	constant	1	Gruessner and Watzin 1996	microcosm, lab	*No effect*	Chl-a of periphyton on artificial substrate	Peri	NA	<	0.1
68	20	1	multiple	1	Gustavson and Wängberg 1995 (1)	lake enclosure (4)	*No effect*	community tolerance	Phyto	NA	<	0.1
69	20	20	multiple	1	Gustavson and Wängberg 1995 (1)	lake enclosure (4)	*No effect*	community tolerance	Phyto	NA		0.4
70	20	10	multiple	1	Gustavson and Wängberg 1995 (1)	lake enclosure (4)	*No effect*	community tolerance	Phyto	NA	<	0.4
71	28	2	2 short pulses 24-hours @	1	Jurgensen and Hoagland 1990	stream enclosures	*No Effect*	cell density, biomass	Peri	NA	<	0.1
72	28	30	2 short pulses 24-hours @	1	Jurgensen and Hoagland 1990	stream enclosures	*No Effect*	cell density, biomass	Peri	NA		5.2
73	28	100	2 short pulses 24-hours @	1	Jurgensen and Hoagland 1990	stream enclosures	*No Effect*	cell density, biomass	Peri	NA		12.8
74	63	5	constant	1	Jüttner et al. 1995	pond enclosures	*No Effect*	one algal species; DO, pH, conductivity	Phyto	NA	<	0.5

No.	Duration (d)	Test Conc (µg/L)	Single / Constant / Multiple	Brock Effect Score	Reference(s)	Ecosystem	Results	Measurement Endpoint	Plant Group	Recovery	> or <	AVG % change in community structure (Steinhaus similarity) of primary producers
75	30	25	?	1	Lynch et al. 1985	artificial streams, laboratory (5)	*No Effect*	standing biomass, rate of primary production, community respiration	Peri	NA		5.1
76	21	3.2	constant	1	Pratt et al. 1988	microcosms, laboratory flowing	*No effect*	DO, potassium, magnesium, calcium	Peri	NA	<	0.1
77	21	10	constant	1	Pratt et al. 1988	microcosms, laboratory flowing	*No effect*	DO, potassium, magnesium, calcium	Peri	NA	<	0.4

(1) Study not included in Brock et al (2000)
(2) Esfenvalerate added
(3) Concentration of atrazine reduced to 1ug/l by day-14
(4) Copper added
(5) Use of DMSO as solvent

VII.Appendix 2: Summary of Atrazine Monitoring Data

Table VII-1 Summary of Detection Frequencies by Monitoring Site and Year

Site	Year	Non Detects	Total Samples	Frequency of Detection	Not Analyzed	Not Sampled
IA-01	2004	3	37	91.9		
	2005	14	38	63.2		
IA-02	2004	4	34	88.2	1	
	2005	14	39	64.1		1
IL-01	2004	0	37	100.0		
	2005	22	38	42.1		
IL-02	2004	0	37	100.0		
	2005	8	38	78.9		
IL-03	2005	25	38	34.2		
	2006	27	38	28.9		
IL-04	2005	11	36	69.4		
	2006	8	38	78.9		
IL-05	2004	0	35	100.0		
	2005	15	36	58.3		
IL-06	2004	3	33	90.9		2
	2005	29	36	19.4		
IL-07	2004	3	34	91.2		
	2005	7	36	80.6		
IL-08	2005	0	35	100.0		
	2006	4	37	89.2		
IL-09	2004	0	34	100.0		
	2005	0	36	100.0		
IN-01	2004	4	37	89.2		
	2005	15	36	58.3		
IN-02	2004	0	37	100.0		
	2005	0	36	100.0		
IN-03	2005	0	36	100.0		
	2006	7	40	82.5		
IN-04	2004	0	37	100.0		
	2005	3	32	90.6		4
	2006	9	39	76.9		
IN-05	2004	0	37	100.0		
	2005	1	36	97.2		
	2006	7	40	82.5		
IN-06	2005	15	36	58.3		
	2006	11	40	72.5		
IN-07	2005	5	36	86.1		
	2006	15	40	62.5		
IN-08	2005	5	36	86.1		
	2006	6	40	85.0		
IN-09	2005	1	33	97.0		3

Site	Year	Non Detects	Total Samples	Frequency of Detection	Not Analyzed	Not Sampled
	2006	6	40	85.0		
IN-10	2005	2	36	94.4		
	2006	8	40	80.0		
IN-11	2005	0	30	100.0		6
	2006	6	40	85.0		
KY-01	2005	8	35	77.1		
	2006	14	36	61.1		
KY-02	2005	0	32	100.0		3
	2006	2	28	92.9	3	5
MN-01	2005	11	37	70.3		
	2006	30	37	18.9		3
MO-01	2004	0	34	100.0		
	2005	0	37	100.0		
	2006	5	33	84.8		2
MO-02	2004	0	34	100.0		
	2005	0	36	100.0		
	2006	1	35	97.1		
MO-03	2004	0	34	100.0		
	2005	0	33	100.0		2
	2006	2	21	90.5		14
NE-01	2004	3	36	91.7	2	
	2005	11	36	69.4	1	1
NE-02	2005	5	36	86.1		
	2006	15	40	62.5		
NE-03	2004	3	38	92.1		
	2005	13	37	64.9		
NE-04	2005	0	22	100.0		15
	2006	1	10	90.0		30
NE-05	2005	2	24	91.7		13
	2006	7	15	53.3		25
NE-06	2004	3	36	91.7		2
	2005	11	33	66.7		4
	2006	24	27	11.1		13
NE-07	2005	5	29	82.8		8
	2006	2	3	33.3		37
OH-01	2004	9	38	76.3		
	2005	11	35	68.6		
OH-02	2005	14	35	60.0		
	2006	8	40	80.0		
OH-03	2004	16	38	57.9		
	2005	22	35	37.1		
OH-04	2005	8	35	77.1		
	2006	20	40	50.0		
TN-01	2005	0	34	100.0		
	2006	13	35	62.9		

Table VII-2 Summary of Rolling Averages From Ecological Watershed Monitoring Data for Comparison with CASM Thresholds

Site	Year	Max. concentration (ug/l)						Annual average (ug/L)
		Peak	14-day	21-day	30-day	60-day	90-day	
IA-01	2004	10.0	3.7	2.6	2.1	1.2	0.9	0.3
	2005	1.2	0.5	0.4	0.3	0.3	0.3	0.2
IA-02	2004	1.8	1.1	1.0	0.8	0.6	0.5	0.2
	2005	5.5	2.1	1.5	1.4	0.8	0.6	0.2
IL-01	2004	13.2	6.6	5.0	4.1	2.5	1.9	0.6
	2005	0.6	0.3	0.3	0.3	0.3	0.3	0.2
IL-02	2004	4.9	2.9	2.6	2.3	1.5	1.1	0.4
	2005	2.9	1.8	1.4	1.1	0.6	0.5	0.2
IL-03	2005	5.6	1.8	1.3	1.0	0.6	0.4	0.2
	2006	2.5	0.9	0.7	0.5	0.3	0.2	0.1
IL-04	2005	2.8	1.4	1.0	0.8	0.5	0.4	0.2
	2006	11.5	3.4	2.4	1.8	1.8	1.4	0.4
IL-05	2004	22.1	7.2	5.0	3.6	2.0	1.4	0.4
	2005	1.8	0.7	0.5	0.4	0.3	0.2	0.1
IL-06	2004	2.2	1.1	0.9	0.7	0.5	0.4	0.2
	2005	0.2	0.2	0.2	0.2	0.2	0.2	0.1
IL-07	2004	21.8	7.0	5.3	4.2	2.4	1.7	0.5
	2005	2.3	0.9	0.7	0.6	0.5	0.4	0.2
IL-08	2005	5.6	4.4	3.6	2.8	1.8	1.4	0.6
	2006	33.1	11.0	7.6	8.1	4.4	3.0	0.9
IL-09	2004	13.2	8.1	6.8	6.3	4.6	3.4	1.1
	2005	16.0	6.2	4.6	3.4	2.3	1.8	0.7
IN-01	2004	8.6	4.0	3.2	3.5	2.4	1.6	0.6
	2005	4.4	1.4	1.0	1.0	0.7	0.5	0.3
IN-02	2004	9.3	6.3	5.0	4.5	2.8	2.1	0.7
	2005	20.3	6.3	4.7	4.3	3.0	2.1	0.7
IN-03	2005	7.6	4.3	3.4	3.3	2.3	1.8	0.6
	2006	16.9	10.6	8.0	6.2	3.9	2.9	0.9
IN-04	2004	78.1	23.8	16.3	12.0	6.4	4.4	1.2
	2005	8.8	3.6	2.6	2.1	1.4	1.0	0.4
	2006	10.2	5.6	4.5	3.7	2.2	1.6	0.5
IN-05	2004	28.9	14.9	15.5	11.9	7.0	4.9	1.4
	2005	17.3	7.8	5.8	4.5	4.1	3.5	1.1
	2006	41.3	17.9	14.1	13.1	7.4	5.4	1.5
IN-06	2005	7.2	2.9	2.4	1.8	1.0	0.7	0.2
	2006	9.4	4.0	3.4	2.7	1.9	1.4	0.5
IN-07	2005	22.6	9.6	7.2	6.4	3.9	2.7	0.8
	2006	10.5	5.4	4.1	3.6	2.0	1.4	0.4
IN-08	2005	21.1	6.9	5.5	4.9	2.8	2.0	0.6
	2006	20.7	8.9	7.6	7.7	4.4	3.1	0.9
IN-09	2005	9.4	3.7	2.8	2.4	1.7	1.3	0.4
	2006	8.3	3.0	2.1	1.8	1.2	0.9	0.3
IN-10	2005	12.4	6.1	4.6	4.0	2.8	2.2	0.6

Site	Year	Max. concentration (ug/l)						Annual average (ug/L)
		Peak	14-day	21-day	30-day	60-day	90-day	
	2006	16.4	7.5	6.1	6.3	3.6	2.6	0.8
IN-11	2005	208.8	65.1	44.4	31.5	16.2	11.3	3.3
	2006	9.8	5.9	4.4	3.3	1.9	1.4	0.5
KY-01	2005	2.2	1.5	1.3	1.2	0.9	0.7	0.2
	2006	22.4	6.9	4.8	3.6	1.9	1.3	0.4
KY-02	2005	19.3	8.7	8.7	7.1	4.5	3.6	1.3
	2006	14.3	4.7	4.2	3.9	2.3	1.7	0.6
MN-01	2005	5.8	2.6	1.9	1.4	0.8	0.6	0.2
	2006	0.2	0.2	0.1	0.1	0.1	0.1	0.1
MO-01	2004	65.9	39.6	29.6	28.6	19.4	13.8	3.9
	2005	182.8	78.1	54.2	42.5	25.7	17.8	4.8
	2006	82.8	48.2	41.1	31.6	17.5	12.0	3.2
MO-02	2004	53.8	33.0	29.7	25.9	16.8	12.3	4.1
	2005	28.1	18.7	17.0	14.6	11.5	9.1	3.6
	2006	43.2	34.7	31.6	27.4	15.4	11.5	3.3
MO-03	2004	59.0	23.3	17.2	13.1	8.1	6.1	2.2
	2005	12.3	8.7	7.5	6.9	5.5	4.4	1.8
	2006	3.9	2.3	2.0	1.9	1.5	1.3	0.9
NE-01	2004	19.2	13.0	9.8	7.5	4.3	3.0	0.8
	2005	16.7	6.6	5.2	5.6	3.6	2.5	0.7
NE-02	2005	20.7	11.4	11.8	10.7	6.3	4.3	1.1
	2006	82.0	28.6	19.5	14.1	7.3	5.0	1.3
NE-03	2004	2.3	1.1	1.2	1.0	0.6	0.5	0.2
	2005	11.9	3.7	2.5	2.1	1.2	0.8	0.3
NE-04	2005	36.0	36.0	34.8	27.3	17.4	11.9	3.1
	2006	4.1	4.1	4.0	3.1	1.7	1.2	0.4
NE-05	2005	49.9	23.8	23.3	19.9	16.5	11.4	2.9
	2006	6.8	6.8	6.8	6.8	5.1	3.5	0.9
NE-06	2004	7.7	2.8	2.8	2.1	1.7	1.6	0.4
	2005	33.1	20.6	13.9	11.4	6.0	4.1	1.1
	2006	0.1	0.1	0.1	0.1	0.1	0.1	0.1
NE-07	2005	112.2	80.0	61.9	45.2	22.7	16.6	4.5
	2006	***	***	***	***	***	***	***
OH-01	2004	18.3	8.8	7.7	5.7	3.2	2.2	0.6
	2005	3.0	1.0	0.7	0.9	0.6	0.5	0.2
OH-02	2005	18.1	7.1	5.1	4.0	2.9	2.1	0.6
	2006	14.0	5.9	5.8	5.2	2.9	2.1	0.6
OH-03	2004	21.5	9.1	8.1	7.3	4.5	3.0	0.8
	2005	8.2	3.0	2.1	1.6	0.9	0.6	0.2
OH-04	2005	20.2	8.0	5.7	4.7	2.7	1.9	0.5
	2006	6.3	2.6	2.3	1.7	1.0	0.7	0.2
TN-01	2005	7.6	5.6	4.8	4.0	2.9	2.2	0.8
	2006	10.7	3.6	3.1	2.4	2.0	1.6	0.6

Table VII-3 Sites Ranked from Lowest to Highest Based on Annual Average Flow

Site	Year	Annual Average Flow (m3/s)	Annual Average Flow (cfs)
NE 06	2005	0.0295	1.0418
MO 01	2006	0.06513	2.3001
MO 01	2004	0.0772	2.7263
NE 03	2004	0.0774	2.7334
MO 01	2005	0.08858	3.1282
NE 06	2004	0.1026	3.6233
NE 06	2006	0.1245	4.3967
NE 03	2005	0.1364	4.8170
KY 01	2005	0.1855	6.5509
NE 04	2006	0.1866	6.5898
IN 05	2005	0.2044	7.2184
IN 05	2004	0.2344	8.2778
NE 07	2006	0.2425	8.5639
IN 05	2006	0.2623	9.2631
NE 04	2005	0.2691	9.5033
IN 11	2005	0.3237	11.4315
TN 01	2006	0.3389	11.9683
IN 04	2006	0.3555	12.5545
IN 02	2005	0.4027	14.2214
KY 01	2006	0.405	14.3026
IN 04	2005	0.4182	14.7687
IL 01	2005	0.4262	15.0513
IN 10	2005	0.4313	15.2314
NE 07	2005	0.4352	15.3691
MN 01	2006	0.4661	16.4603
TN 01	2005	0.4876	17.2196
IN 03	2005	0.5519	19.4903
IL 06	2005	0.5803	20.4933
IA 02	2004	0.5893	20.8111
IL 07	2005	0.5896	20.8217
IA 02	2005	0.5971	21.0866
OH 03	2004	0.5985	21.1360
OH 03	2005	0.6065	21.4185
IL 04	2005	0.6073	21.4468
NE 05	2006	0.6329	22.3509
MO 03	2006	0.7017	24.7805
MO 02	2005	0.7322	25.8576
OH 01	2005	0.7636	26.9665
OH 02	2005	0.7761	27.4080
IL 09	2005	0.7808	27.5740

Site	Year	Annual Average Flow (m3/s)	Annual Average Flow (cfs)
IN 08	2005	0.7816	27.6022
MO 02	2004	0.8015	28.3050
MN 01	2005	0.8021	28.3262
IN 10	2006	0.8311	29.3503
MO 02	2006	0.8407	29.6893
IL 07	2004	0.8412	29.7070
IL 06	2004	0.8502	30.0248
IN 02	2004	0.8655	30.5651
IL 09	2004	0.9329	32.9454
OH 1	2004	0.9805	34.6264
NE 05	2005	0.9973	35.2196
OH 02	2006	1.0262	36.2403
IN 03	2006	1.0295	36.3568
IN 11	2006	1.0419	36.7947
IL 03	2006	1.0674	37.6952
NE 02	2006	1.0733	37.9036
IN 08	2006	1.1999	42.3745
NE 01	2004	1.2133	42.8477
IN 04	2004	1.2165	42.9607
IL 03	2005	1.3122	46.3403
KY 02	2005	1.3156	46.4604
IA 01	2004	1.4214	50.1967
IL 02	2005	1.5879	56.0767
IN 09	2005	1.5895	56.1332
NE 01	2005	1.6282	57.4999
KY 02	2006	1.8037	63.6977
IN 01	2004	1.8082	63.8566
MO 03	2005	1.9744	69.7259
IA 01	2005	1.9808	69.9520
IL 02	2004	2.0305	71.7071
IN 09	2006	2.2518	79.5223
IL 05	2005	2.3536	83.1174
NE 02	2005	2.402	84.8266
MO 03	2004	2.4098	85.1021
IL 04	2006	2.7688	97.7802
IL 01	2004	2.8955	102.2546
IL 05	2004	2.9136	102.8938
IL 08	2006	3.5539	125.5060
IN 06	2005	3.763	132.8903
IN 01	2005	4.1299	145.8474
IL 08	2005	4.1452	146.3877

Site	Year	Annual Average Flow (m3/s)	Annual Average Flow (cfs)
OH 04	2005	5.4524	192.5515
IN 07	2005	5.6568	199.7699
IN 07	2006	5.7476	202.9765
OH 04	2006	5.9098	208.7046
IN 06	2006	6.0462	213.5216

Table VII-4 Summary of Rolling Average Concentrations (ppb) and SSI% for PRZM Augmented Chemographs from Snyder, et al (2007)

		PRZM Augmented				
Site	Year	14-day rolling average	30-day rolling average	60-day rolling average	90-day rolling average	SSI%
IA 01	2004	10.35	7.83	5.07	3.46	1.5
IA 01	2005	4.71	2.6	2.06	1.46	0
IA 02	2004	7.74	5.08	3.51	2.51	0.4
IA 02	2005	4.21	3.29	2.68	1.86	0.4
IL 01	2004	7.93	5.85	3.91	2.81	0
IL 01	2005	3.12	2.56	1.42	1	0.4
IL 02	2004	13.53	8.08	5.28	3.69	1.7
IL 02	2005	2.37	1.2	0.74	0.81	0
IL 03	2005	8.72	4.83	2.81	2.17	1.1
IL 03	2006	3.48	1.96	1.12	1.07	0.4
IL 04	2005	2.84	2.1	1.11	0.85	0
IL 04	2006	6.97	5.8	4.53	3.41	0.7
IL 05	2004	11.94	9.12	5.46	3.95	2
IL05	2005	3.91	2.12	1.1	0.8	0
IL 06	2004	6.86	6.04	3.76	2.64	0.73
IL 06	2005	2.39	1.14	0.81	0.56	0.3
IL 07	2004	12.45	9.23	5.49	3.78	1.6
IL 07	2005	6.78	3.55	2.01	1.79	0.9
IL 08	2005	7.25	5.44	4.27	3.21	1.2
IL 08	2006	17.43	11.34	6.61	5.34	3.6
IL 09	2004	12.47	11.05	7.92	5.61	2.4
IL 09	2005	7.3	5.35	3.7	3.51	1.4
IN 01	2004	13.27	9.02	7.75	5.39	2.9
IN 01	2005	4.56	3.2	2.67	1.88	0.8
IN 02	2004	8.34	7.2	4.63	3.26	0.8
IN 02	2005	5.84	3.96	2.91	2.13	0
IN 03	2005	4.2	3.27	2.29	1.89	0
IN 03	2006	11.32	7.59	6.48	4.75	0.7
IN 04	2004	29.99	17.87	10.61	7.23	4.7
IN 04	2005	17.57	9.19	7.6	5.37	3
IN 04	2006	11.26	6.67	4.02	2.84	1
IN 05	2004	15.2	12.44	8.22	5.86	1.4
IN 05	2005	7.97	5.63	3.99	4.04	0.1
IN 05	2006	12.3	10.64	7.05	5.36	0.9
IN 06	2005	3.44	2.12	1.12	0.89	0
IN 06	2006	5.07	3.42	2.19	1.96	0
IN 07	2005	6.8	5.4	3.59	2.58	0.5
IN 07	2006	8.76	5.65	4.41	3.09	0.5
IN 08	2005	6.93	4.92	2.79	2.31	0
IN 08	2006	11.12	9.14	5.49	4.24	1.1

		PRZM Augmented				
Site	Year	14-day rolling average	30-day rolling average	60-day rolling average	90-day rolling average	SSI%
IN 09	2005	11.59	6.81	5.86	4.23	2.5
IN 09	2006	4.89	3.06	2.27	1.86	0
IN 10	2005	6.02	5.21	3.99	3.08	0
IN 10	2006	11.2	8.95	5.12	3.87	1.1
IN 11	2005	45.35	22.39	12.45	8.67	5.7
IN 11	2006	7.29	5.22	3.25	2.33	0
MO 01	2004	28.1	21.79	16.66	11.9	5.7
MO 01	2005	65.31	36.89	23.2	11.9	5.7
MO 01	2006	44.39	31	19.19	13.17	7.7
MO 02	2004	31.22	25.65	16.94	12.53	5
MO 02	2005	19.61	17.04	14.4	10.98	3.9
MO 02	2006	30.27	25.23	15.33	11.25	5.4
MO 03	2004	18.91	11.48	7.93	5.95	1.6
MO 03	2005	10.47	8.53	6.63	5.17	0
MO 03	2006	5.18	3.22	2.16	1.8	0
NE 01	2004	13.38	7.77	4.45	3.18	0
NE 01	2005	8.29	7.41	5.1	3.51	0.8
NE 02	2005	10.86	9.78	6.24	4.29	0.4
NE 02	2006	28.15	15.97	8.29	5.59	3.7
NE 03	2004	7.23	4.01	2.29	1.6	1
NE 03	2005	3.88	2.35	1.33	0.95	0
NE 06	2004	5.37	3.13	2.84	2.31	0.4
NE 06	2005	14.71	9.25	5.06	3.43	0.7
NE 06	2006	1.54	1.41	0.74	0.52	0.01
KY 01	2005	1.88	1.52	1.09	0.93	0
KY 01	2006	7.4	4.95	3.18	2.33	0.4
KY 02	2005	10.73	8.34	5.25	4.16	0.4
KY 02	2006	7.53	7.11	4.11	2.91	0
MN 01	2005	5.13	3.81	2.29	1.71	0.4
MN 01	2006	2.54	1.56	1.05	0.87	0.4
OH 01	2004	8.05	6.03	3.7	2.62	0
OH 01	2005	2.08	1.67	1.15	0.91	0
OH 02	2005	7.7	4.51	4.04	3.48	0.4
OH 02	2006	7.27	6.54	4.17	3	0
OH 03	2004	8.97	7.34	6.51	4.38	1.8
OH 03	2005	4.26	3.44	1.82	1.23	0.4
OH 04	2005	7.85	6.35	4.93	3.94	1.7
OH 04	2006	5.79	4.6	3.3	2.33	0.7
TN 01	2005	4.92	3.78	3.04	2.3	0
TN 01	2006	3.62	2.67	1.85	1.62	0

VIII. Appendix 3: Comparisons of precipitation during monitoring years to historical averages

The monthly precipitation measurements reported for the monitoring sites were compared to percentiles for the historical monthly totals for the site. The historical weather data, provided to EPA by Syngenta, were collected by the National Weather Service. The data, cited in Hampton et al (2007a), comes from these sources:

National Oceanic & Atmospheric Administration (NOAA). 2002a. Cooperative Summary of the Day TD3200. National Climatic Data Center, Asheville, NC. Eastern United States, Puerto Rico, and the Virgin Islands CD, version 1.0, released November 2002.

National Oceanic & Atmospheric Administration (NOAA). 2002b. Cooperative Summary of the Day TD3200. National Climatic Data Center, Asheville, N.C. Central United States CD, version 1.0, released November 2002.

National Oceanic & Atmospheric Administration (NOAA). 2005. National Data Centers, U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Environmental Satellite, Data and Information Service http://www.nndc.noaa.gov.

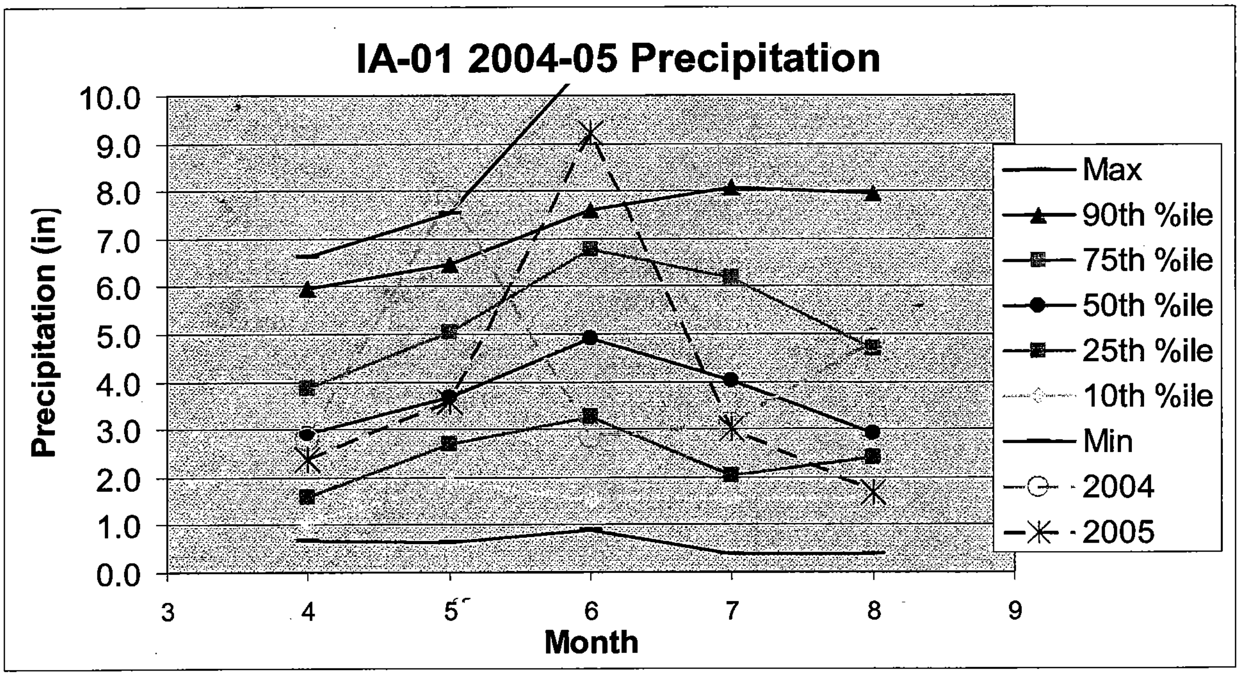
The crop planting dates in the illustrations come from USDA National Agricultural Statistics Service (NASS) for the state and/or crop reporting district (Hampton et al., 2007a).

1. IA-01, 2004-05

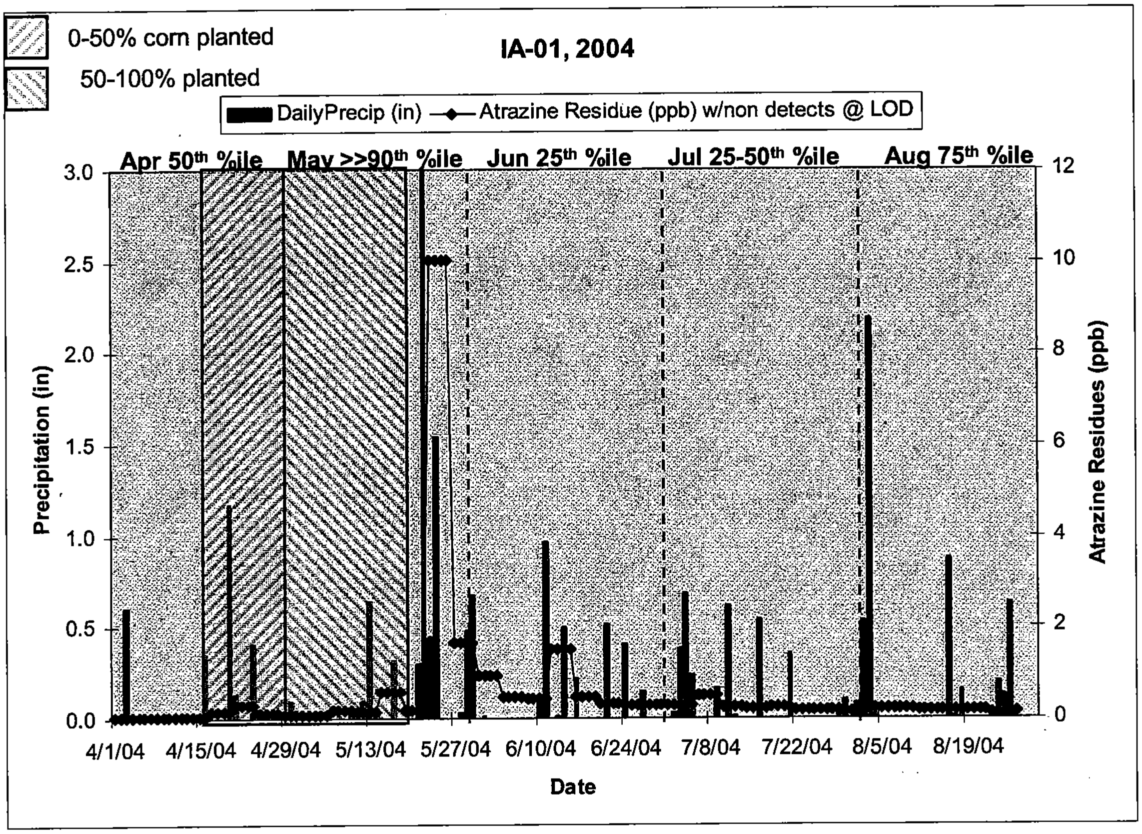
Watershed Location: Wolf Creek, IA
NWS Weather Station:

	April Total (in)	May Total (in)	June Total (in)	July Total (in)	August Total (in)	Apr-Aug Total (in)
Historical precipitation summaries, 1978-2001						
Max	6.60	7.52	10.77	12.25	13.72	37.78
90th %ile	5.94	6.45	7.59	8.08	7.93	28.36
75th %ile	3.85	5.03	6.77	6.17	4.70	23.11
50th %ile	2.90	3.66	4.89	4.03	2.91	20.69
25th %ile	1.59	2.69	3.26	2.02	2.42	16.40
10th %ile	1.04	1.91	1.51	1.54	1.59	13.49
Min	0.65	0.64	0.88	0.39	0.39	10.51
Monthly totals during the monitoring study						
2004	2.79	7.85	2.84	3.11	4.85	21.44
2005	2.38	3.58	9.22	3	1.68	19.86

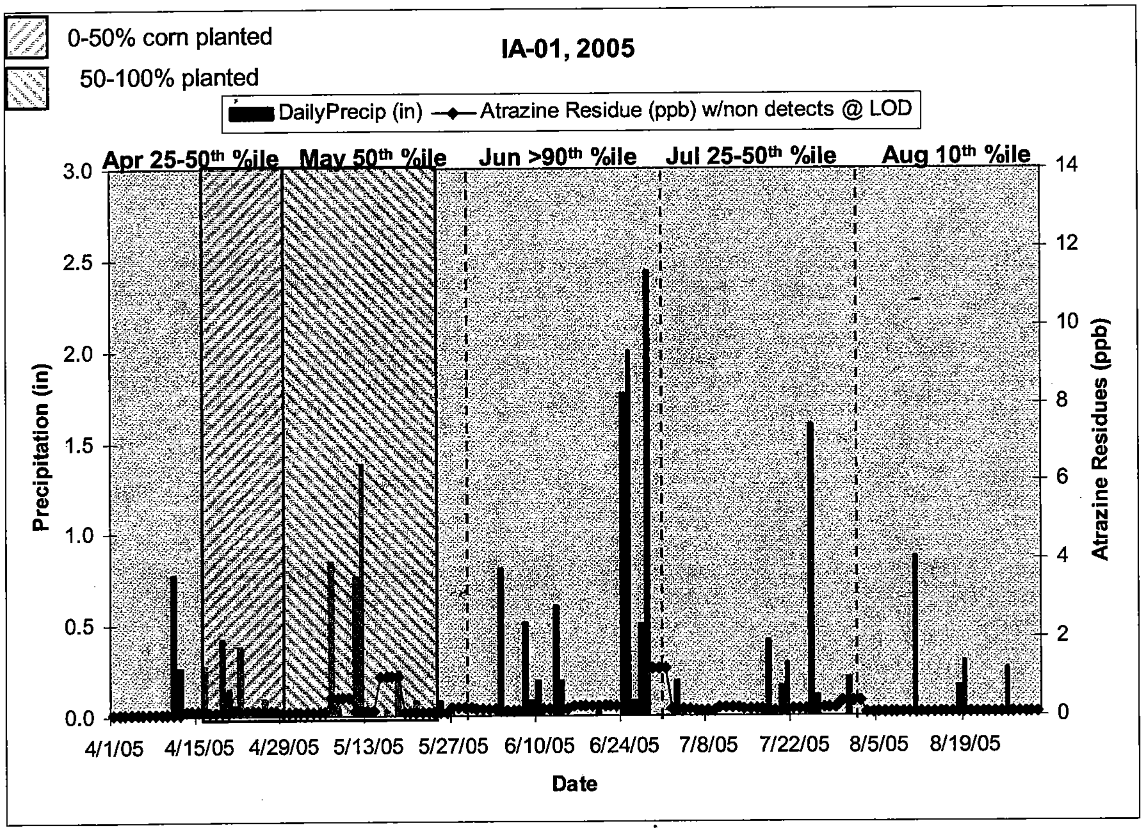
The monthly precipitation for May 2004 and June 2005 exceeded the historical 75th percentile for the monitoring site. Overall, the precipitation for the remaining months generally fell within the 25th to 75th percentile range.



The following figures show the daily precipitation and atrazine residues in water for 2004 and 2005. The planting season is shaded to provide a point of reference for the likely timing of applications in the watershed.



▨ 0-50% corn planted
▨ 50-100% planted
IA-01, 2004
DailyPrecip (in)
Atrazine Residue (ppb) w/non detects @ LOD
Apr 50th %ile
May >>90th %ile
Jun 25th %ile
Jul 25-50th %ile
Aug 75th %ile
Precipitation (in)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Atrazine Residues (ppb)
0
2
4
6
8
10
12
4/1/04
4/15/04
4/29/04
5/13/04
5/27/04
6/10/04
6/24/04
7/8/04
7/22/04
8/5/04
8/19/04
Date



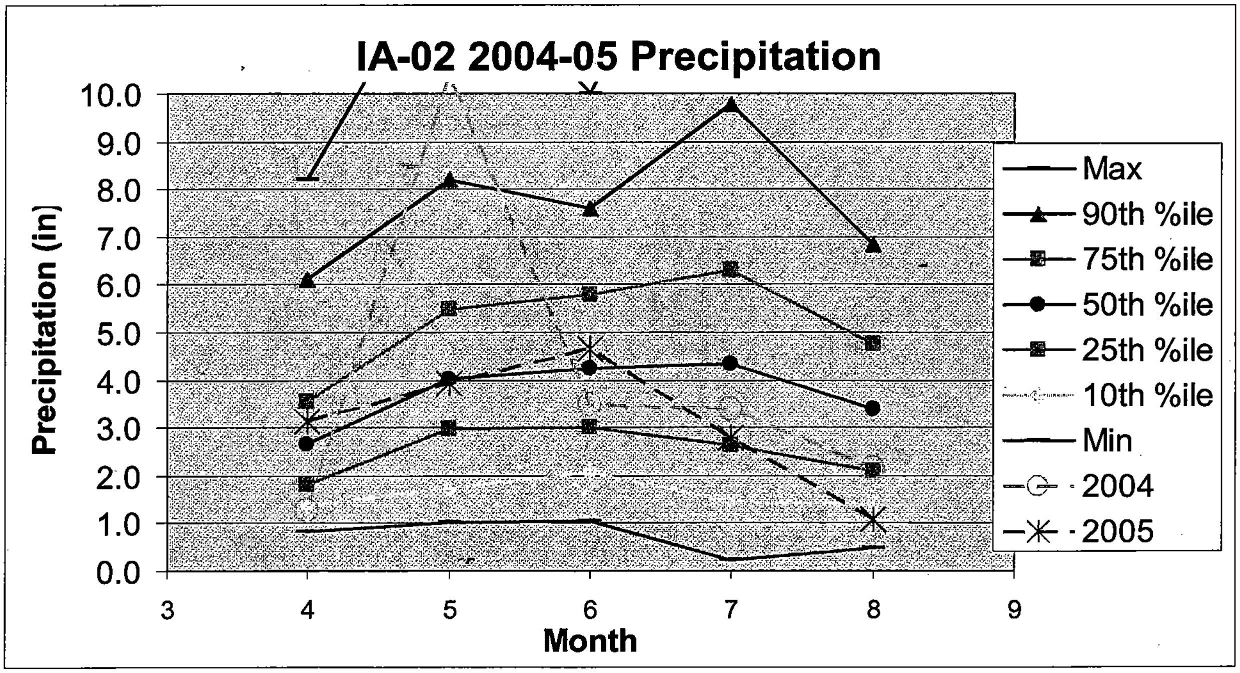
▨ 0-50% corn planted
▨ 50-100% planted
IA-01, 2005
DailyPrecip (in)
Atrazine Residue (ppb) w/non detects @ LOD
Apr 25-50th %ile
May 50th %ile
Jun >90th %ile
Jul 25-50th %ile
Aug 10th %ile
Precipitation (in)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Atrazine Residues (ppb)
0
2
4
6
8
10
12
14
4/1/05
4/15/05
4/29/05
5/13/05
5/27/05
6/10/05
6/24/05
7/8/05
7/22/05
8/5/05
8/19/05
Date

2. IA-02, 2004-05

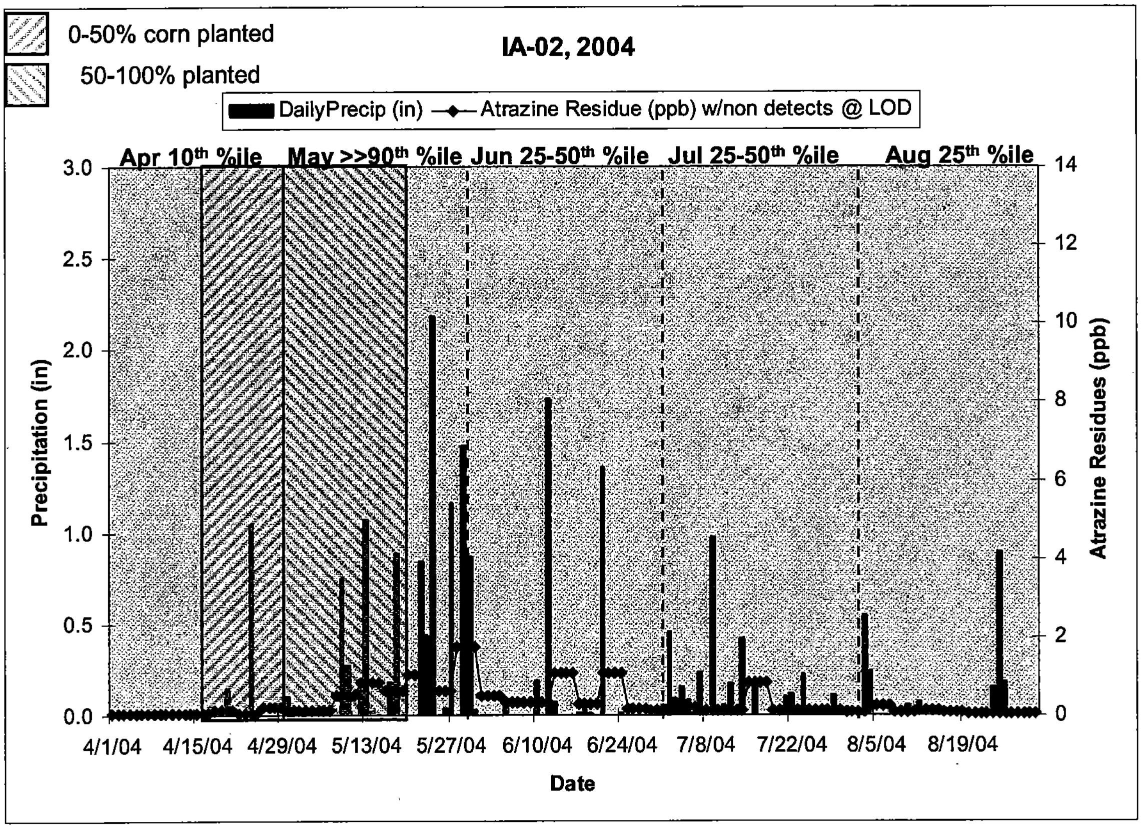
Watershed Location: Nishnabotna River, IA
NWS Weather Station:

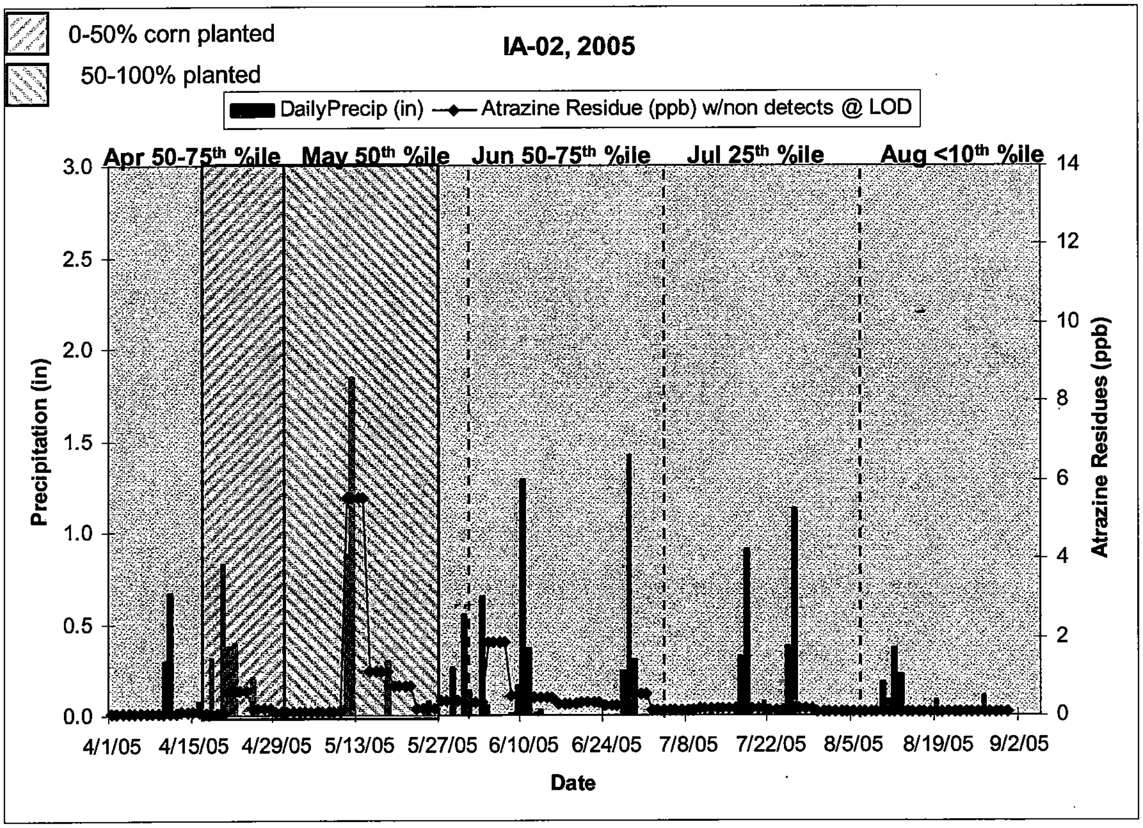
	April Total (in)	May Total (in)	June Total (in)	July Total (in)	August Total (in)	Apr-Aug Total (in)
Historical precipitation summaries, 1949-2001						
Max	8.19	13.29	9.99	16.18	16.63	38.71
90th %ile	6.12	8.20	7.58	9.78	6.85	30.38
75th %ile	3.53	5.46	5.79	6.29	4.74	23.84
50th %ile	2.65	4.02	4.25	4.33	3.39	20.14
25th %ile	1.81	2.98	3.00	2.63	2.08	16.57
10th %ile	1.35	1.74	2.07	1.45	1.38	14.62
Min	0.82	1.02	1.04	0.22	0.46	12.01
Monthly totals during the monitoring study						
2004	1.28	10.38	3.48	3.4	2.15	20.69
2005	3.14	3.93	4.64	2.79	1.09	15.59

The monthly precipitation in 2004 fluctuated from low (10th percentile) for April to high (>90th percentile) for May 2004; precipitation for the remaining months fell between the 25th to 50th percentile. Monthly precipitation totals in 2005 were roughly at the median for April through June, dropping at or below the 25th percentile in July and August.



The following figures show the daily precipitation and atrazine residues in water for 2004 and 2005. The planting season is shaded to provide a point of reference for the likely timing of applications in the watershed.


0-50% corn planted
50-100% planted
IA-02, 2004
DailyPrecip (in)
Atrazine Residue (ppb) w/non detects @ LOD
Apr 10th %ile
May >>90th %ile
Jun 25-50th %ile
Jul 25-50th %ile
Aug 25th %ile
Precipitation (in)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Atrazine Residues (ppb)
14
12
10
8
6
4
2
0
4/1/04
4/15/04
4/29/04
5/13/04
5/27/04
6/10/04
6/24/04
7/8/04
7/22/04
8/5/04
8/19/04
Date

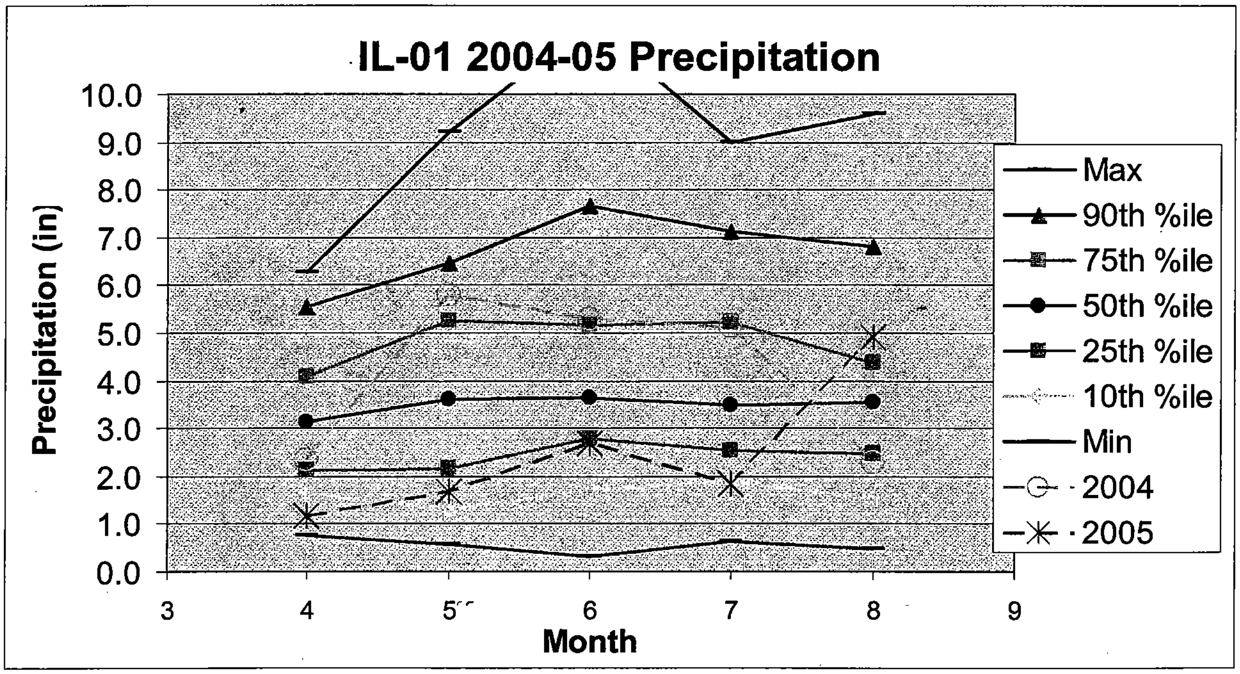

0-50% corn planted
50-100% planted
IA-02, 2005
DailyPrecip (in)
Atrazine Residue (ppb) w/non detects @ LOD
Apr 50-75th %ile
May 50th %ile
Jun 50-75th %ile
Jul 25th %ile
Aug <10th %ile
Precipitation (in)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Atrazine Residues (ppb)
14
12
10
8
6
4
2
0
4/1/05
4/15/05
4/29/05
5/13/05
5/27/05
6/10/05
6/24/05
7/8/05
7/22/05
8/5/05
8/19/05
9/2/05
Date

3. IL-01, 2004-05

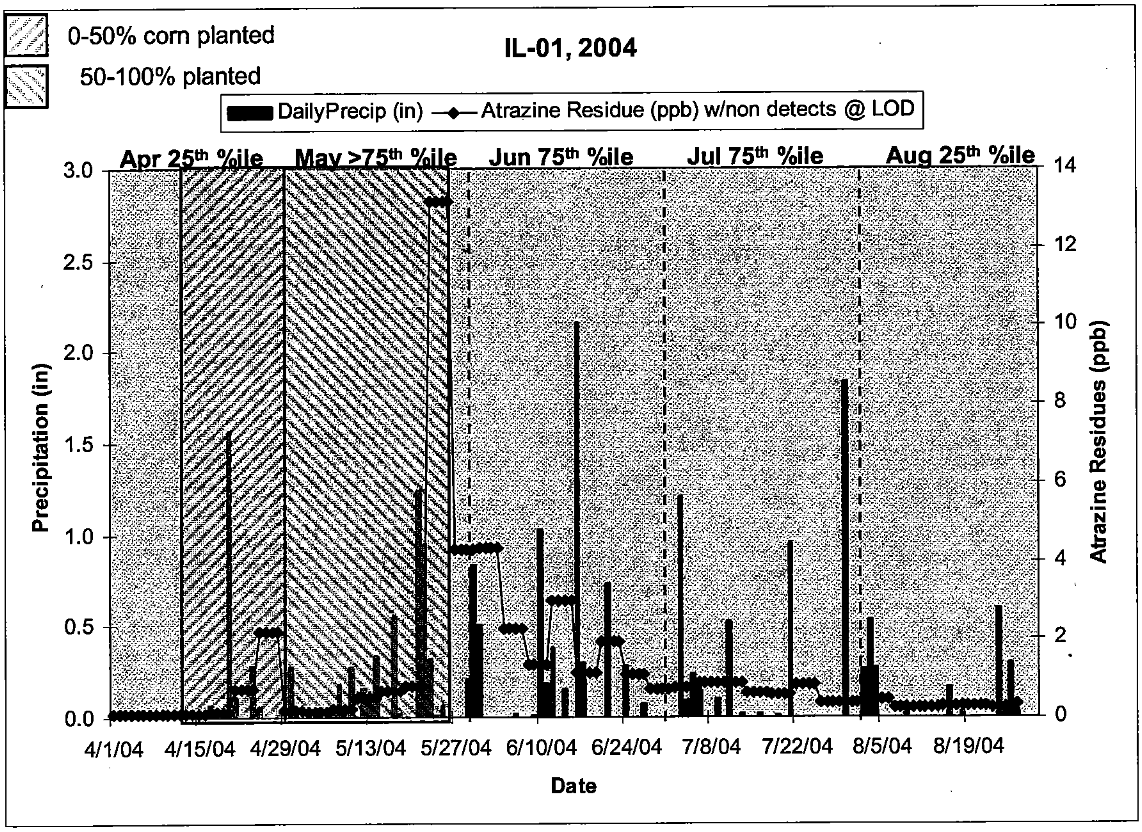
Watershed Location: Pecatonica River, IL
NWS Weather Station:

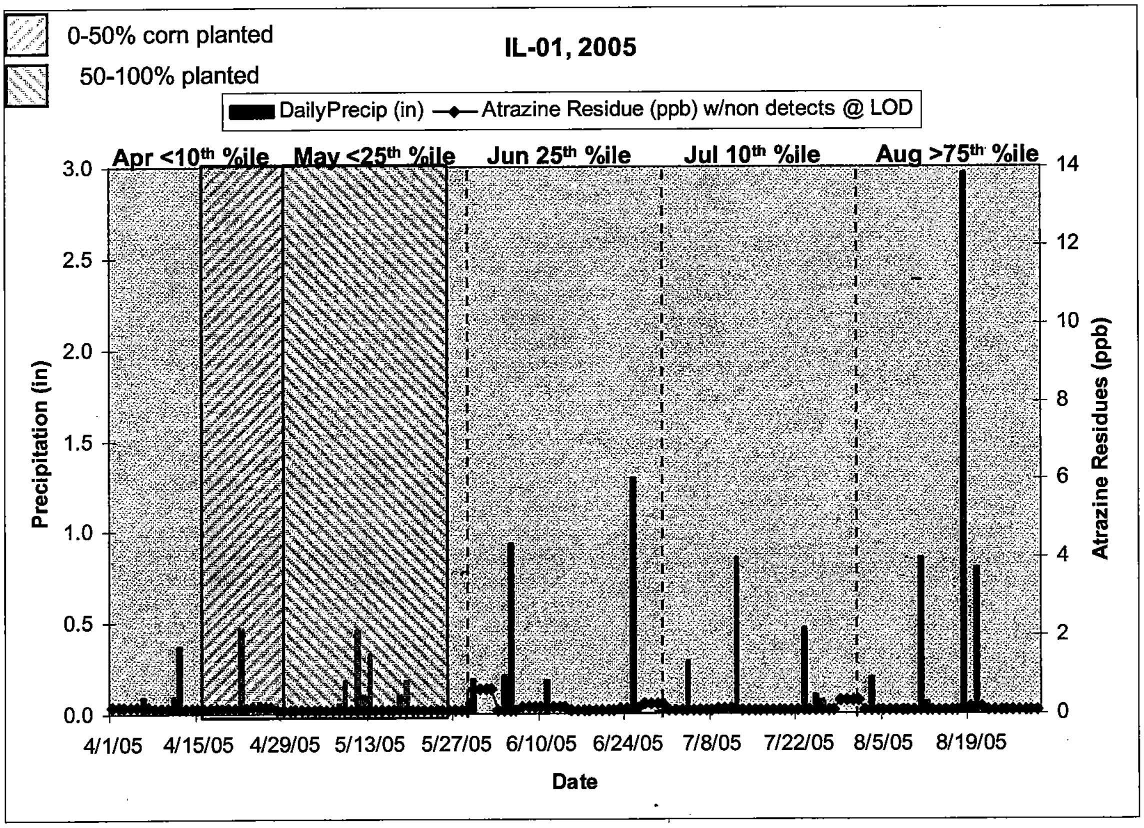
	April Total (in)	May Total (in)	June Total (in)	July Total (in)	August Total (in)	Apr-Aug Total (in)
Historical precipitation summaries, 1948-2001						
Max	6.26	9.22	11.48	8.98	9.59	29.60
90th %ile	5.52	6.46	7.66	7.14	6.82	24.90
75th %ile	4.09	5.24	5.15	5.21	4.37	21.96
50th %ile	3.14	3.61	3.64	3.50	3.54	19.06
25th %ile	2.11	2.16	2.78	2.54	2.48	16.42
10th %ile	1.64	1.28	1.71	1.88	1.51	12.43
Min	0.76	0.56	0.31	0.63	0.48	8.62
Monthly totals during the monitoring study						
2004	2.35	5.78	5.3	5.12	2.27	20.82
2005	1.18	1.67	2.7	1.83	4.92	12.3

Monthly precipitation in 2004 was low (around the 25th percentile) in April and August and high (ar or above the 75th percentile) in May through July. IN 2005, monthly precipitation was consistently below the 25th percentile for April through July.



The following figures show the daily precipitation and atrazine residues in water for 2004 and 2005. The planting season is shaded to provide a point of reference for the likely timing of applications in the watershed.


0-50% corn planted
50-100% planted
IL-01, 2004
DailyPrecip (in)
Atrazine Residue (ppb) w/non detects @ LOD
Apr 25th %ile
May >75th %ile
Jun 75th %ile
Jul 75th %ile
Aug 25th %ile
Precipitation (in)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Atrazine Residues (ppb)
14
12
10
8
6
4
2
0
4/1/04
4/15/04
4/29/04
5/13/04
5/27/04
6/10/04
6/24/04
7/8/04
7/22/04
8/5/04
8/19/04
Date

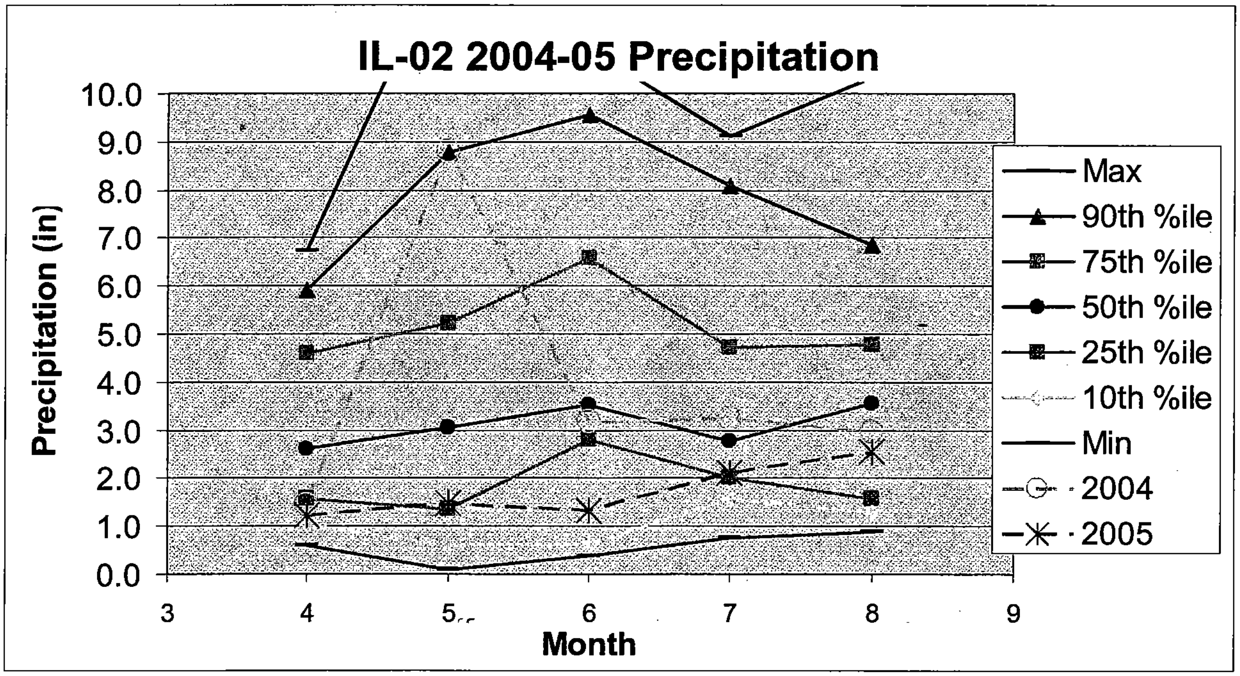

0-50% corn planted
50-100% planted
IL-01, 2005
DailyPrecip (in)
Atrazine Residue (ppb) w/non detects @ LOD
Apr <10th %ile
May <25th %ile
Jun 25th %ile
Jul 10th %ile
Aug >75th %ile
Precipitation (in)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Atrazine Residues (ppb)
14
12
10
8
6
4
2
0
4/1/05
4/15/05
4/29/05
5/13/05
5/27/05
6/10/05
6/24/05
7/8/05
7/22/05
8/5/05
8/19/05
Date

4. IL-02, 2004-05

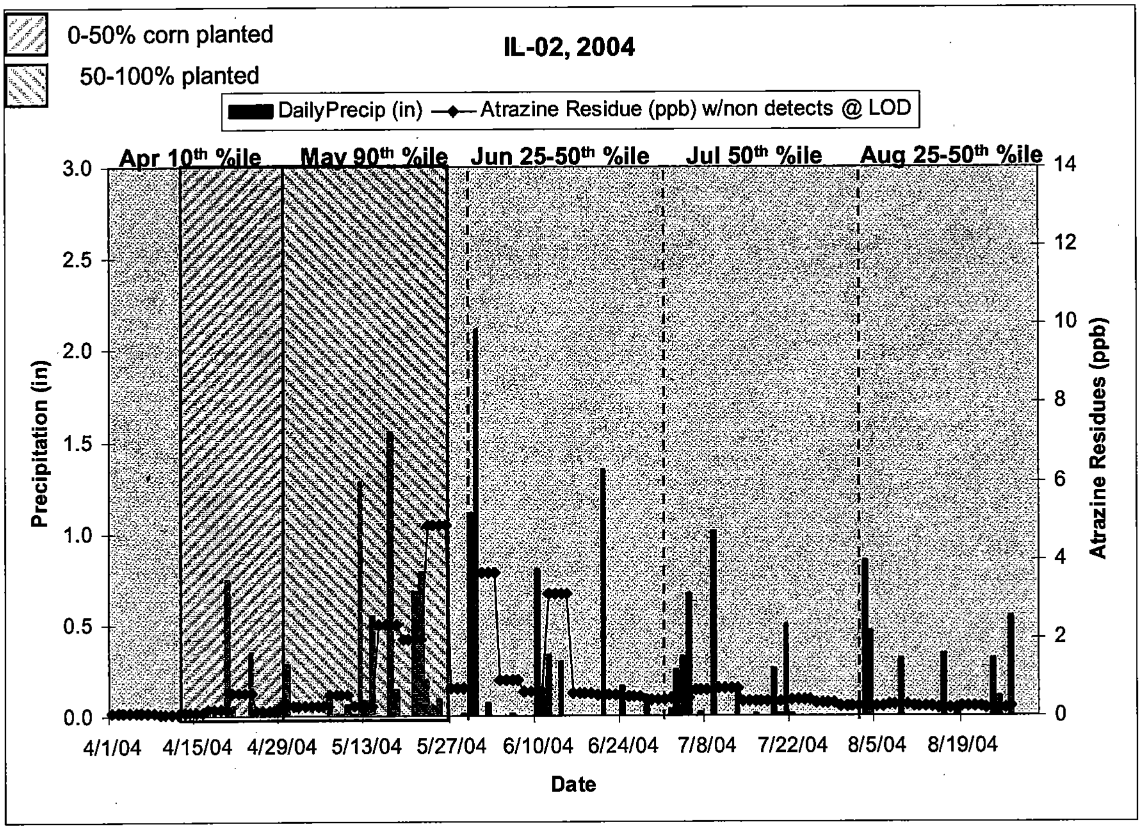
Watershed Location: Pine Creek, IL
NWS Weather Station:

	April Total (in)	May Total (in)	June Total (in)	July Total (in)	August Total (in)	Apr-Aug Total (in)
Historical precipitation summaries, 1950-51, 1987-2001						
Max	6.74	13.19	10.91	9.12	10.36	32.10
90th %ile	5.92	8.77	9.57	8.09	6.87	29.44
75th %ile	4.59	5.23	6.58	4.73	4.78	26.18
50th %ile	2.60	3.05	3.51	2.77	3.54	17.87
25th %ile	1.59	1.35	2.80	2.00	1.57	12.92
10th %ile	1.02	0.61	0.63	1.57	1.29	10.59
Min	0.61	0.11	0.38	0.75	0.87	8.73
Monthly totals during the monitoring study						
2004	1.45	8.81	3.17	3.23	2.97	19.63
2005	1.23	1.47	1.32	2.12	2.56	8.7

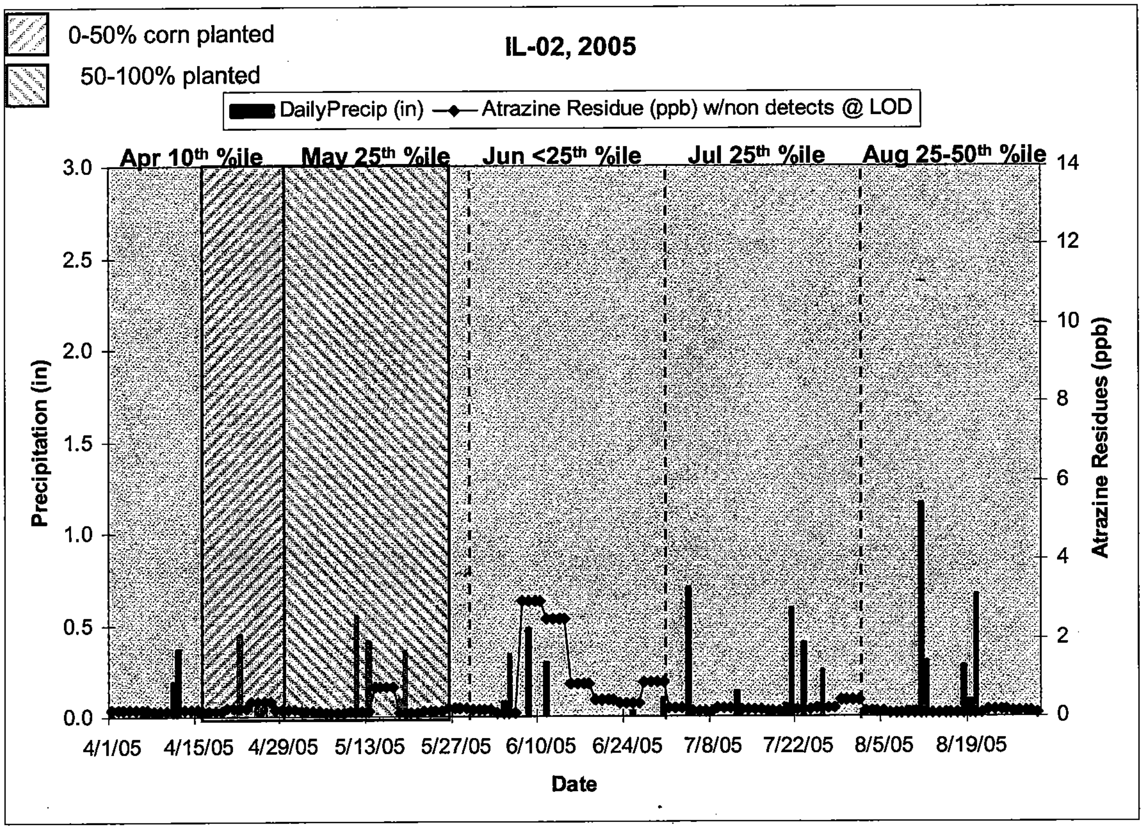
Monthly precipitation in 2004 was low (around the 25th percentile) in April, high in May (90th percentile), and at or around the 50th percentile in subsequent months. In 2005, monthly precipitation was at or below the 75th percentile from April through July.



The following figures show the daily precipitation and atrazine residues in water for 2004 and 2005. The planting season is shaded to provide a point of reference for the likely timing of applications in the watershed.



0-50% corn planted
50-100% planted
IL-02, 2004
DailyPrecip (in)
Atrazine Residue (ppb) w/non detects @ LOD
Apr 10th %ile
May 90th %ile
Jun 25-50th %ile
Jul 50th %ile
Aug 25-50th %ile
Precipitation (in)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Atrazine Residues (ppb)
14
12
10
8
6
4
2
0
4/1/04
4/15/04
4/29/04
5/13/04
5/27/04
6/10/04
6/24/04
7/8/04
7/22/04
8/5/04
8/19/04
Date



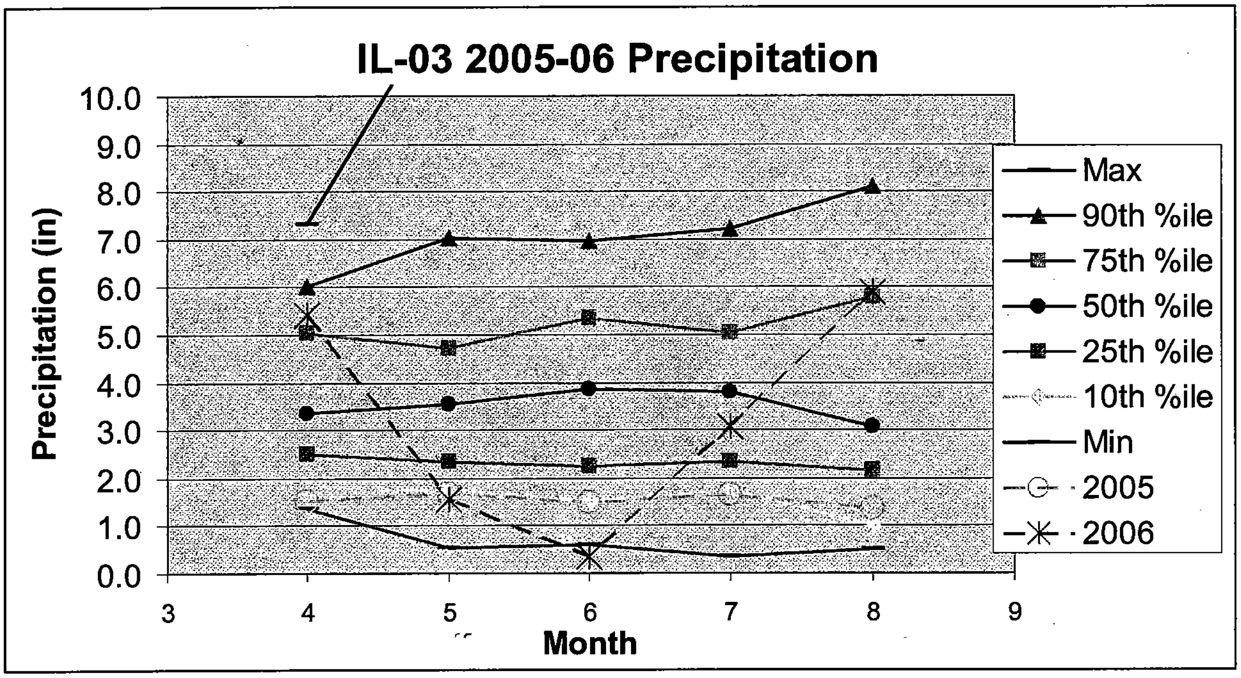
0-50% corn planted
50-100% planted
IL-02, 2005
DailyPrecip (in)
Atrazine Residue (ppb) w/non detects @ LOD
Apr 10th %ile
May 25th %ile
Jun <25th %ile
Jul 25th %ile
Aug 25-50th %ile
Precipitation (in)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Atrazine Residues (ppb)
14
12
10
8
6
4
2
0
4/1/05
4/15/05
4/29/05
5/13/05
5/27/05
6/10/05
6/24/05
7/8/05
7/22/05
8/5/05
8/19/05
Date

5. IL-03, 2005-06

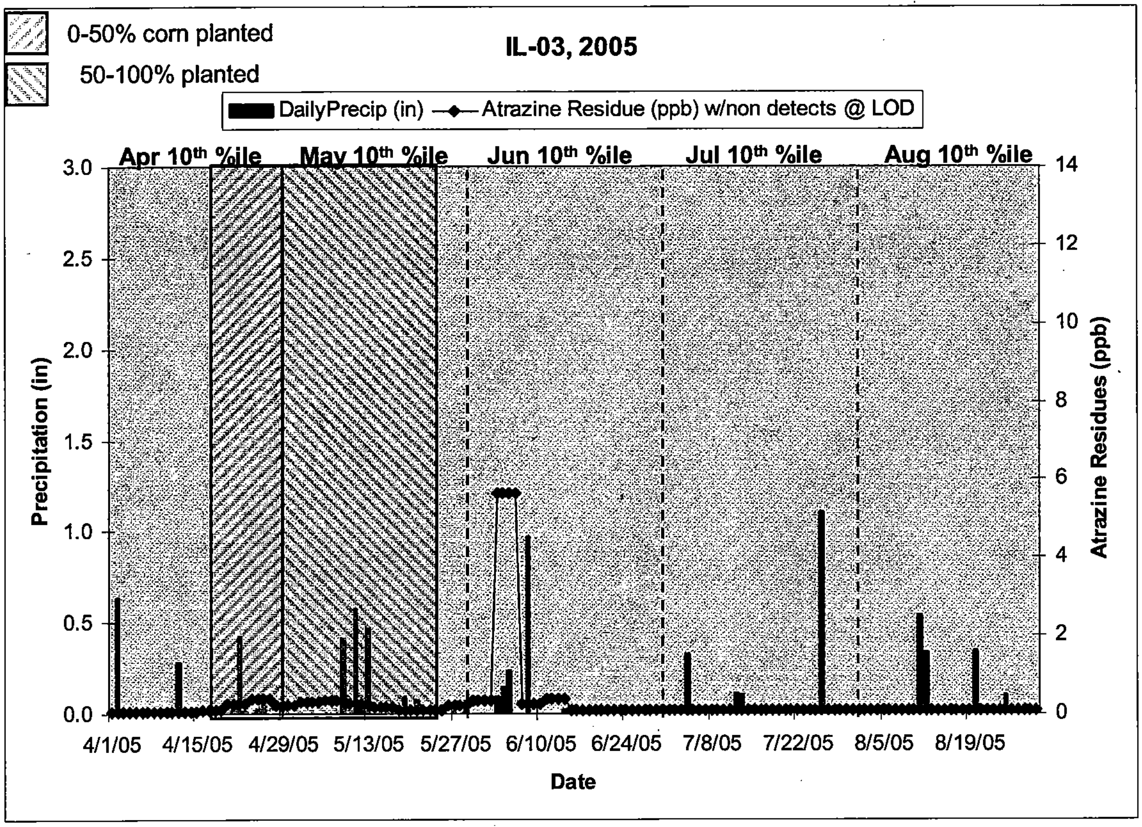
Watershed Location: Spring Creek Watershed, IL
NWS Weather Station:

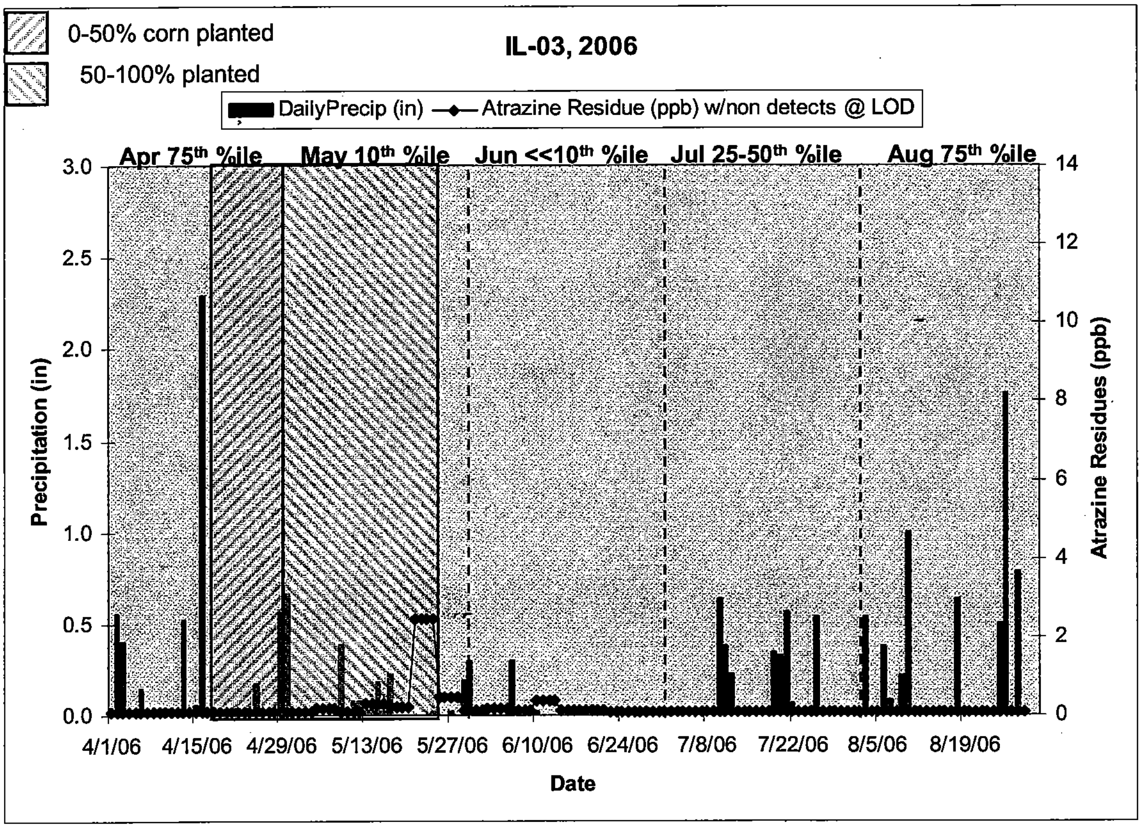
	April Total (in)	May Total (in)	June Total (in)	July Total (in)	August Total (in)	Apr-Aug Total (in)
Historical precipitation summaries, 1948-2001						
Max	7.31	12.19	11.58	12.85	13.69	31.64
90th %ile	6.02	7.03	6.98	7.22	8.11	27.38
75th %ile	5.04	4.73	5.34	5.04	5.79	23.22
50th %ile	3.36	3.55	3.88	3.80	3.07	19.00
25th %ile	2.51	2.33	2.26	2.35	2.15	17.04
10th %ile	1.69	1.77	1.53	1.76	1.01	13.44
Min	1.35	0.55	0.60	0.35	0.52	11.06
Monthly totals during the monitoring study						
2005	1.52	1.67	1.49	1.65	1.36	7.69
2006	5.41	1.55	0.36	3.08	5.88	16.28

Monthly precipitation for 2005 was consistently at or below the 10th percentile for April through July. Precipitation in 2006 was above the 75th percentile in April but fell below the 10th percentile in May and June (June was the lowest total for the record period).



The following figures show the daily precipitation and atrazine residues in water for 2005 and 2006. The planting season is shaded to provide a point of reference for the likely timing of applications in the watershed.


▨ 0-50% corn planted
▨ 50-100% planted
IL-03, 2005
DailyPrecip (in)
Atrazine Residue (ppb) w/non detects @ LOD
Apr 10th %ile
May 10th %ile
Jun 10th %ile
Jul 10th %ile
Aug 10th %ile
Precipitation (in)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Atrazine Residues (ppb)
14
12
10
8
6
4
2
0
4/1/05
4/15/05
4/29/05
5/13/05
5/27/05
6/10/05
6/24/05
7/8/05
7/22/05
8/5/05
8/19/05
Date

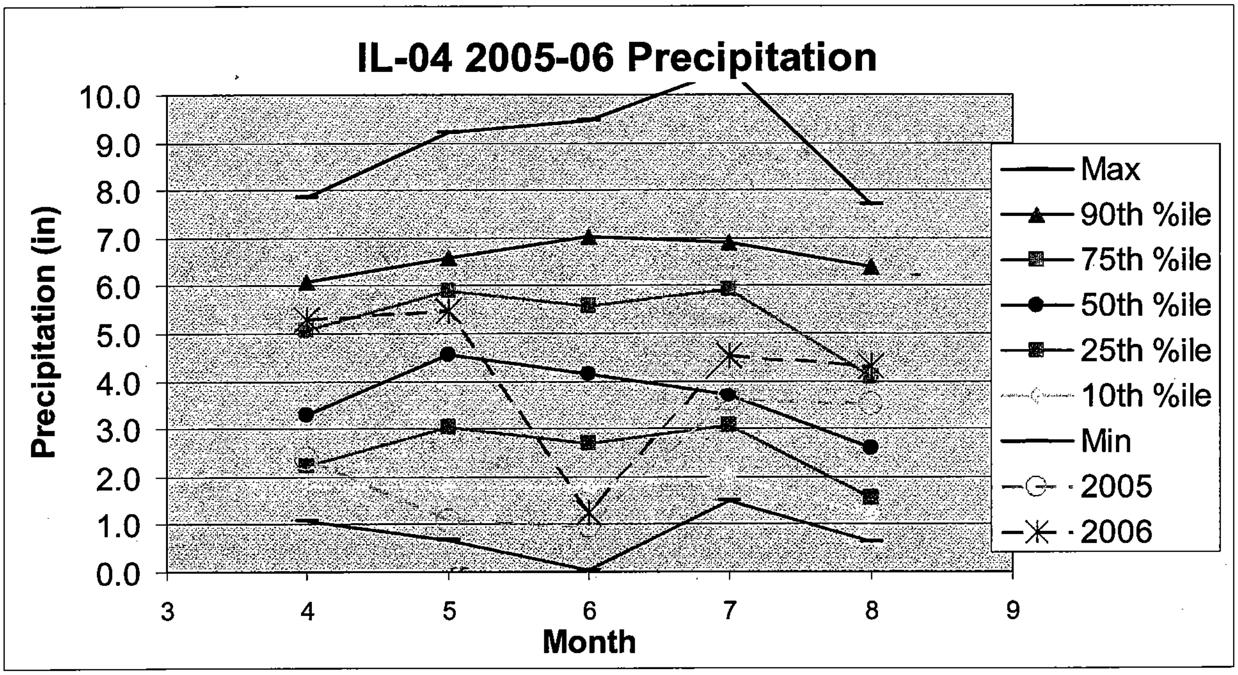

▨ 0-50% corn planted
▨ 50-100% planted
IL-03, 2006
DailyPrecip (in)
Atrazine Residue (ppb) w/non detects @ LOD
Apr 75th %ile
May 10th %ile
Jun <<10th %ile
Jul 25-50th %ile
Aug 75th %ile
Precipitation (in)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Atrazine Residues (ppb)
14
12
10
8
6
4
2
0
4/1/06
4/15/06
4/29/06
5/13/06
5/27/06
6/10/06
6/24/06
7/8/06
7/22/06
8/5/06
8/19/06
Date

6. IL-04, 2005-06

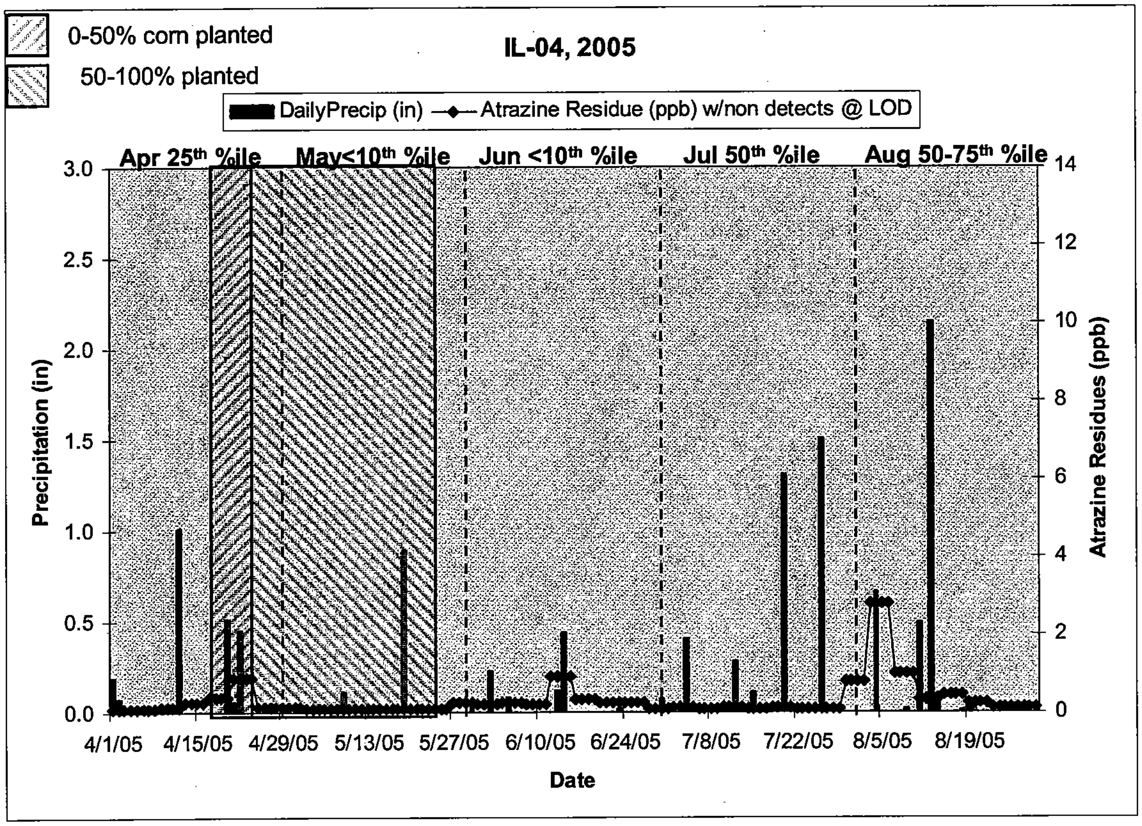
Watershed Location: Iroquois River Watershed, IL
NWS Weather Station:

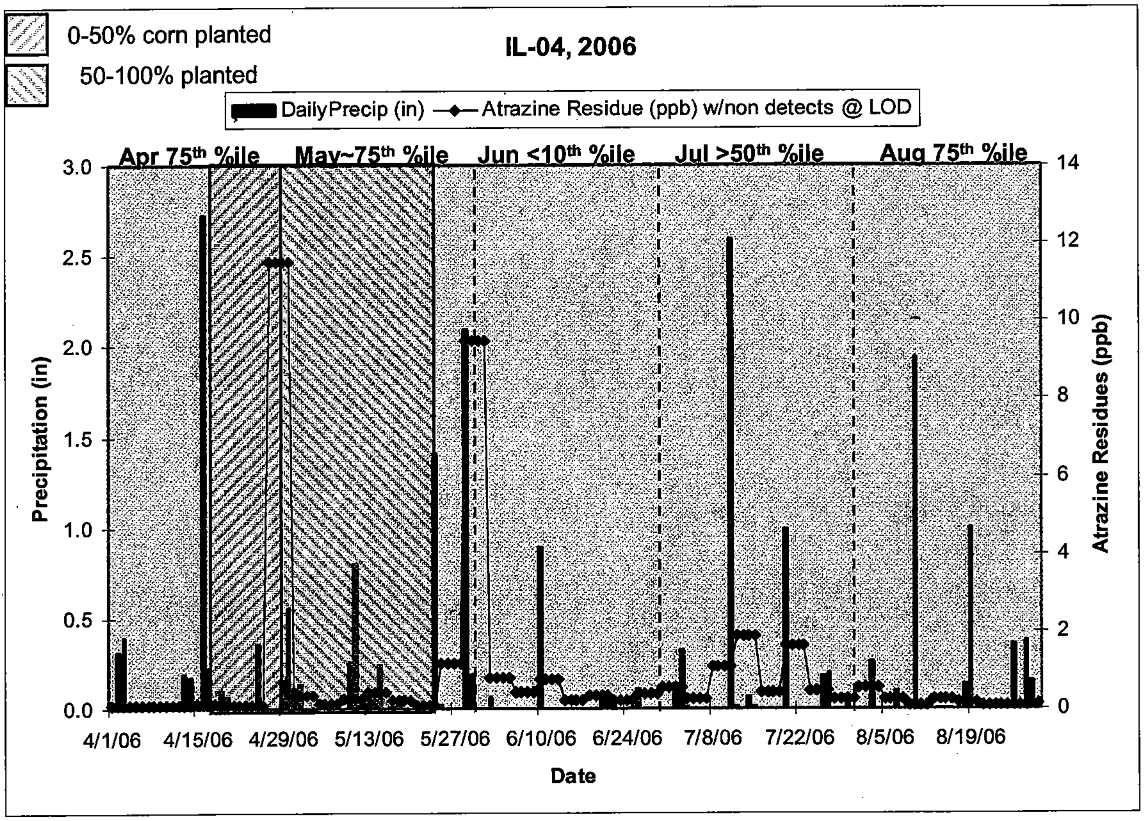
	April Total (in)	May Total (in)	June Total (in)	July Total (in)	August Total (in)	Apr-Aug Total (in)
Historical precipitation summaries, 1948-51, 1973-2001						
Max	7.84	9.22	9.47	10.55	7.70	31.00
90th %ile	6.09	6.58	7.04	6.91	6.38	24.95
75th %ile	5.05	5.89	5.57	5.92	4.07	22.64
50th %ile	3.29	4.55	4.16	3.69	2.61	20.70
25th %ile	2.23	3.04	2.70	3.08	1.55	16.78
10th %ile	1.82	1.78	1.77	2.00	1.19	14.43
Min	1.07	0.67	0.03	1.49	0.62	8.61
Monthly totals during the monitoring study						
2005	2.37	1.09	0.96	3.60	3.50	7.69
2006	5.28	5.49	1.23	4.54	4.31	16.28

Monthly precipitation for 2005 was near the 25th percentile in April and below the 10th percentile in May and June. Rainfall was at or above the median in July and August. In 2006, precipitation was near the 75th percentile in all but June, which was below the 10th percentile.



The following figures show the daily precipitation and atrazine residues in water for 2005 and 2006. The planting season is shaded to provide a point of reference for the likely timing of applications in the watershed.


0-50% corn planted
50-100% planted
IL-04, 2005
DailyPrecip (in)
Atrazine Residue (ppb) w/non detects @ LOD
Apr 25th %ile
May<10th %ile
Jun <10th %ile
Jul 50th %ile
Aug 50-75th %ile
Precipitation (in)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Atrazine Residues (ppb)
14
12
10
8
6
4
2
0
4/1/05
4/15/05
4/29/05
5/13/05
5/27/05
6/10/05
6/24/05
7/8/05
7/22/05
8/5/05
8/19/05
Date

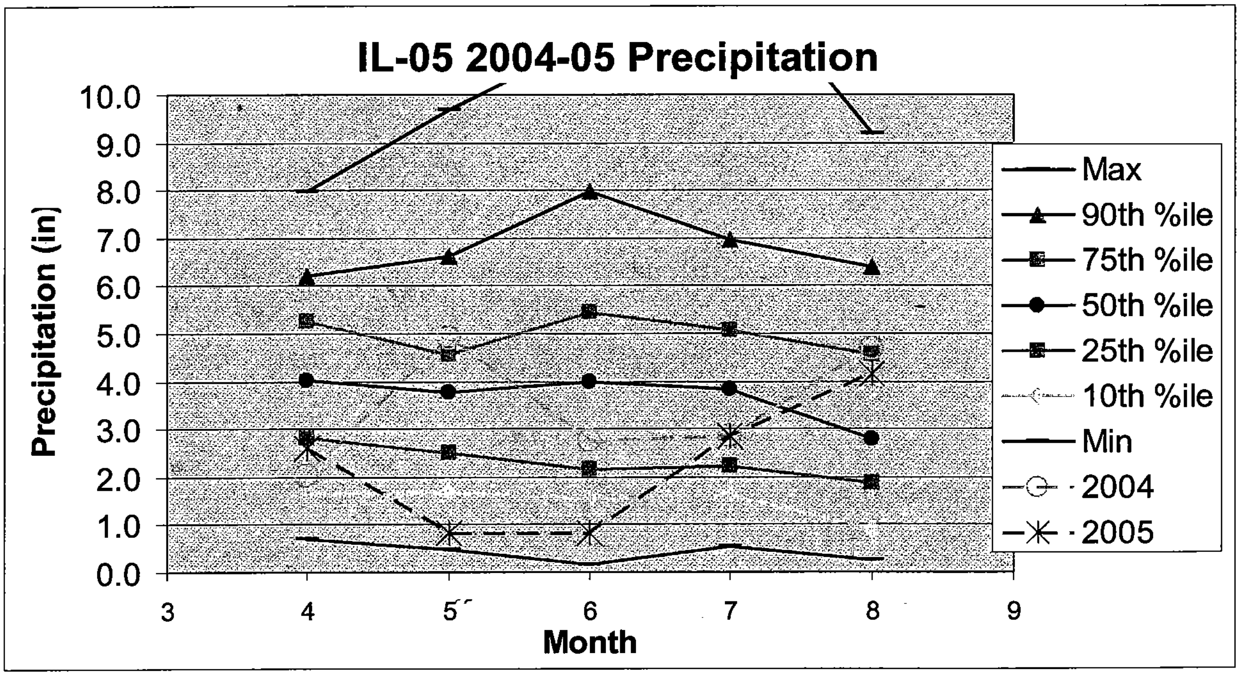

0-50% corn planted
50-100% planted
IL-04, 2006
DailyPrecip (in)
Atrazine Residue (ppb) w/non detects @ LOD
Apr 75th %ile
May~75th %ile
Jun <10th %ile
Jul >50th %ile
Aug 75th %ile
Precipitation (in)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Atrazine Residues (ppb)
14
12
10
8
6
4
2
0
4/1/06
4/15/06
4/29/06
5/13/06
5/27/06
6/10/06
6/24/06
7/8/06
7/22/06
8/5/06
8/19/06
Date

7. IL-05, 2004-05

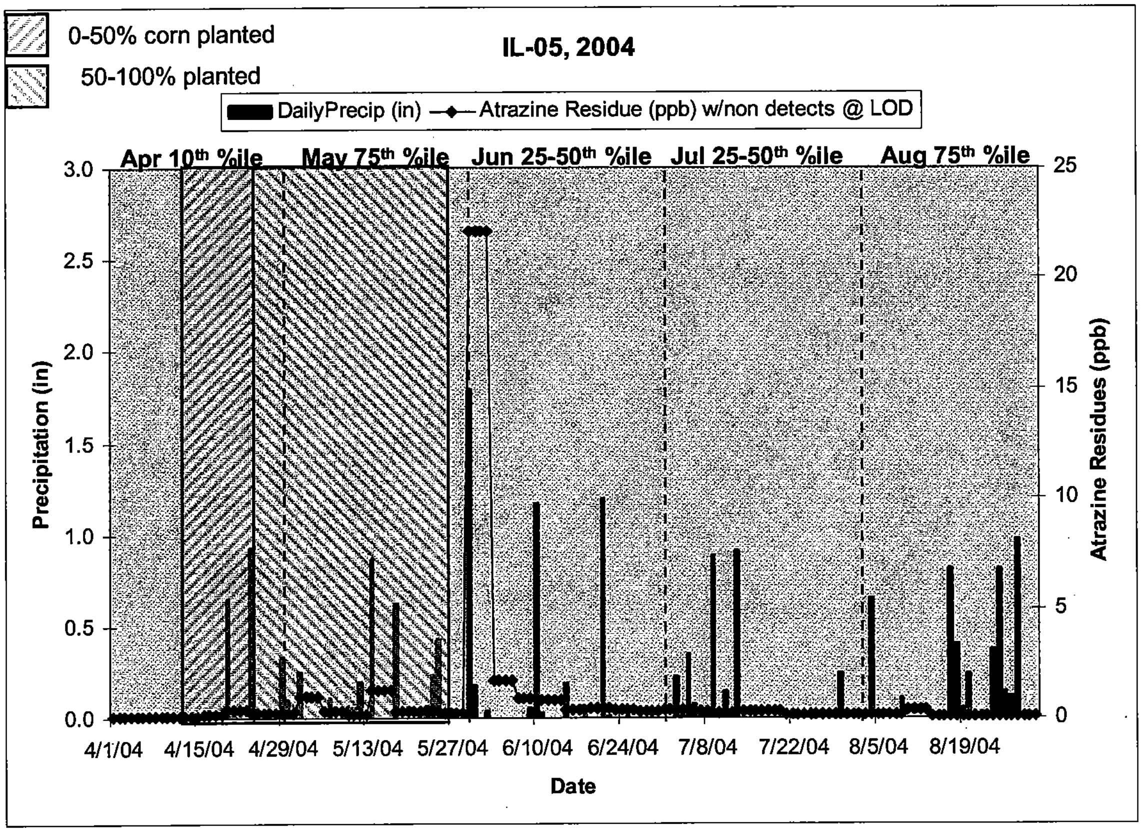
Watershed Location: Panther Creek, IL
NWS Weather Station:

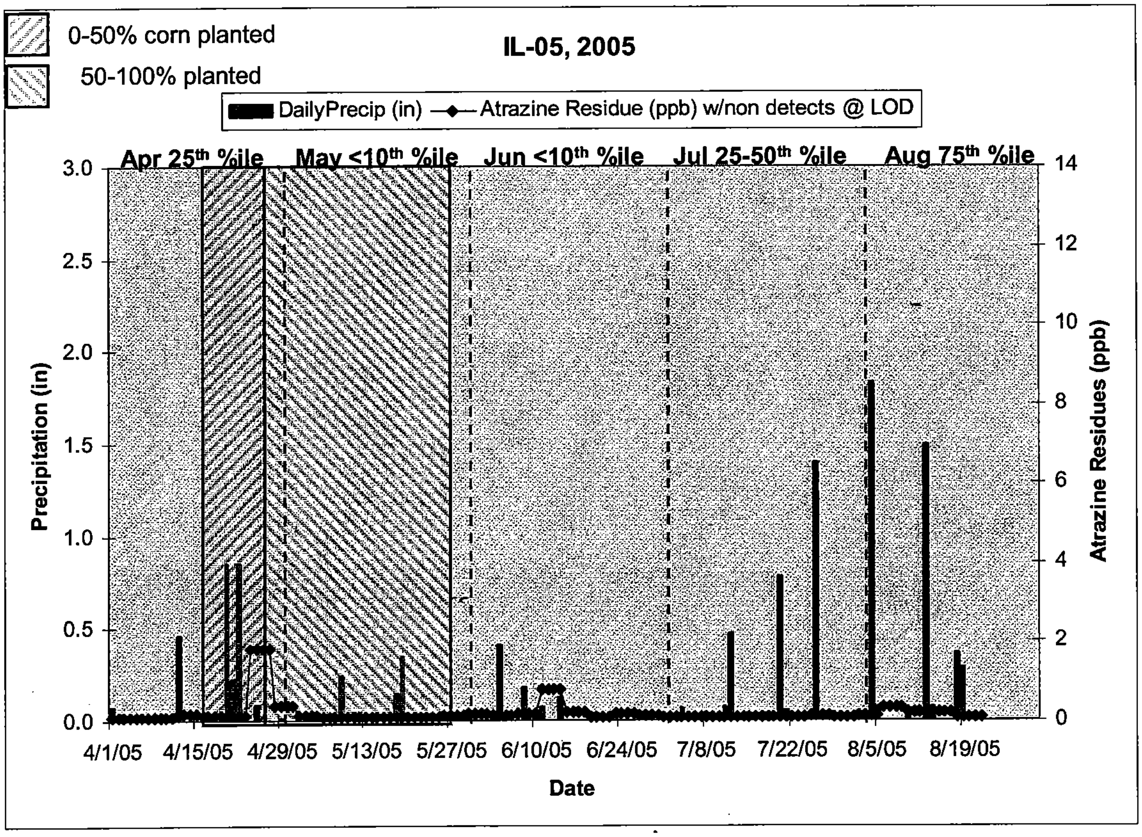
	April Total (in)	May Total (in)	June Total (in)	July Total (in)	August Total (in)	Apr-Aug Total (in)
Historical precipitation summaries, 1948-2001						
Max	7.96	9.68	11.15	12.82	9.18	35.79
90th %ile	6.20	6.62	7.99	6.96	6.40	25.24
75th %ile	5.25	4.57	5.45	5.06	4.55	23.08
50th %ile	4.03	3.78	4.00	3.83	2.78	19.19
25th %ile	2.82	2.51	2.14	2.21	1.86	16.46
10th %ile	1.69	1.67	1.55	1.60	0.92	12.83
Min	0.69	0.47	0.17	0.55	0.25	5.97
Monthly totals during the monitoring study						
2004	2.02	4.92	2.76	2.85	4.67	17.22
2005	2.59	0.82	0.83	2.86	4.13	11.23

Monthly precipitation for 2004 was low (25th to <10th percentile) for April through June. In 2005, rainfall was low (below the 25th percentile) in April and high (75th percentile) in May and August.



The following figures show the daily precipitation and atrazine residues in water for 2004 and 2005. The planting season is shaded to provide a point of reference for the likely timing of applications in the watershed.


0-50% corn planted
50-100% planted
IL-05, 2004
DailyPrecip (in)
Atrazine Residue (ppb) w/non detects @ LOD
Apr 10th %ile
May 75th %ile
Jun 25-50th %ile
Jul 25-50th %ile
Aug 75th %ile
Precipitation (in)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Atrazine Residues (ppb)
25
20
15
10
5
0
4/1/04
4/15/04
4/29/04
5/13/04
5/27/04
6/10/04
6/24/04
7/8/04
7/22/04
8/5/04
8/19/04
Date

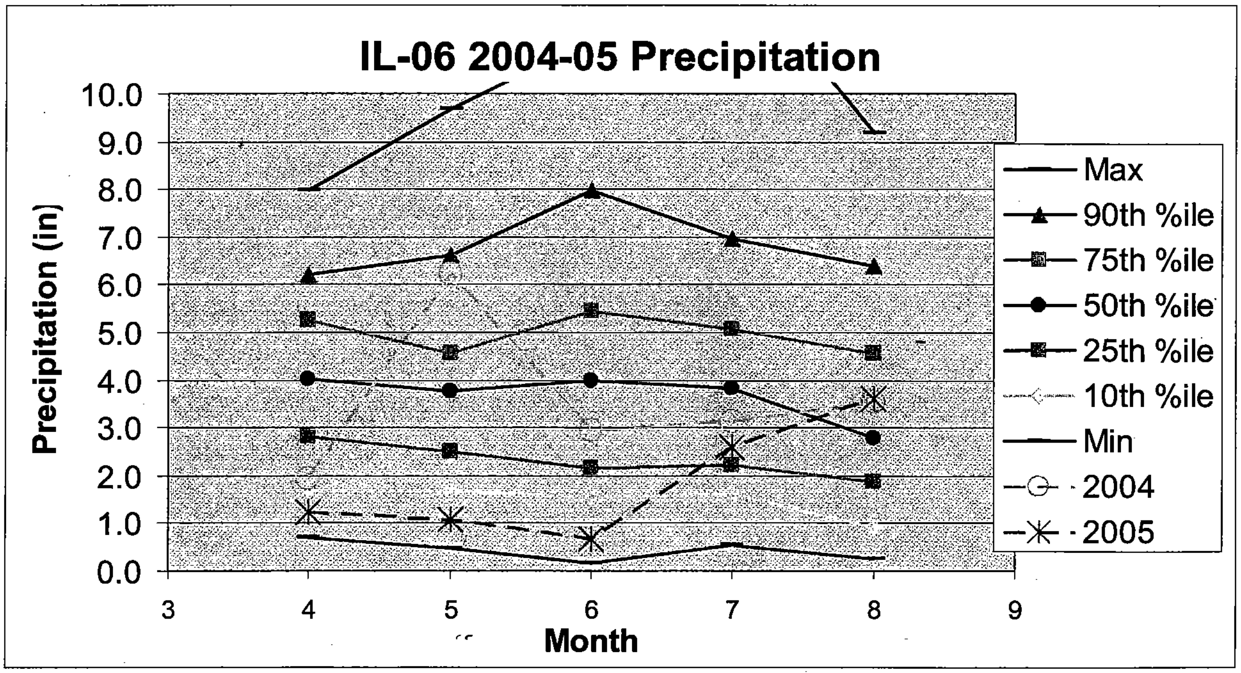

0-50% corn planted
50-100% planted
IL-05, 2005
DailyPrecip (in)
Atrazine Residue (ppb) w/non detects @ LOD
Apr 25th %ile
May <10th %ile
Jun <10th %ile
Jul 25-50th %ile
Aug 75th %ile
Precipitation (in)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Atrazine Residues (ppb)
14
12
10
8
6
4
2
0
4/1/05
4/15/05
4/29/05
5/13/05
5/27/05
6/10/05
6/24/05
7/8/05
7/22/05
8/5/05
8/19/05
Date

8. IL-06, 2004-05

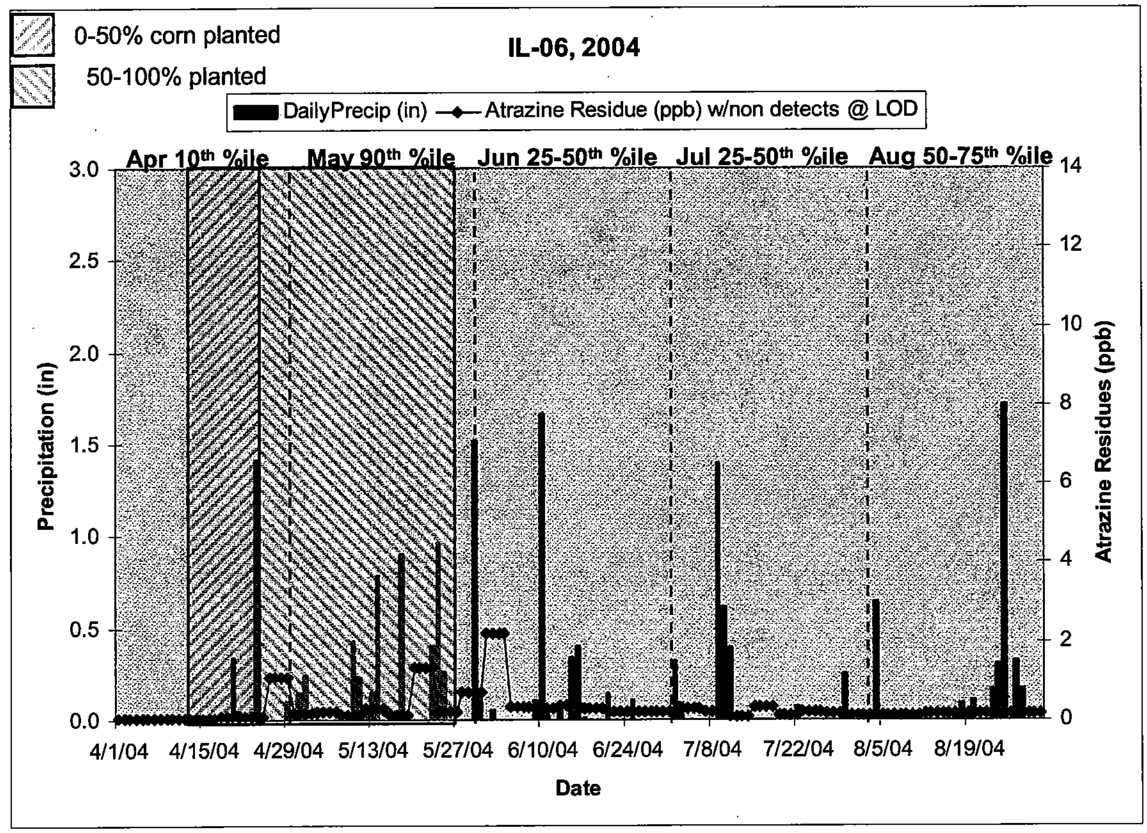
Watershed Location: Sugar Creek West Fork, IL
NWS Weather Station:

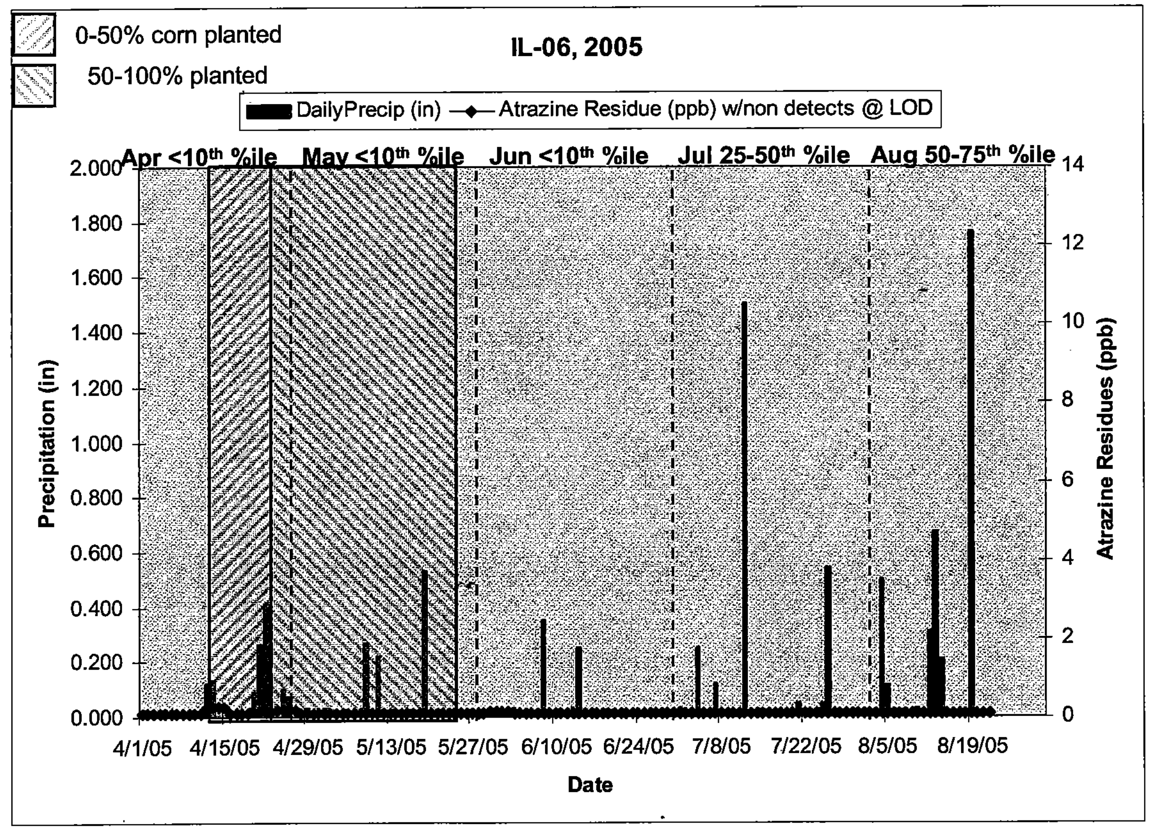
	April Total (in)	May Total (in)	June Total (in)	July Total (in)	August Total (in)	Apr-Aug Total (in)
Historical precipitation summaries, 1948-2001						
Max	7.96	9.68	11.15	12.82	9.18	35.79
90th %ile	6.20	6.62	7.99	6.96	6.40	25.22
75th %ile	5.25	4.57	5.45	5.06	4.55	23.03
50th %ile	4.03	3.78	4.00	3.83	2.78	18.92
25th %ile	2.82	2.51	2.14	2.21	1.86	16.31
10th %ile	1.69	1.67	1.55	1.60	0.92	12.84
Min	0.69	0.47	0.17	0.55	0.25	5.97
Monthly totals during the monitoring study						
2004	1.94	6.19	2.95	3.13	3.56	17.77
2005	1.23	1.09	0.68	2.59	3.61	9.2

Monthly precipitation for 2004 was low (<25th percentile) for April and high (>75th percentile) for May. In 2005, rainfall was low (below the 10th percentile) in April through June.



The following figures show the daily precipitation and atrazine residues in water for 2004 and 2005. The planting season is shaded to provide a point of reference for the likely timing of applications in the watershed.


0-50% corn planted
50-100% planted
IL-06, 2004
DailyPrecip (in)
Atrazine Residue (ppb) w/non detects @ LOD
Apr 10th %ile
May 90th %ile
Jun 25-50th %ile
Jul 25-50th %ile
Aug 50-75th %ile
Precipitation (in)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Atrazine Residues (ppb)
14
12
10
8
6
4
2
0
4/1/04
4/15/04
4/29/04
5/13/04
5/27/04
6/10/04
6/24/04
7/8/04
7/22/04
8/5/04
8/19/04
Date

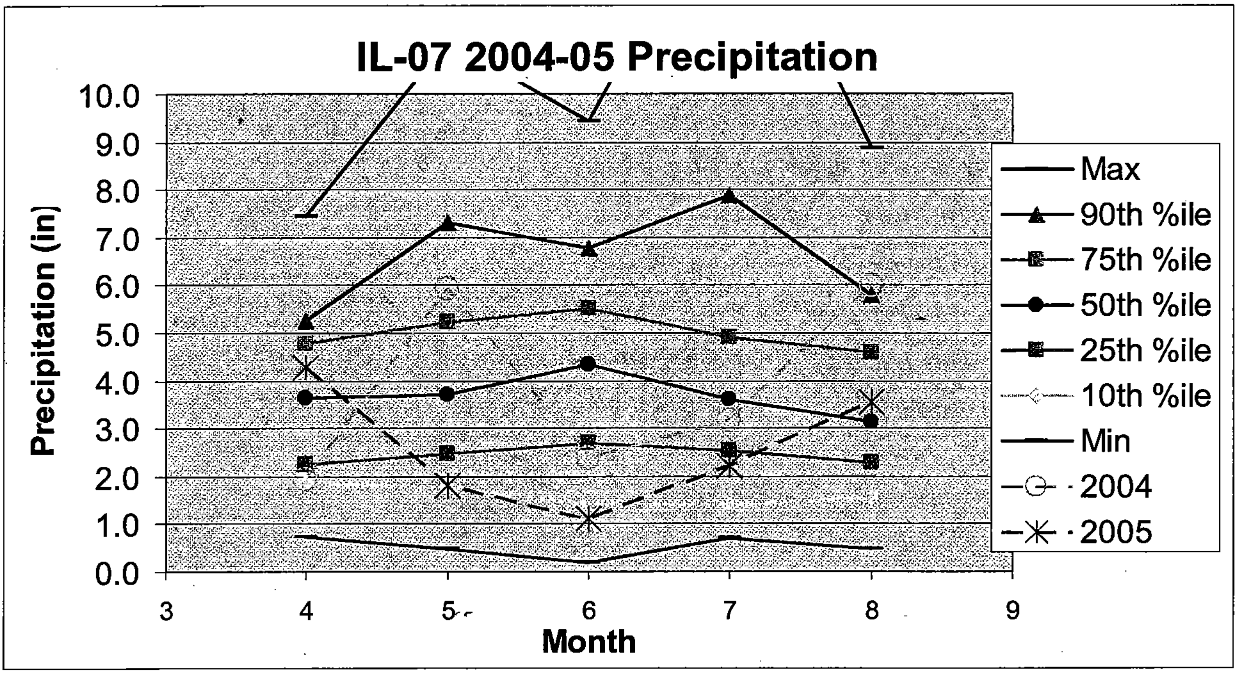

0-50% corn planted
50-100% planted
IL-06, 2005
DailyPrecip (in)
Atrazine Residue (ppb) w/non detects @ LOD
Apr <10th %ile
May <10th %ile
Jun <10th %ile
Jul 25-50th %ile
Aug 50-75th %ile
Precipitation (in)
2.000
1.800
1.600
1.400
1.200
1.000
0.800
0.600
0.400
0.200
0.000
Atrazine Residues (ppb)
14
12
10
8
6
4
2
0
4/1/05
4/15/05
4/29/05
5/13/05
5/27/05
6/10/05
6/24/05
7/8/05
7/22/05
8/5/05
8/19/05
Date

9. IL-07, 2004-05

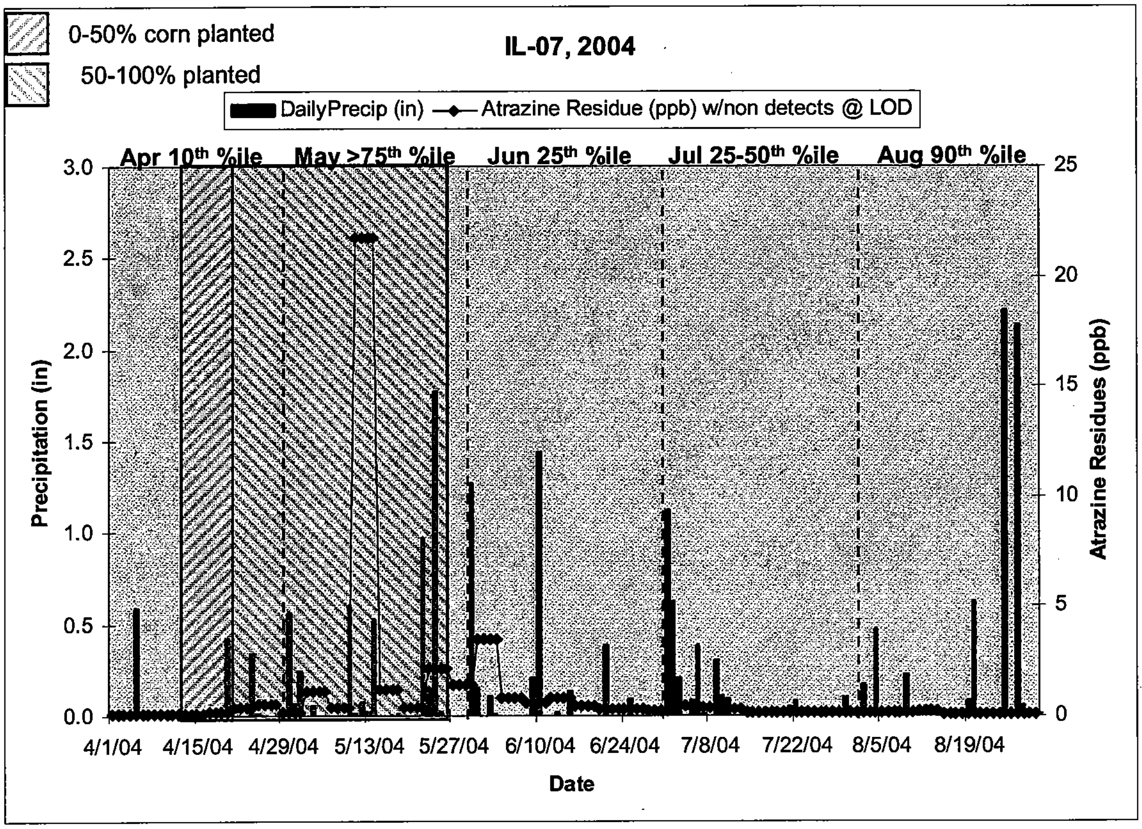
Watershed Location: Grindstone Creek, IL
NWS Weather Station:

	April Total (in)	May Total (in)	June Total (in)	July Total (in)	August Total (in)	Apr-Aug Total (in)
Historical precipitation summaries, 1948-2001						
Max	7.43	11.12	9.43	14.92	8.87	31.58
90th %ile	5.26	7.31	6.78	7.88	5.78	27.55
75th %ile	4.77	5.22	5.52	4.90	4.58	22.62
50th %ile	3.63	3.69	4.34	3.62	3.13	18.83
25th %ile	2.26	2.47	2.70	2.54	2.29	16.46
10th %ile	1.88	1.76	1.43	1.40	1.55	13.88
Min	0.74	0.47	0.20	0.71	0.46	9.04
Monthly totals during the monitoring study						
2004	1.92	5.91	2.38	3.16	5.98	19.35
2005	4.26	1.8	1.12	2.23	3.56	12.97

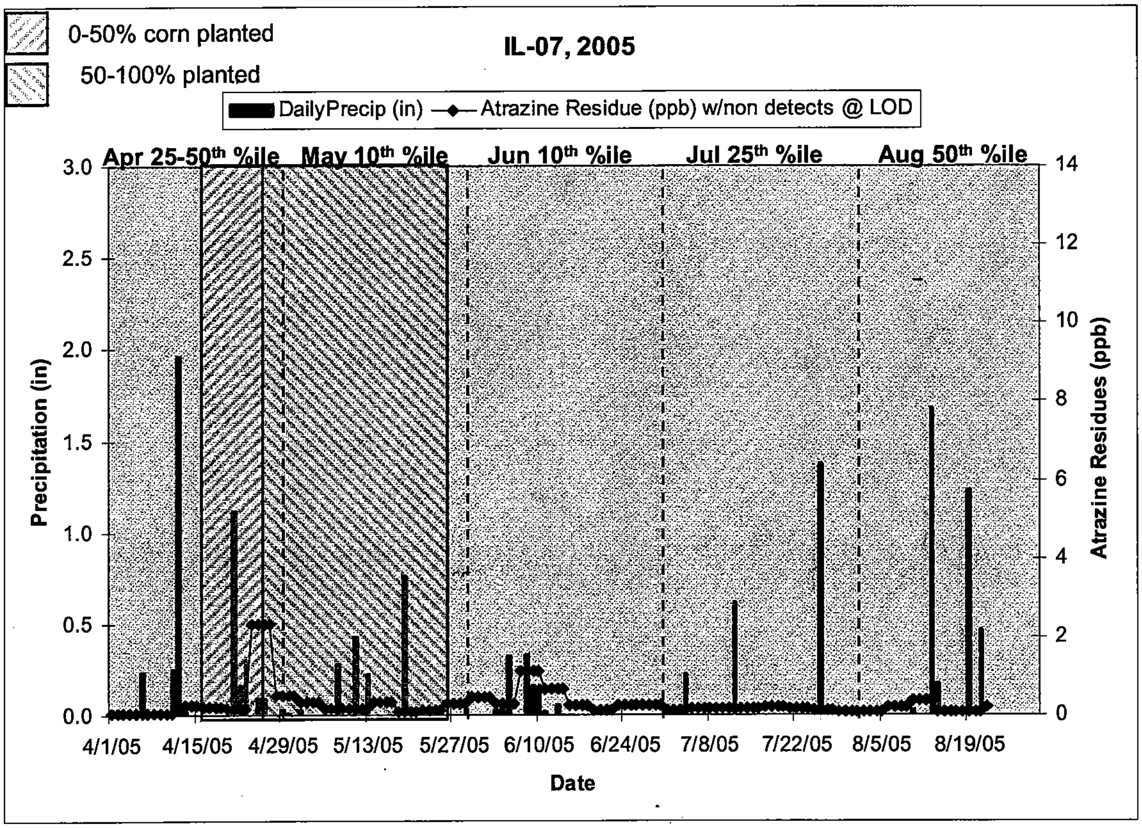
Monthly precipitation for 2004 was low (10th percentile) for April and high (>75th percentile) for May and August. In 2005, rainfall was low (below the 25th percentile) in May through July.



The following figures show the daily precipitation and atrazine residues in water for 2004 and 2005. The planting season is shaded to provide a point of reference for the likely timing of applications in the watershed.



▨ 0-50% corn planted
▨ 50-100% planted
IL-07, 2004
DailyPrecip (in)
Atrazine Residue (ppb) w/non detects @ LOD
Apr 10th %ile
May >75th %ile
Jun 25th %ile
Jul 25-50th %ile
Aug 90th %ile
Precipitation (in)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Atrazine Residues (ppb)
25
20
15
10
5
0
4/1/04
4/15/04
4/29/04
5/13/04
5/27/04
6/10/04
6/24/04
7/8/04
7/22/04
8/5/04
8/19/04
Date



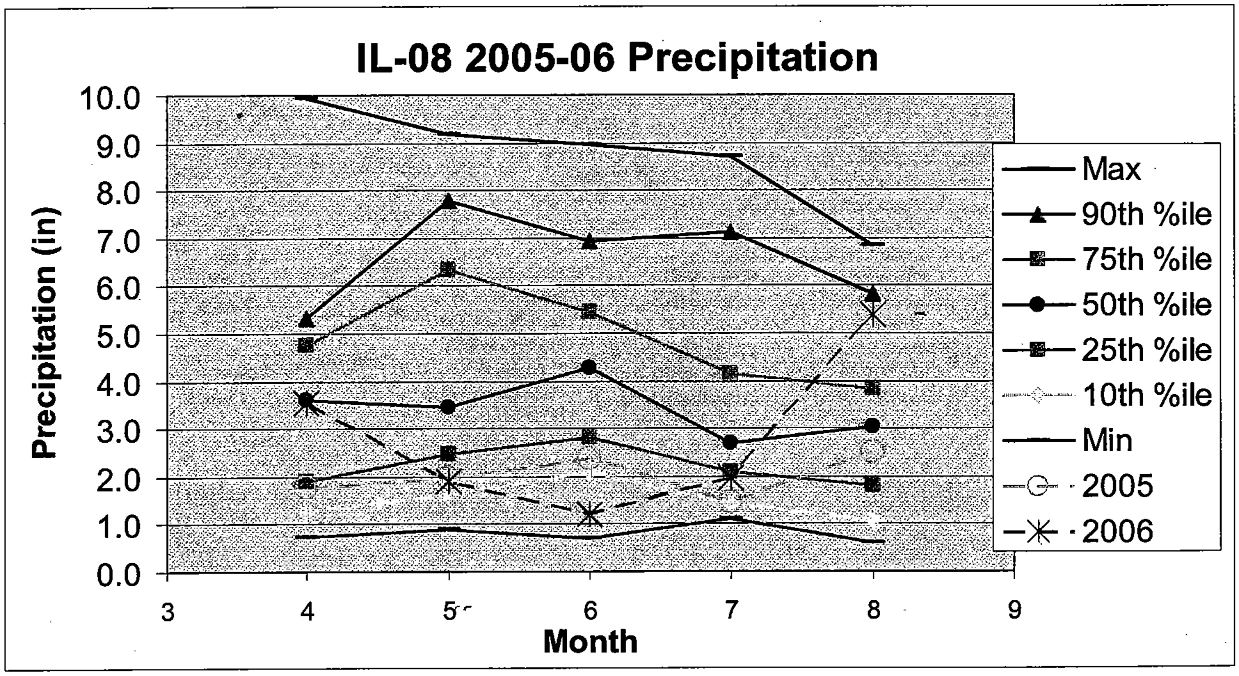
▨ 0-50% corn planted
▨ 50-100% planted
IL-07, 2005
DailyPrecip (in)
Atrazine Residue (ppb) w/non detects @ LOD
Apr 25-50th %ile
May 10th %ile
Jun 10th %ile
Jul 25th %ile
Aug 50th %ile
Precipitation (in)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Atrazine Residues (ppb)
14
12
10
8
6
4
2
0
4/1/05
4/15/05
4/29/05
5/13/05
5/27/05
6/10/05
6/24/05
7/8/05
7/22/05
8/5/05
8/19/05
Date

10. IL-08, 2005-06

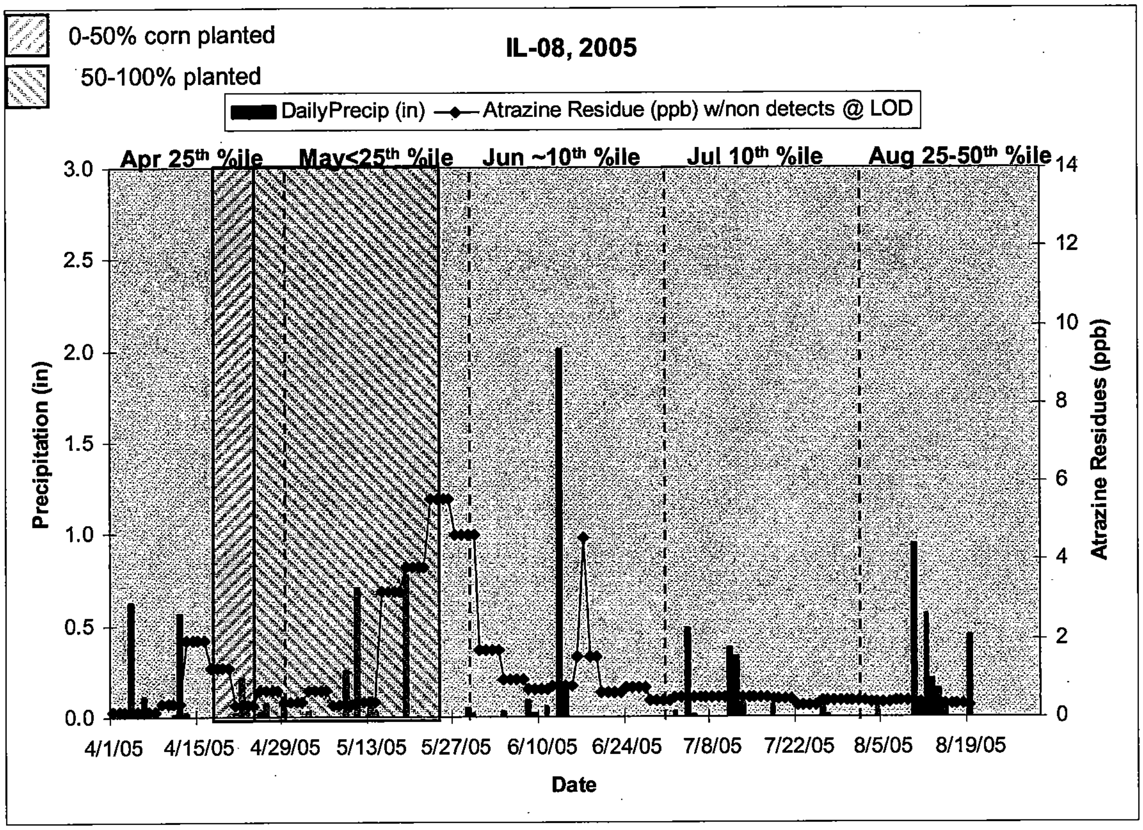
Watershed Location: Horse Creek Watershed, IL
NWS Weather Station:

	April Total (in)	May Total (in)	June Total (in)	July Total (in)	August Total (in)	Apr-Aug Total (in)
Historical precipitation summaries, 1973-2001						
Max	9.93	9.17	8.96	8.70	6.82	33.81
90th %ile	5.32	7.78	6.92	7.13	5.84	22.82
75th %ile	4.76	6.34	5.43	4.16	3.84	21.75
50th %ile	3.61	3.44	4.27	2.70	3.03	19.15
25th %ile	1.91	2.48	2.83	2.08	1.80	15.81
10th %ile	1.28	1.62	2.09	1.42	1.09	14.15
Min	0.74	0.89	0.69	1.12	0.60	6.56
Monthly totals during the monitoring study						
2005	1.78	1.95	2.37	1.46	2.51	10.07
2006	3.54	1.89	1.2	1.95	5.38	13.96

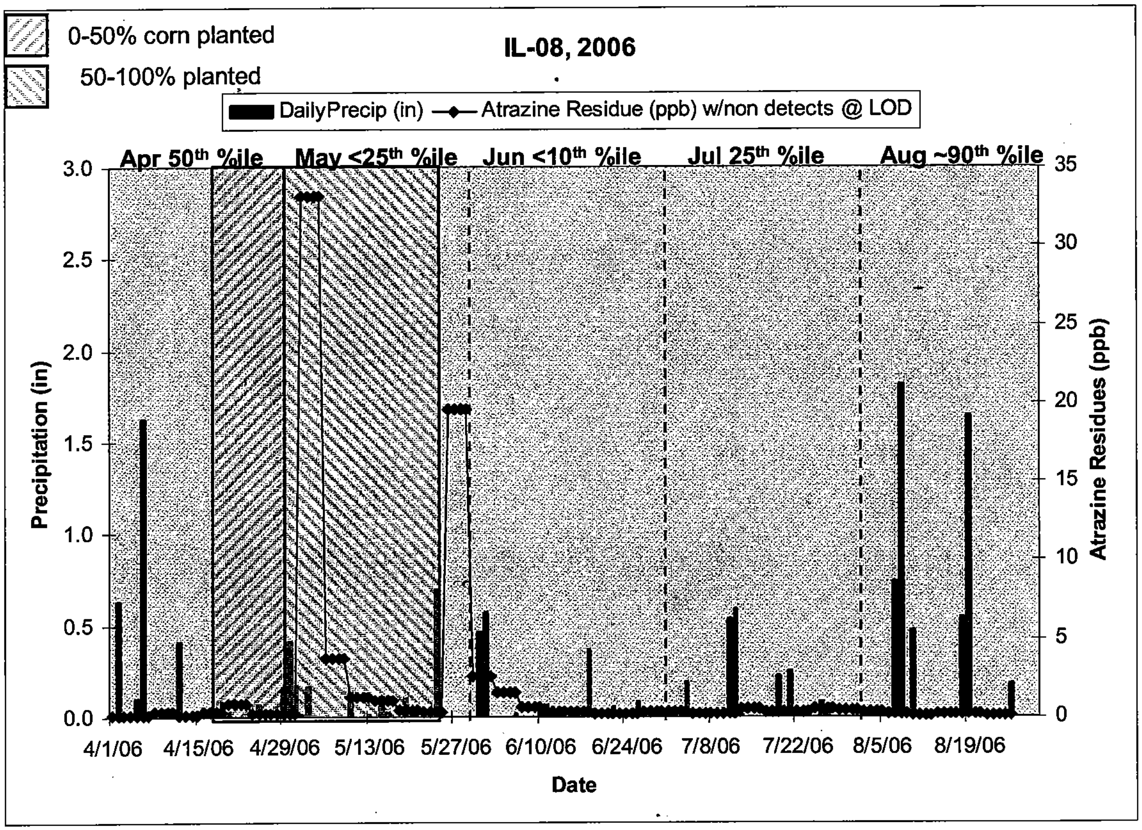
Monthly precipitation for 2005 fell between 25th and 10th percentile from April through July. While precipitation in April 2006 was near the median, monthly totals for May through July were below the 25th percentile.



The following figures show the daily precipitation and atrazine residues in water for 2005 and 2006. The planting season is shaded to provide a point of reference for the likely timing of applications in the watershed.



▨ 0-50% corn planted
▨ 50-100% planted
IL-08, 2005
DailyPrecip (in) —◆— Atrazine Residue (ppb) w/non detects @ LOD
Apr 25th %ile
May<25th %ile
Jun ~10th %ile
Jul 10th %ile
Aug 25-50th %ile
Precipitation (in)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Atrazine Residues (ppb)
14
12
10
8
6
4
2
0
4/1/05
4/15/05
4/29/05
5/13/05
5/27/05
6/10/05
6/24/05
7/8/05
7/22/05
8/5/05
8/19/05
Date



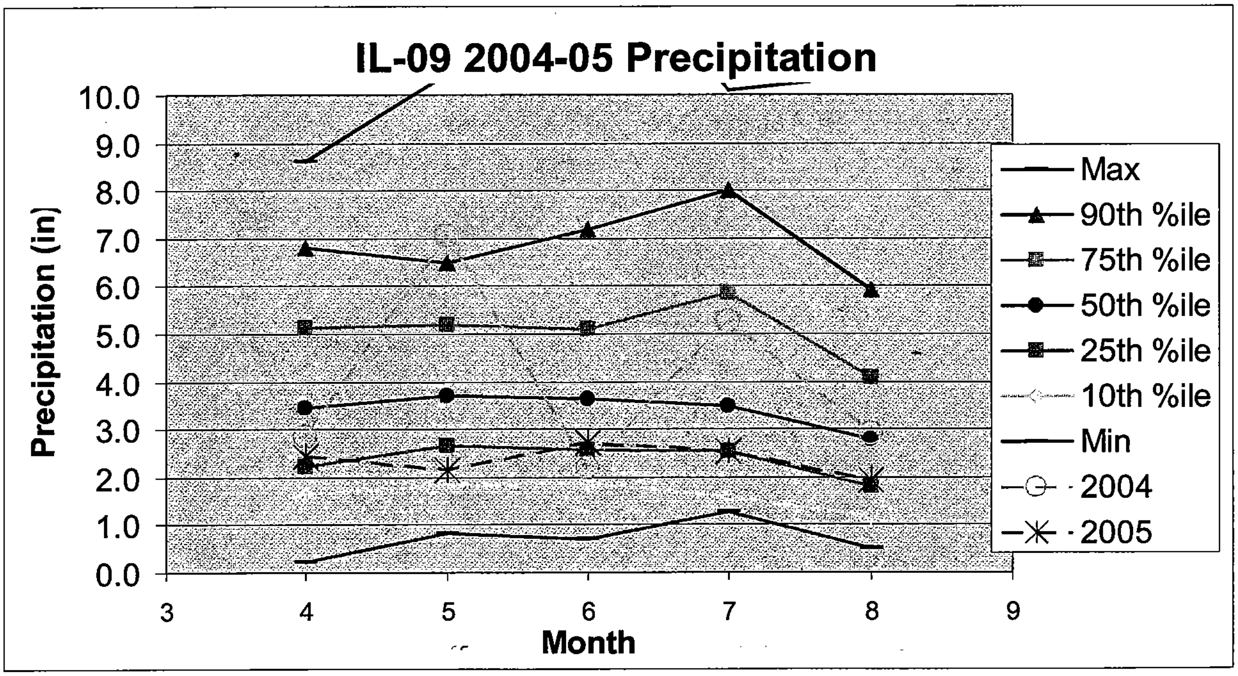
▨ 0-50% corn planted
▨ 50-100% planted
IL-08, 2006
DailyPrecip (in) —◆— Atrazine Residue (ppb) w/non detects @ LOD
Apr 50th %ile
May <25th %ile
Jun <10th %ile
Jul 25th %ile
Aug ~90th %ile
Precipitation (in)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Atrazine Residues (ppb)
35
30
25
20
15
10
5
0
4/1/06
4/15/06
4/29/06
5/13/06
5/27/06
6/10/06
6/24/06
7/8/06
7/22/06
8/5/06
8/19/06
Date

11. IL-09, 2004-05

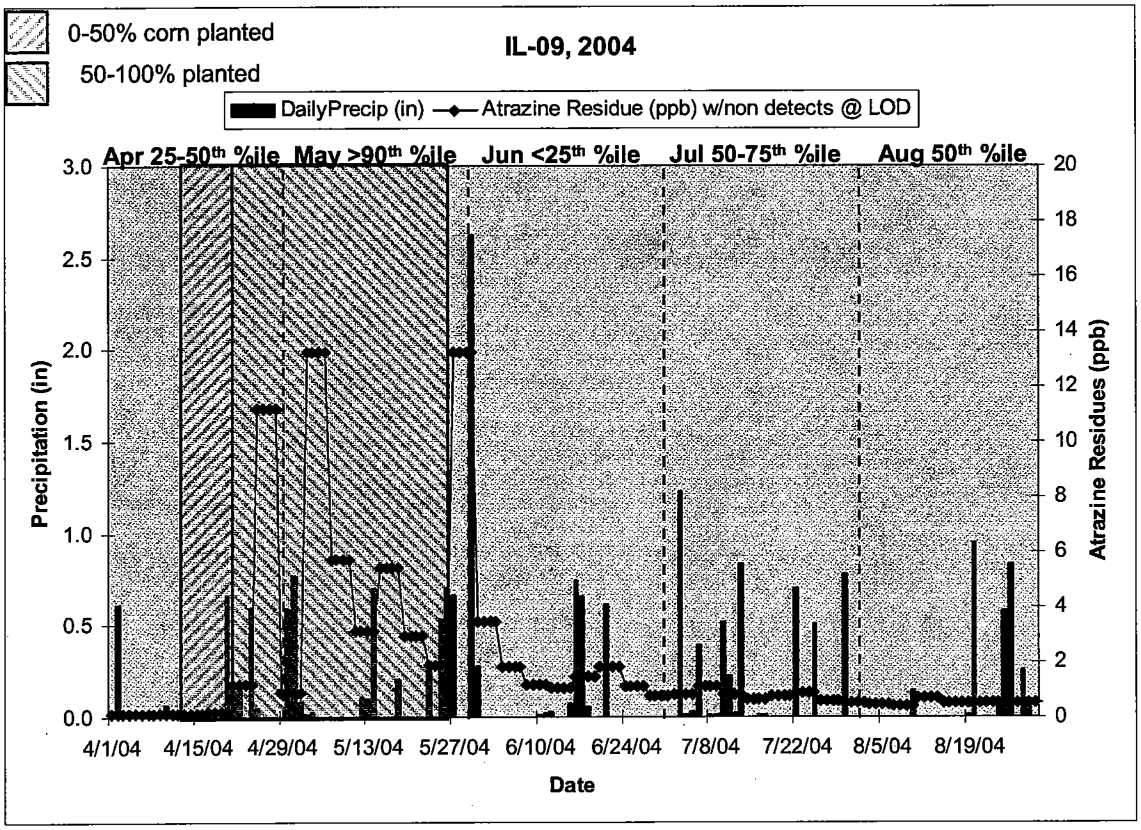
Watershed Location: Muddy Creek, IL
NWS Weather Station:

	April Total (in)	May Total (in)	June Total (in)	July Total (in)	August Total (in)	Apr-Aug Total (in)
Historical precipitation summaries, 1948-2001						
Max	8.62	10.45	13.98	10.10	10.41	32.09
90th %ile	6.80	6.48	7.20	8.01	5.92	25.91
75th %ile	5.12	5.20	5.08	5.86	4.08	22.62
50th %ile	3.44	3.69	3.66	3.49	2.78	18.57
25th %ile	2.22	2.65	2.57	2.54	1.81	16.42
10th %ile	1.66	1.84	1.85	1.57	1.16	12.35
Min	0.22	0.81	0.70	1.26	0.52	8.86
Monthly totals during the monitoring study						
2004	2.86	7.07	2.18	5.26	2.91	20.28
2005	2.45	2.16	2.72	2.54	1.93	11.8

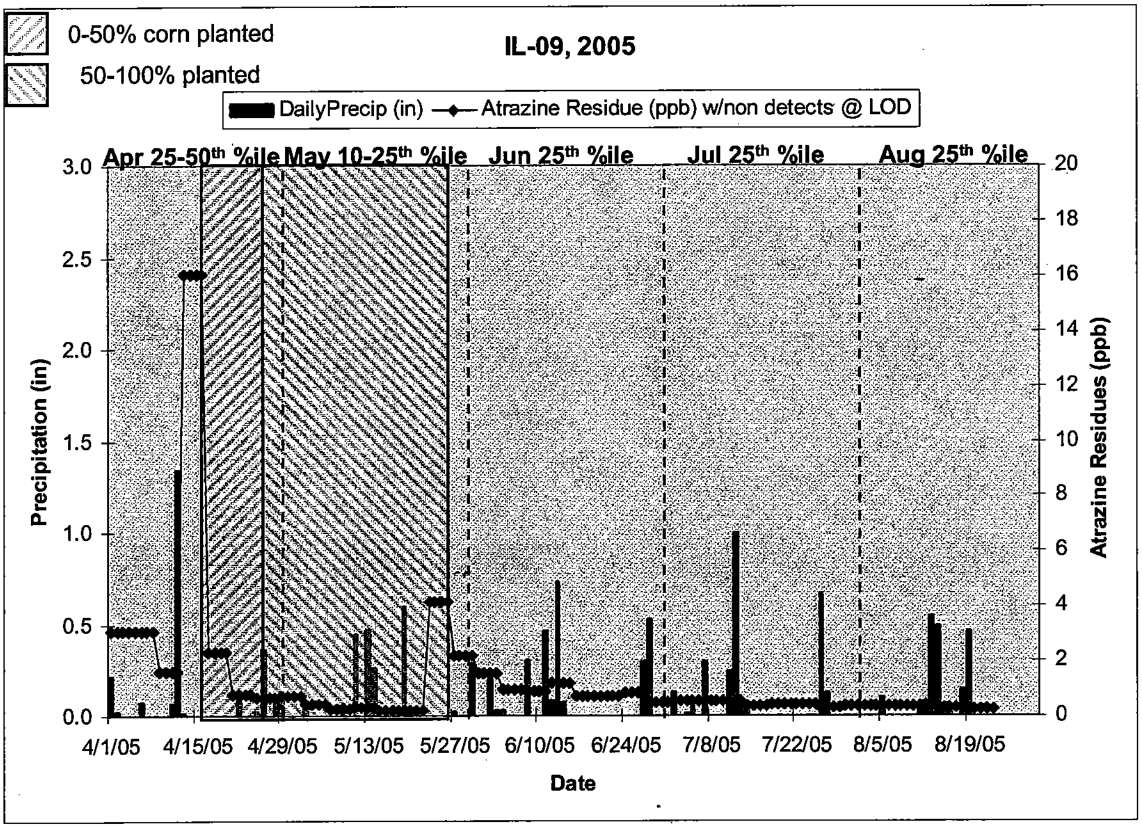
Monthly precipitation for 2004 was high in May (90th percentile) and low (<25th percentile) in June. In 2005, rainfall was low (at or below the 25th percentile) throughout the sample period (April through August).



The following figures show the daily precipitation and atrazine residues in water for 2004 and 2005. The planting season is shaded to provide a point of reference for the likely timing of applications in the watershed.



0-50% corn planted
50-100% planted
IL-09, 2004
DailyPrecip (in)
Atrazine Residue (ppb) w/non detects @ LOD
Apr 25-50th %ile
May >90th %ile
Jun <25th %ile
Jul 50-75th %ile
Aug 50th %ile
Precipitation (in)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Atrazine Residues (ppb)
20
18
16
14
12
10
8
6
4
2
0
4/1/04
4/15/04
4/29/04
5/13/04
5/27/04
6/10/04
6/24/04
7/8/04
7/22/04
8/5/04
8/19/04
Date



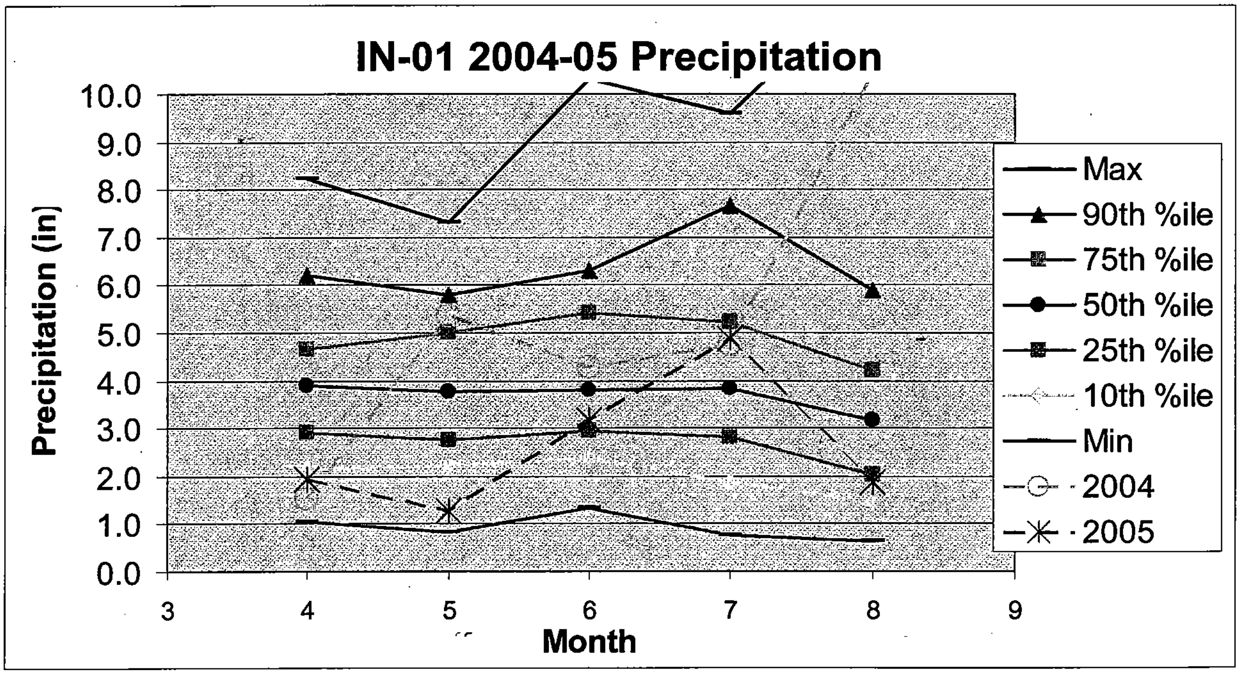
0-50% corn planted
50-100% planted
IL-09, 2005
DailyPrecip (in)
Atrazine Residue (ppb) w/non detects @ LOD
Apr 25-50th %ile
May 10-25th %ile
Jun 25th %ile
Jul 25th %ile
Aug 25th %ile
Precipitation (in)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Atrazine Residues (ppb)
20
18
16
14
12
10
8
6
4
2
0
4/1/05
4/15/05
4/29/05
5/13/05
5/27/05
6/10/05
6/24/05
7/8/05
7/22/05
8/5/05
8/19/05
Date

12. IN-01, 2004-05

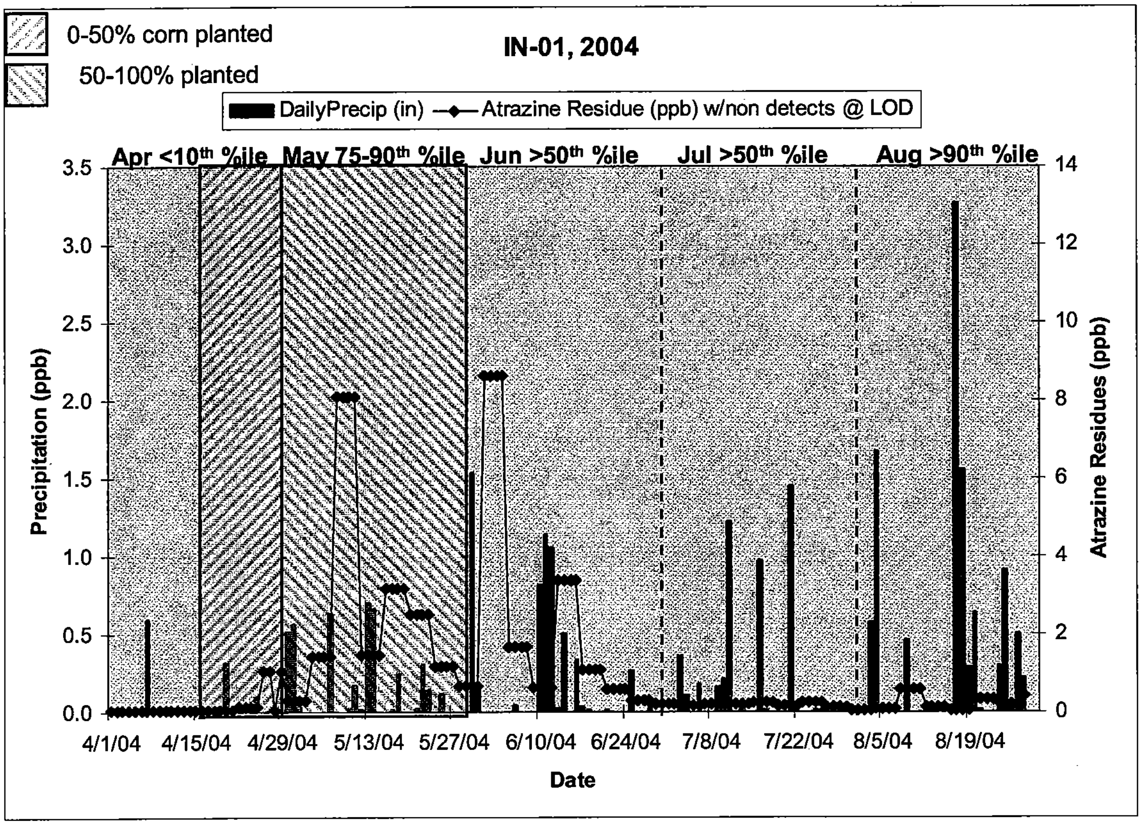
Watershed Location: Mill Creek, IN
NWS Weather Station:

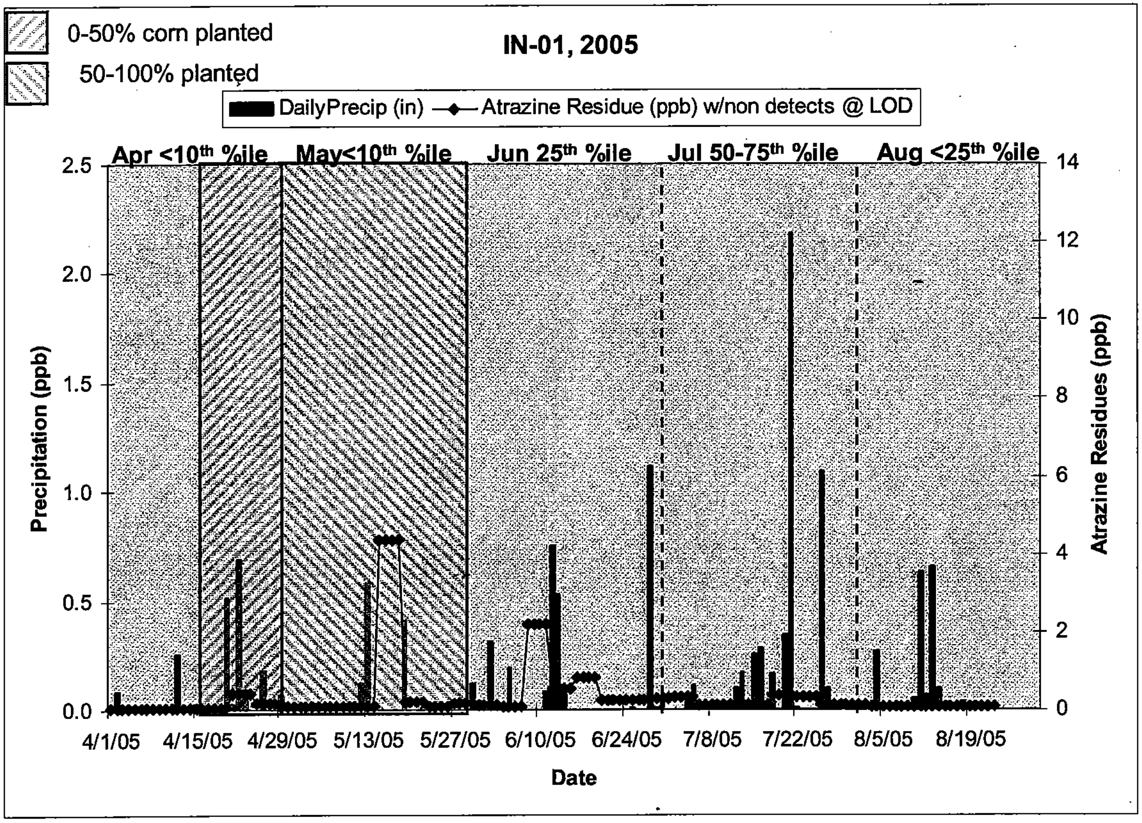
	April Total (in)	May Total (in)	June Total (in)	July Total (in)	August Total (in)	Apr-Aug Total (in)
Historical precipitation summaries, 1948-2001						
Max	8.24	7.32	10.32	9.60	12.39	34.40
90th %ile	6.20	5.80	6.29	7.66	5.89	25.61
75th %ile	4.67	5.00	5.40	5.23	4.21	21.81
50th %ile	3.90	3.78	3.79	3.84	3.18	20.15
25th %ile	2.91	2.74	2.96	2.83	2.04	16.43
10th %ile	2.15	2.21	2.38	1.86	1.44	15.29
Min	1.05	0.83	1.34	0.75	0.63	9.94
Monthly totals during the monitoring study						
2004	1.53	5.34	4.27	4.76	10.41	26.31
2005	1.94	1.27	3.15	4.86	1.87	13.09

Monthly precipitation for 2004 was high in May (above the 75th percentile) and August (>90th percentile). In 2005, rainfall was low (at or below the 10th percentile) in April, May, and August.



The following figures show the daily precipitation and atrazine residues in water for 2004 and 2005. The planting season is shaded to provide a point of reference for the likely timing of applications in the watershed.


▨ 0-50% corn planted
▨ 50-100% planted
IN-01, 2004
DailyPrecip (in)
Atrazine Residue (ppb) w/non detects @ LOD
Apr <10th %ile
May 75-90th %ile
Jun >50th %ile
Jul >50th %ile
Aug >90th %ile
Precipitation (ppb)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Atrazine Residues (ppb)
14
12
10
8
6
4
2
0
4/1/04
4/15/04
4/29/04
5/13/04
5/27/04
6/10/04
6/24/04
7/8/04
7/22/04
8/5/04
8/19/04
Date

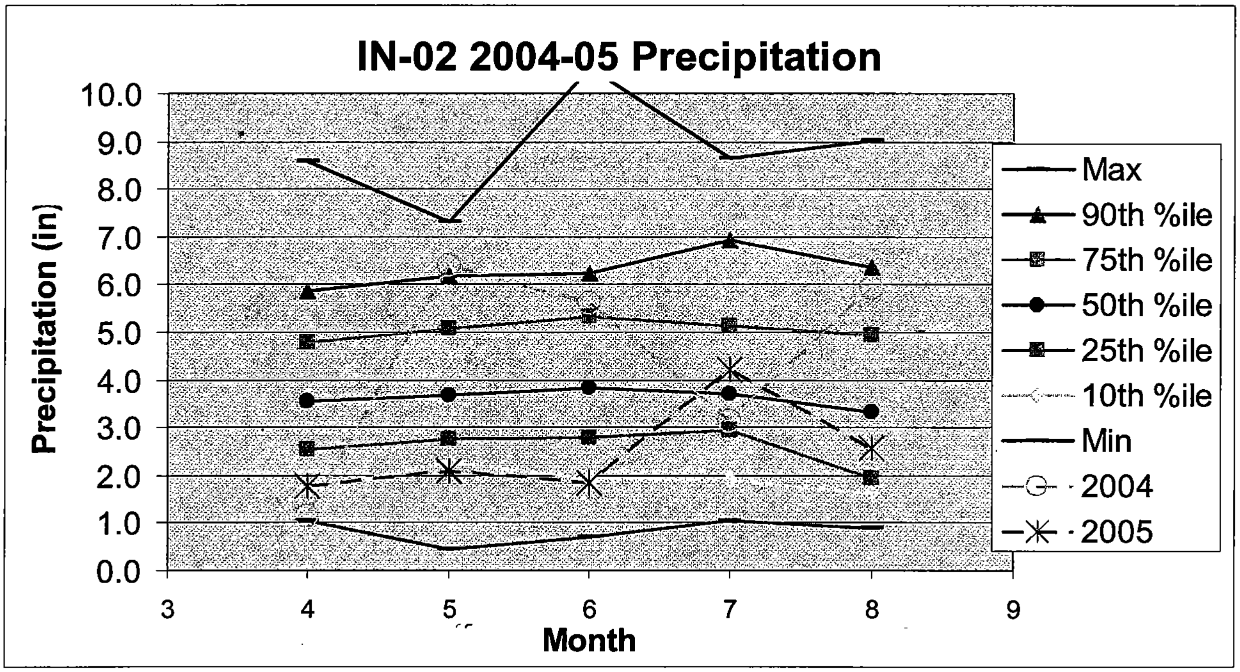

▨ 0-50% corn planted
▨ 50-100% planted
IN-01, 2005
DailyPrecip (in)
Atrazine Residue (ppb) w/non detects @ LOD
Apr <10th %ile
May<10th %ile
Jun 25th %ile
Jul 50-75th %ile
Aug <25th %ile
Precipitation (ppb)
2.5
2.0
1.5
1.0
0.5
0.0
Atrazine Residues (ppb)
14
12
10
8
6
4
2
0
4/1/05
4/15/05
4/29/05
5/13/05
5/27/05
6/10/05
6/24/05
7/8/05
7/22/05
8/5/05
8/19/05
Date

13. IN-02, 2004-05

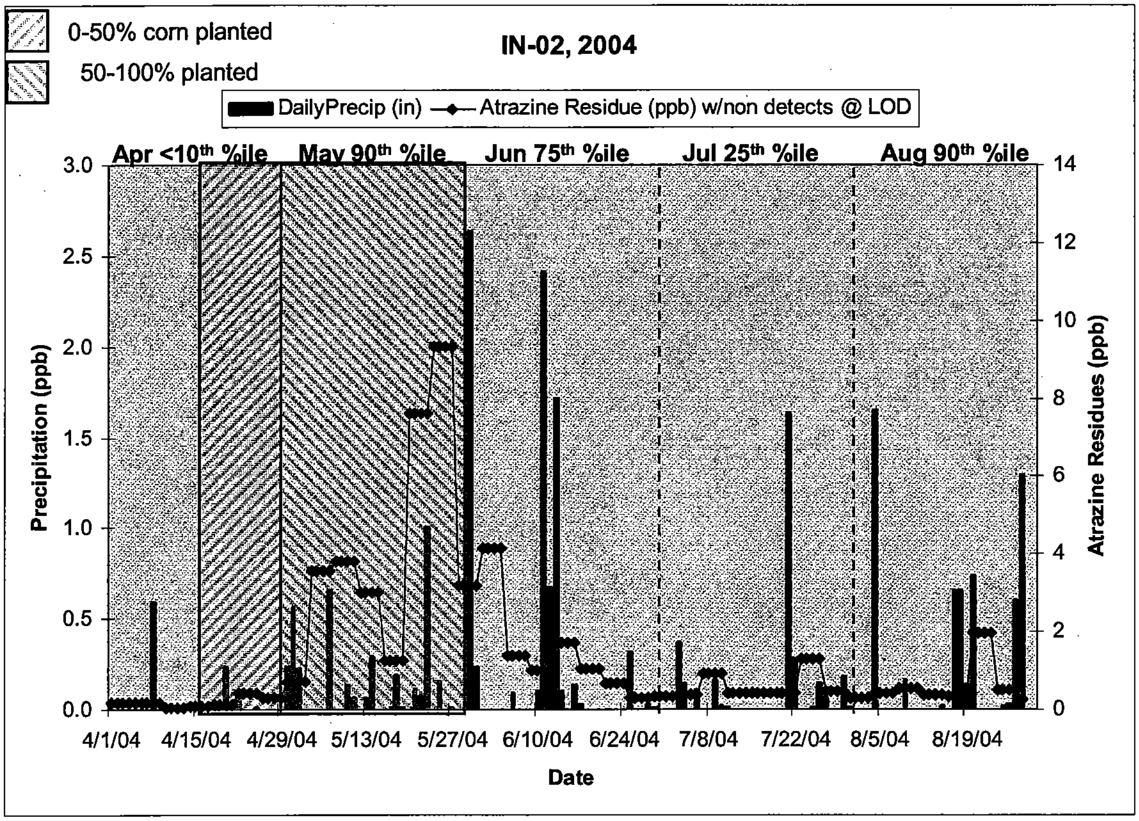
Watershed Location: Eel River, IN
NWS Weather Station:

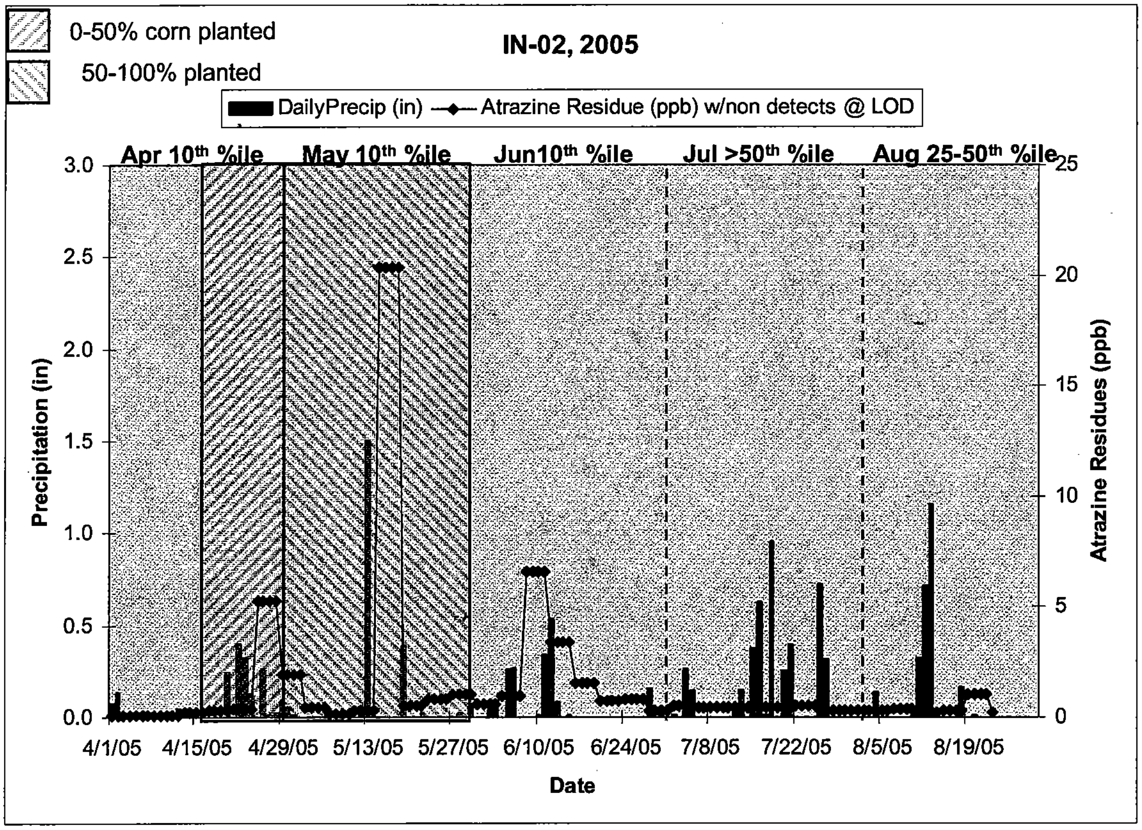
	April Total (in)	May Total (in)	June Total (in)	July Total (in)	August Total (in)	Apr-Aug Total (in)
Historical precipitation summaries, 1948-2001						
Max	8.57	7.31	10.55	8.63	9.02	26.75
90th %ile	5.85	6.16	6.23	6.92	6.35	24.22
75th %ile	4.77	5.06	5.32	5.13	4.92	21.44
50th %ile	3.54	3.69	3.82	3.70	3.34	19.84
25th %ile	2.52	2.75	2.79	2.96	1.93	17.39
10th %ile	1.67	2.27	1.93	1.90	1.60	14.92
Min	1.03	0.43	0.69	1.05	0.90	12.14
Monthly totals during the monitoring study						
2004	1.13	6.38	5.59	3.12	5.93	22.15
2005	1.77	2.09	1.83	4.22	2.56	12.47

Monthly precipitation for 2004 was high (above the 75th percentile) in May, June, and August. In 2005, rainfall was low (at or below the 10th percentile) in April, May, and June.



The following figures show the daily precipitation and atrazine residues in water for 2004 and 2005. The planting season is shaded to provide a point of reference for the likely timing of applications in the watershed.


IN-02, 2004
0-50% corn planted
50-100% planted
DailyPrecip (in)
Atrazine Residue (ppb) w/non detects @ LOD
Apr <10th %ile
May 90th %ile
Jun 75th %ile
Jul 25th %ile
Aug 90th %ile
Precipitation (ppb)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Atrazine Residues (ppb)
14
12
10
8
6
4
2
0
4/1/04
4/15/04
4/29/04
5/13/04
5/27/04
6/10/04
6/24/04
7/8/04
7/22/04
8/5/04
8/19/04
Date

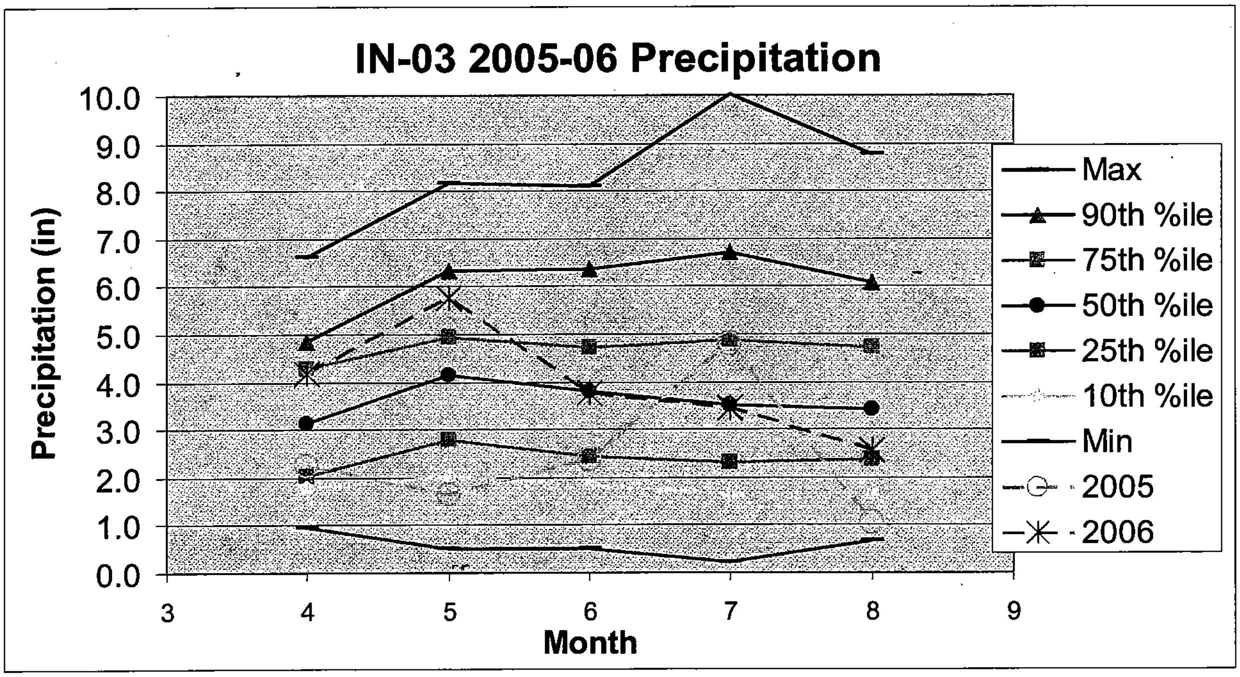

IN-02, 2005
0-50% corn planted
50-100% planted
DailyPrecip (in)
Atrazine Residue (ppb) w/non detects @ LOD
Apr 10th %ile
May 10th %ile
Jun10th %ile
Jul >50th %ile
Aug 25-50th %ile
Precipitation (in)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Atrazine Residues (ppb)
25
20
15
10
5
0
4/1/05
4/15/05
4/29/05
5/13/05
5/27/05
6/10/05
6/24/05
7/8/05
7/22/05
8/5/05
8/19/05
Date

14. IN-03, 2005-06

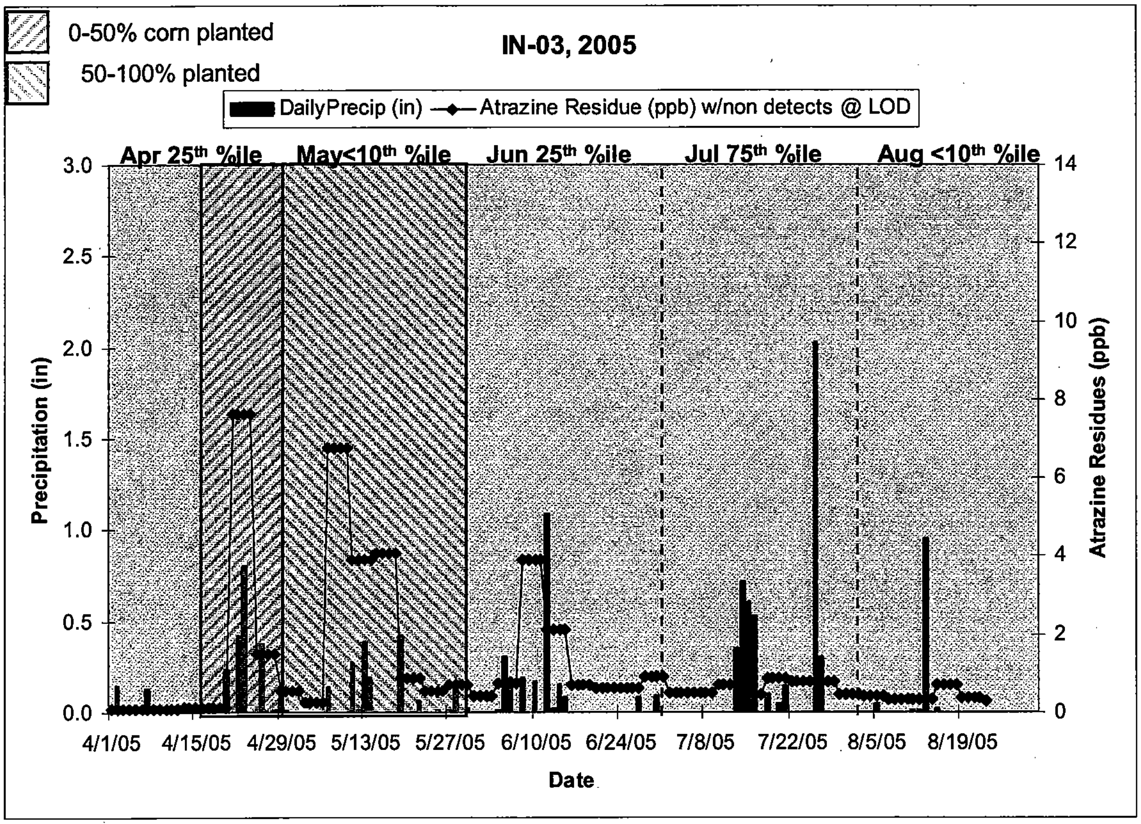
Watershed Location: Eightmile Creek Watershed, IN
NWS Weather Station:

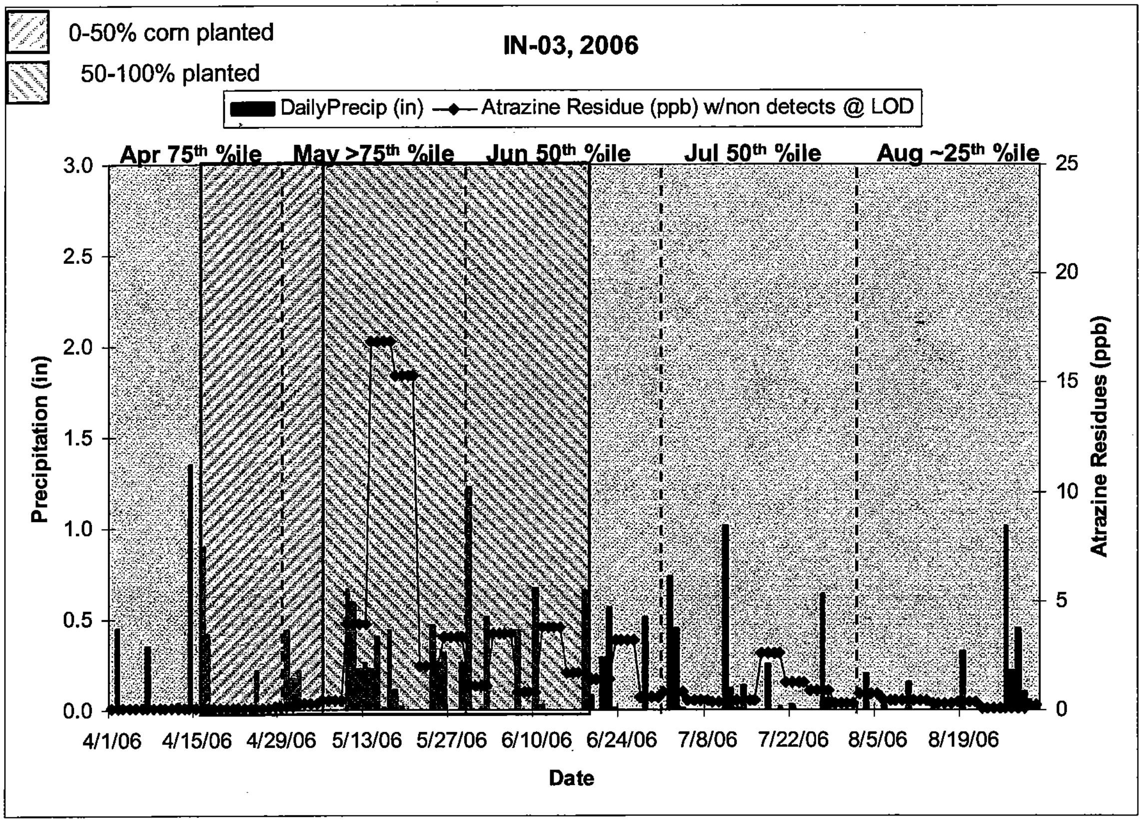
	April Total (in)	May Total (in)	June Total (in)	July Total (in)	August Total (in)	Apr-Aug Total (in)
Historical precipitation summaries, 1971-2001						
Max	6.61	8.16	8.10	10.03	8.77	26.21
90th %ile	4.84	6.33	6.36	6.71	6.08	23.44
75th %ile	4.27	4.94	4.72	4.87	4.71	21.26
50th %ile	3.13	4.16	3.79	3.51	3.43	19.20
25th %ile	2.03	2.77	2.44	2.32	2.39	16.71
10th %ile	1.77	2.03	1.83	1.64	1.63	14.36
Min	0.96	0.51	0.50	0.23	0.66	10.36
Monthly totals during the monitoring study						
2005	2.24	1.63	2.36	4.78	1.03	12.04
2006	4.18	5.77	3.76	3.45	2.57	19.73

Monthly precipitation for 2005 was at or below the 25th percentile from April through June (NOTE: precipitation wasn't recorded for the full month of August in 2005). July was a wetter than normal month. In 2006, monthly precipitation totals were at or above the median from April through July.



The following figures show the daily precipitation and atrazine residues in water for 2005 and 2006. The planting season is shaded to provide a point of reference for the likely timing of applications in the watershed.


0-50% corn planted
50-100% planted
IN-03, 2005
DailyPrecip (in)
Atrazine Residue (ppb) w/non detects @ LOD
Apr 25th %ile
May<10th %ile
Jun 25th %ile
Jul 75th %ile
Aug <10th %ile
Precipitation (in)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Atrazine Residues (ppb)
14
12
10
8
6
4
2
0
4/1/05
4/15/05
4/29/05
5/13/05
5/27/05
6/10/05
6/24/05
7/8/05
7/22/05
8/5/05
8/19/05
Date

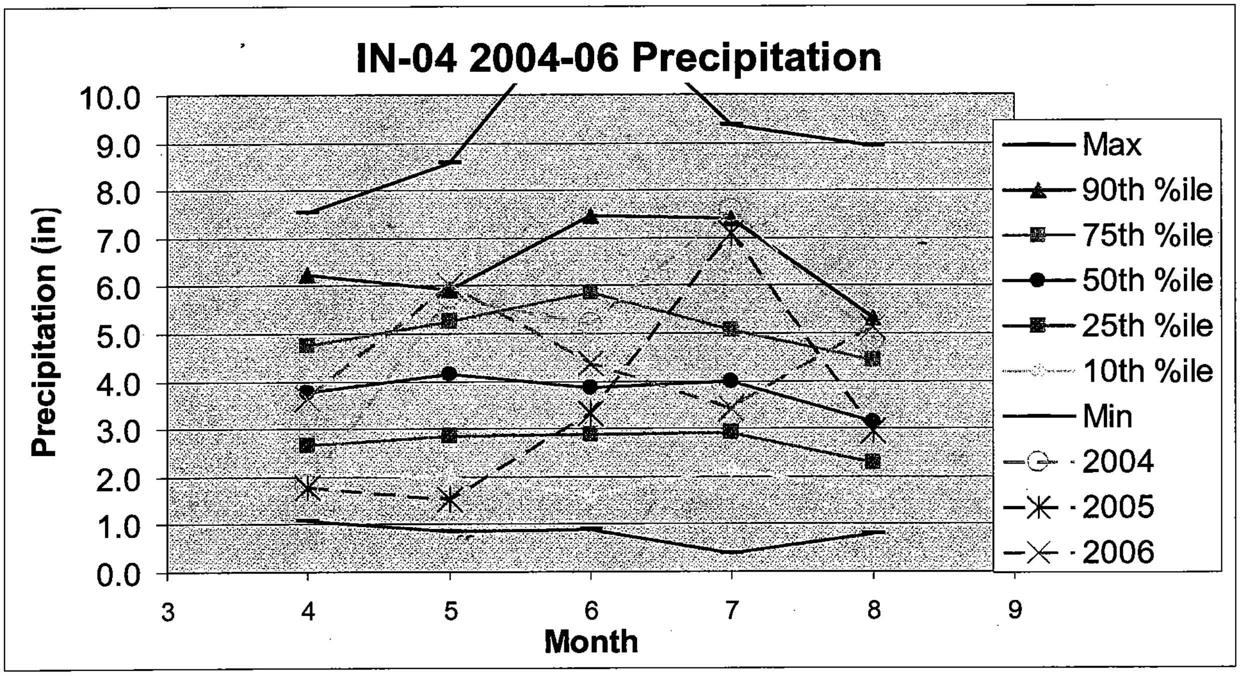

0-50% corn planted
50-100% planted
IN-03, 2006
DailyPrecip (in)
Atrazine Residue (ppb) w/non detects @ LOD
Apr 75th %ile
May >75th %ile
Jun 50th %ile
Jul 50th %ile
Aug ~25th %ile
Precipitation (in)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Atrazine Residues (ppb)
25
20
15
10
5
0
4/1/06
4/15/06
4/29/06
5/13/06
5/27/06
6/10/06
6/24/06
7/8/06
7/22/06
8/5/06
8/19/06
Date

15. IN-04, 2004-06

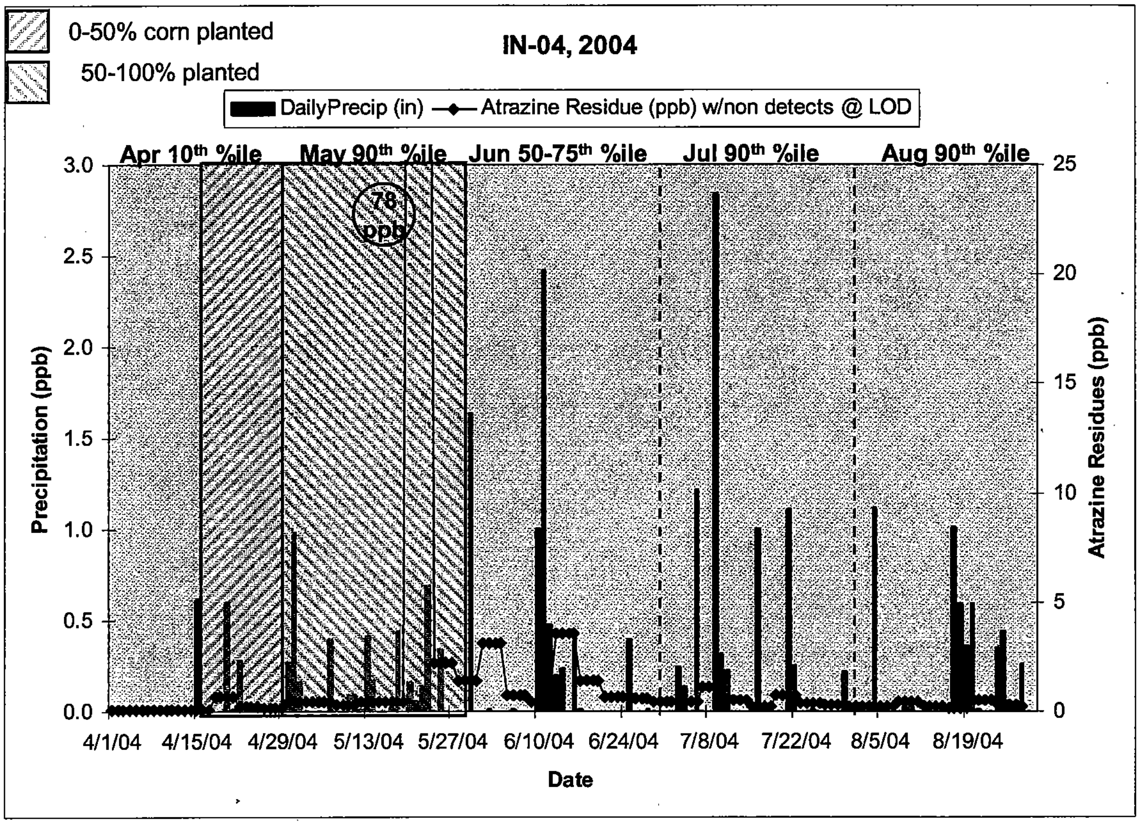
Watershed Location: Rock Creek Watershed, IN
NWS Weather Station:

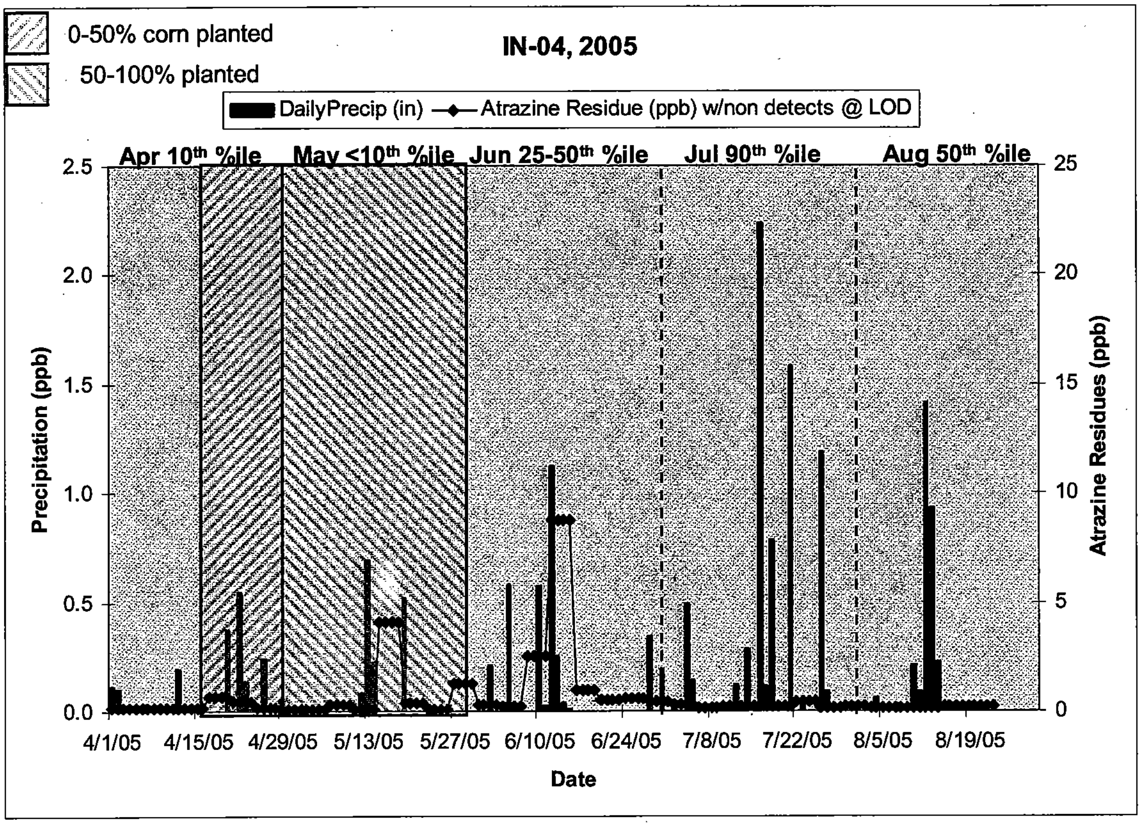
	April Total (in)	May Total (in)	June Total (in)	July Total (in)	August Total (in)	Apr-Aug Total (in)
Historical precipitation summaries, 1948-2001						
Max	7.54	8.59	12.16	9.38	8.91	30.74
90th %ile	6.23	5.91	7.46	7.40	5.31	27.23
75th %ile	4.74	5.24	5.87	5.06	4.44	23.23
50th %ile	3.76	4.14	3.86	3.99	3.13	19.43
25th %ile	2.67	2.86	2.87	2.90	2.27	16.95
10th %ile	2.07	2.00	1.60	2.15	1.69	15.17
Min	1.08	0.85	0.90	0.38	0.78	9.94
Monthly totals during the monitoring study						
2004	1.8	5.75	5.18	7.56	4.86	25.15
2005	1.77	1.51	3.33	7.09	2.95	16.65
2006	3.64	6.01	4.37	3.43	5.12	22.57

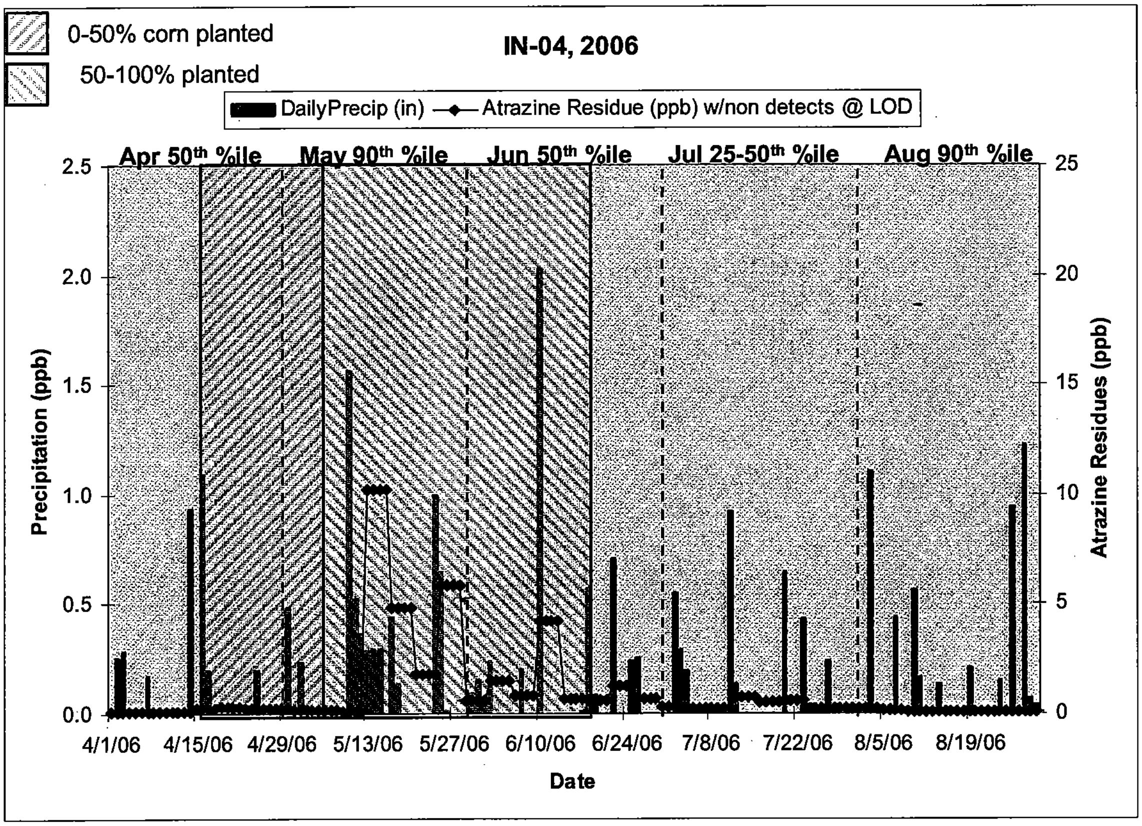
Monthly precipitation in 2004 was high (near the 90th percentile) in May, July, and August. In 2005, monthly precipitation was low (at or below the 10th percentile) in April and May and high (>75th percentile) in July. In 2006, monthly precipitation totals were high (>75th percentile) in May and August.



The following figures show the daily precipitation and atrazine residues in water for 2004, 2005 and 2006. The planting season is shaded to provide a point of reference for the likely timing of applications in the watershed.




0-50% corn planted
50-100% planted
IN-04, 2005
DailyPrecip (in)
Atrazine Residue (ppb) w/non detects @ LOD
Apr 10th %ile
May <10th %ile
Jun 25-50th %ile
Jul 90th %ile
Aug 50th %ile
Precipitation (ppb)
2.5
2.0
1.5
1.0
0.5
0.0
Atrazine Residues (ppb)
25
20
15
10
5
0
4/1/05
4/15/05
4/29/05
5/13/05
5/27/05
6/10/05
6/24/05
7/8/05
7/22/05
8/5/05
8/19/05
Date

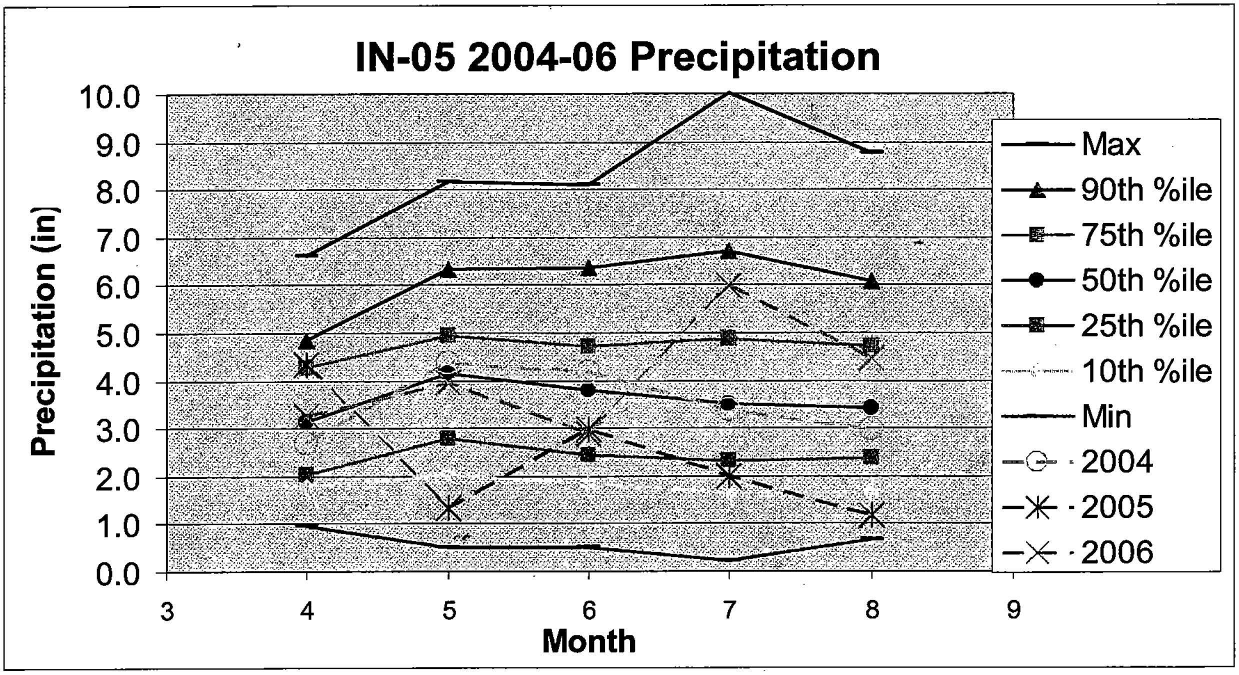

0-50% corn planted
50-100% planted
IN-04, 2006
DailyPrecip (in)
Atrazine Residue (ppb) w/non detects @ LOD
Apr 50th %ile
May 90th %ile
Jun 50th %ile
Jul 25-50th %ile
Aug 90th %ile
Precipitation (ppb)
2.5
2.0
1.5
1.0
0.5
0.0
Atrazine Residues (ppb)
25
20
15
10
5
0
4/1/06
4/15/06
4/29/06
5/13/06
5/27/06
6/10/06
6/24/06
7/8/06
7/22/06
8/5/06
8/19/06
Date

16. IN-05, 2004-06

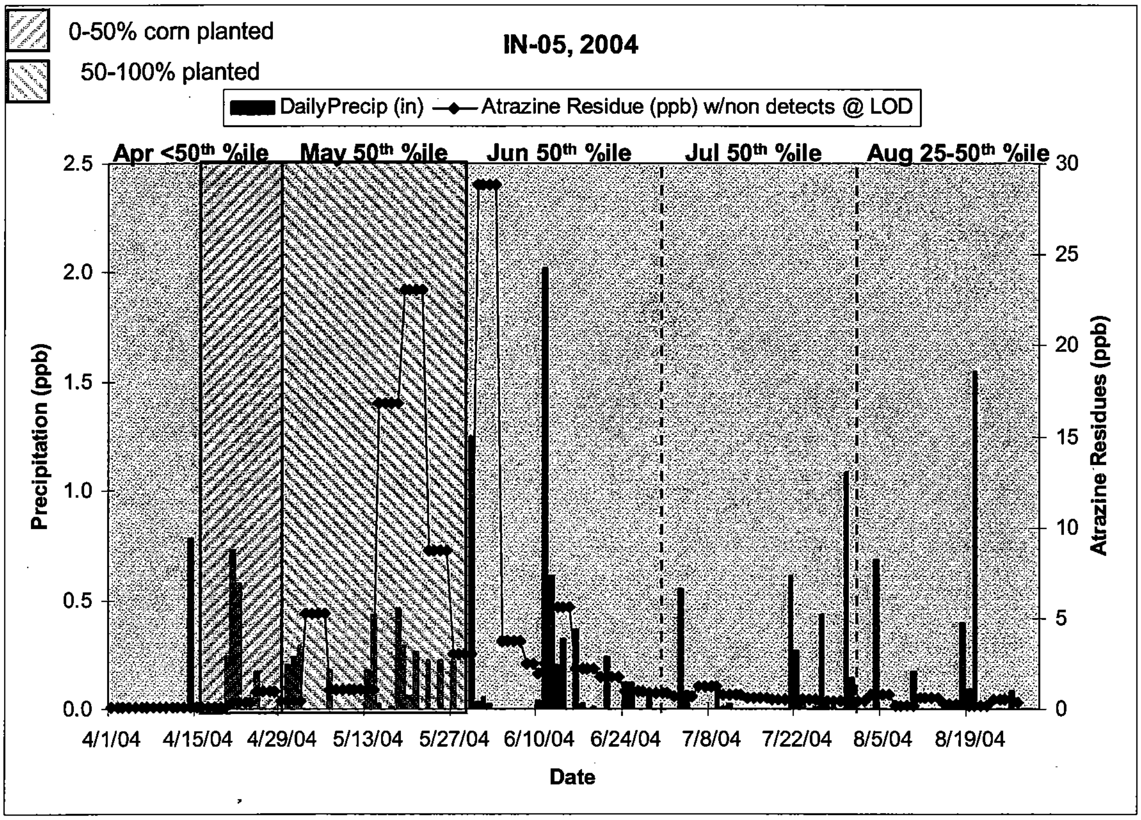
Watershed Location: Limber Lost Creek Watershed, IN
NWS Weather Station:

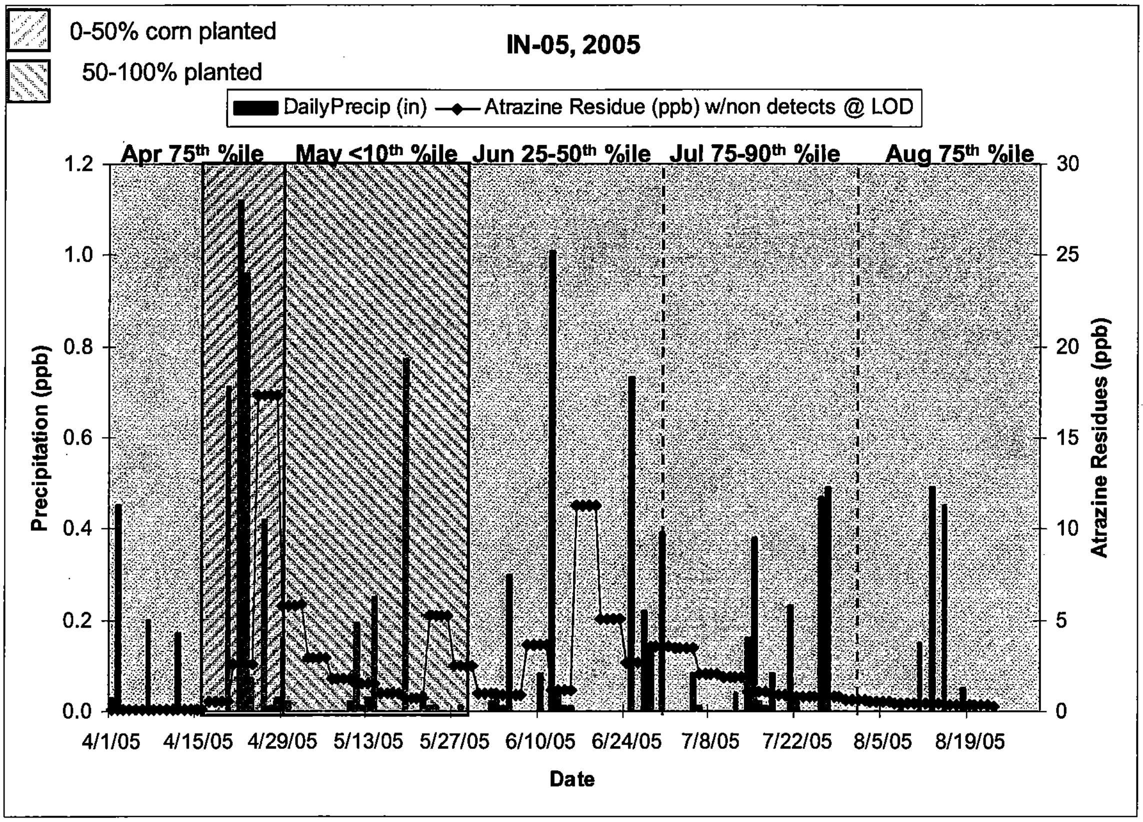
	April Total (in)	May Total (in)	June Total (in)	July Total (in)	August Total (in)	Apr-Aug Total (in)
Historical precipitation summaries, 1971-2001						
Max	6.61	8.16	8.10	10.03	8.77	26.21
90th %ile	4.84	6.33	6.36	6.71	6.08	23.44
75th %ile	4.27	4.94	4.72	4.87	4.71	21.26
50th %ile	3.13	4.16	3.79	3.51	3.43	19.20
25th %ile	2.03	2.77	2.44	2.32	2.39	16.71
10th %ile	1.77	2.03	1.83	1.64	1.63	14.36
Min	0.96	0.51	0.50	0.23	0.66	10.36
Monthly totals during the monitoring study						
2004	2.69	4.36	4.19	3.39	2.97	17.6
2005	4.35	1.34	2.99	1.99	1.18	11.85
2006	3.27	3.94	2.87	5.98	4.45	20.51

Monthly precipitation in 2004 was near the median throughout the sampling period. In 2005, monthly precipitation was high (75th percentile) in April and low (at or below the 10th percentile) in May, July, and August. In 2006, monthly precipitation totals were high (75th percentile) in July and August.

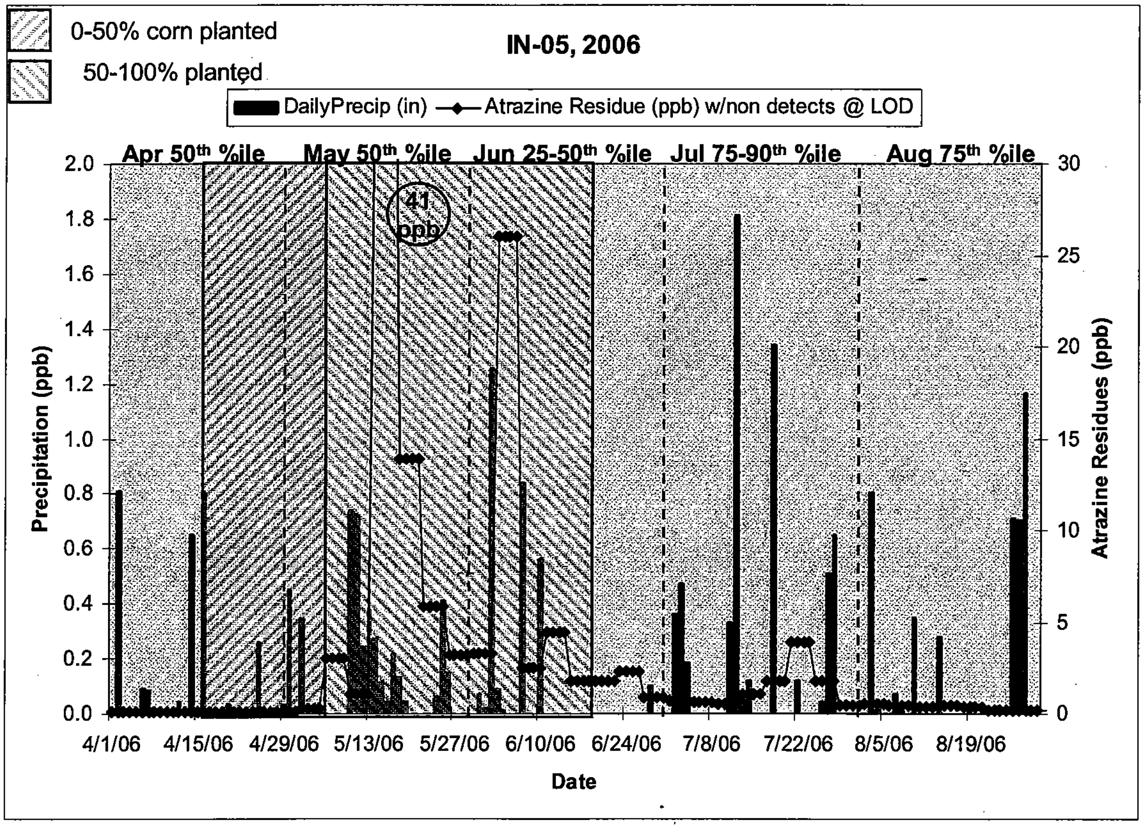


The following figures show the daily precipitation and atrazine residues in water for 2004, 2005 and 2006. The planting season is shaded to provide a point of reference for the likely timing of applications in the watershed.





▨ 0-50% corn planted
▨ 50-100% planted
IN-05, 2005
DailyPrecip (in)
Atrazine Residue (ppb) w/non detects @ LOD
Apr 75th %ile
May <10th %ile
Jun 25-50th %ile
Jul 75-90th %ile
Aug 75th %ile
Precipitation (ppb)
Atrazine Residues (ppb)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
0
5
10
15
20
25
30
4/1/05
4/15/05
4/29/05
5/13/05
5/27/05
6/10/05
6/24/05
7/8/05
7/22/05
8/5/05
8/19/05
Date



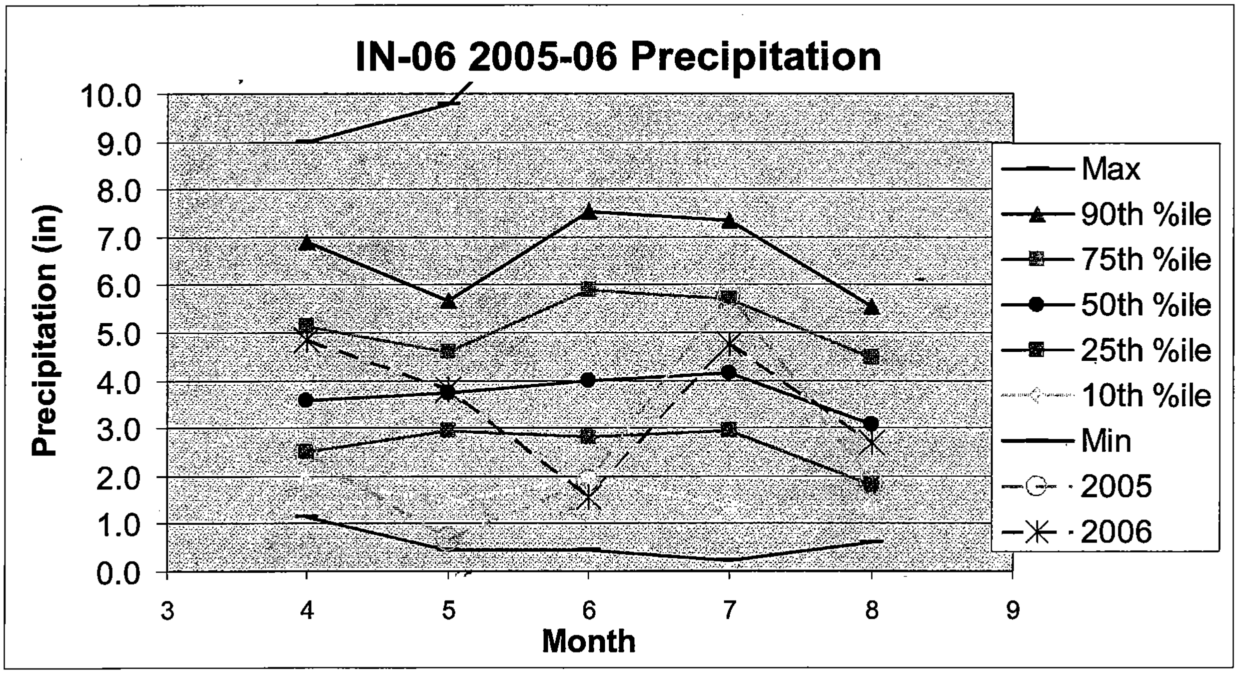
▨ 0-50% corn planted
▨ 50-100% planted
IN-05, 2006
DailyPrecip (in)
Atrazine Residue (ppb) w/non detects @ LOD
Apr 50th %ile
May 50th %ile
Jun 25-50th %ile
Jul 75-90th %ile
Aug 75th %ile
41 ppb
Precipitation (ppb)
Atrazine Residues (ppb)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
0
5
10
15
20
25
30
4/1/06
4/15/06
4/29/06
5/13/06
5/27/06
6/10/06
6/24/06
7/8/06
7/22/06
8/5/06
8/19/06
Date

17. IN-06, 2005-06

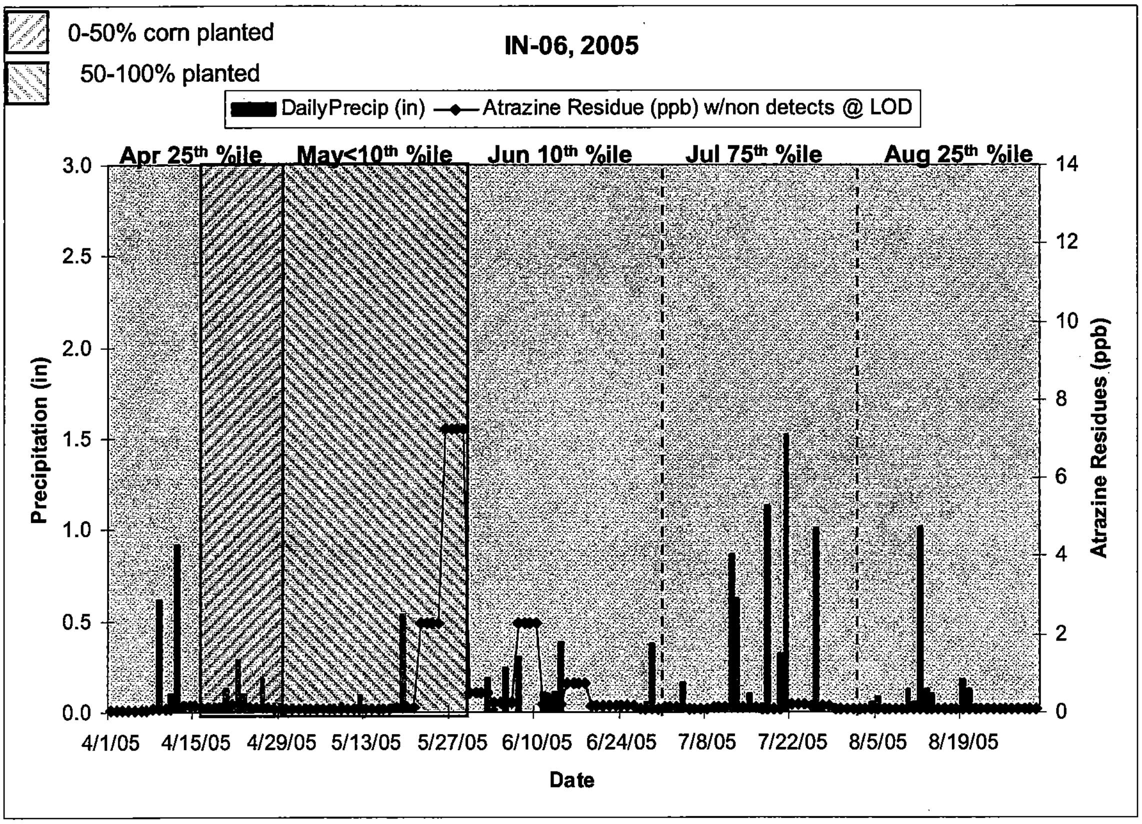
Watershed Location: Vermillion River, North Fork Watershed, IN
NWS Weather Station:

	April Total (in)	May Total (in)	June Total (in)	July Total (in)	August Total (in)	Apr-Aug Total (in)
Historical precipitation summaries, 1948-2001						
Max	8.99	9.78	12.68	12.69	11.02	30.64
90th %ile	6.90	5.67	7.53	7.33	5.53	24.09
75th %ile	5.12	4.60	5.88	5.70	4.45	21.11
50th %ile	3.59	3.73	4.00	4.14	3.07	19.59
25th %ile	2.50	2.95	2.81	2.94	1.79	17.51
10th %ile	1.94	1.47	1.96	1.37	1.33	15.59
Min	1.13	0.44	0.45	0.22	0.61	6.76
Monthly totals during the monitoring study						
2005	2.46	0.68	1.87	5.79	1.85	12.65
2006	4.84	3.81	1.55	4.74	2.7	17.64

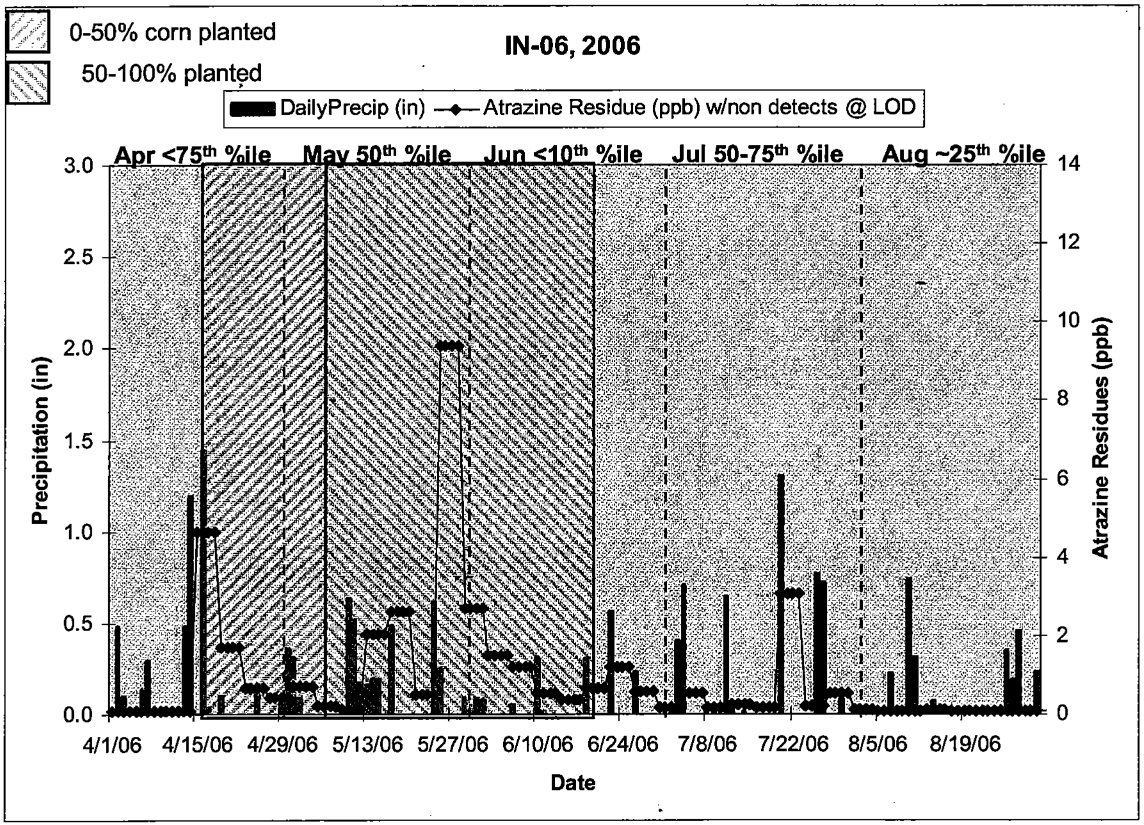
Monthly precipitation for 2005 was at or below the 25th percentile from April through June. July was a wetter than normal month. In 2006, monthly precipitation totals were at or above the median in all months except June, where the monthly total was below the 10th percentile.



The following figures show the daily precipitation and atrazine residues in water for 2005 and 2006. The planting season is shaded to provide a point of reference for the likely timing of applications in the watershed.



▨ 0-50% corn planted
▨ 50-100% planted
IN-06, 2005
DailyPrecip (in)
Atrazine Residue (ppb) w/non detects @ LOD
Apr 25th %ile
May<10th %ile
Jun 10th %ile
Jul 75th %ile
Aug 25th %ile
Precipitation (in)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Atrazine Residues (ppb)
14
12
10
8
6
4
2
0
4/1/05
4/15/05
4/29/05
5/13/05
5/27/05
6/10/05
6/24/05
7/8/05
7/22/05
8/5/05
8/19/05
Date



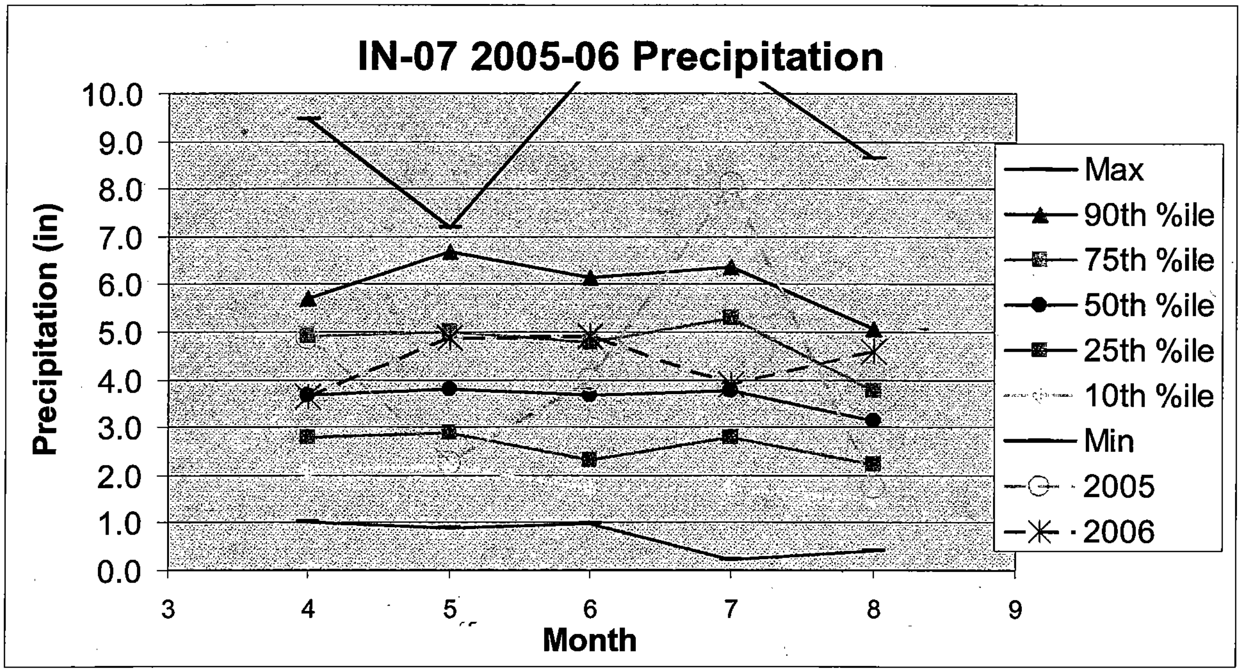
▨ 0-50% corn planted
▨ 50-100% planted
IN-06, 2006
DailyPrecip (in)
Atrazine Residue (ppb) w/non detects @ LOD
Apr <75th %ile
May 50th %ile
Jun <10th %ile
Jul 50-75th %ile
Aug ~25th %ile
Precipitation (in)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Atrazine Residues (ppb)
14
12
10
8
6
4
2
0
4/1/06
4/15/06
4/29/06
5/13/06
5/27/06
6/10/06
6/24/06
7/8/06
7/22/06
8/5/06
8/19/06
Date

18. IN-07 2005-06

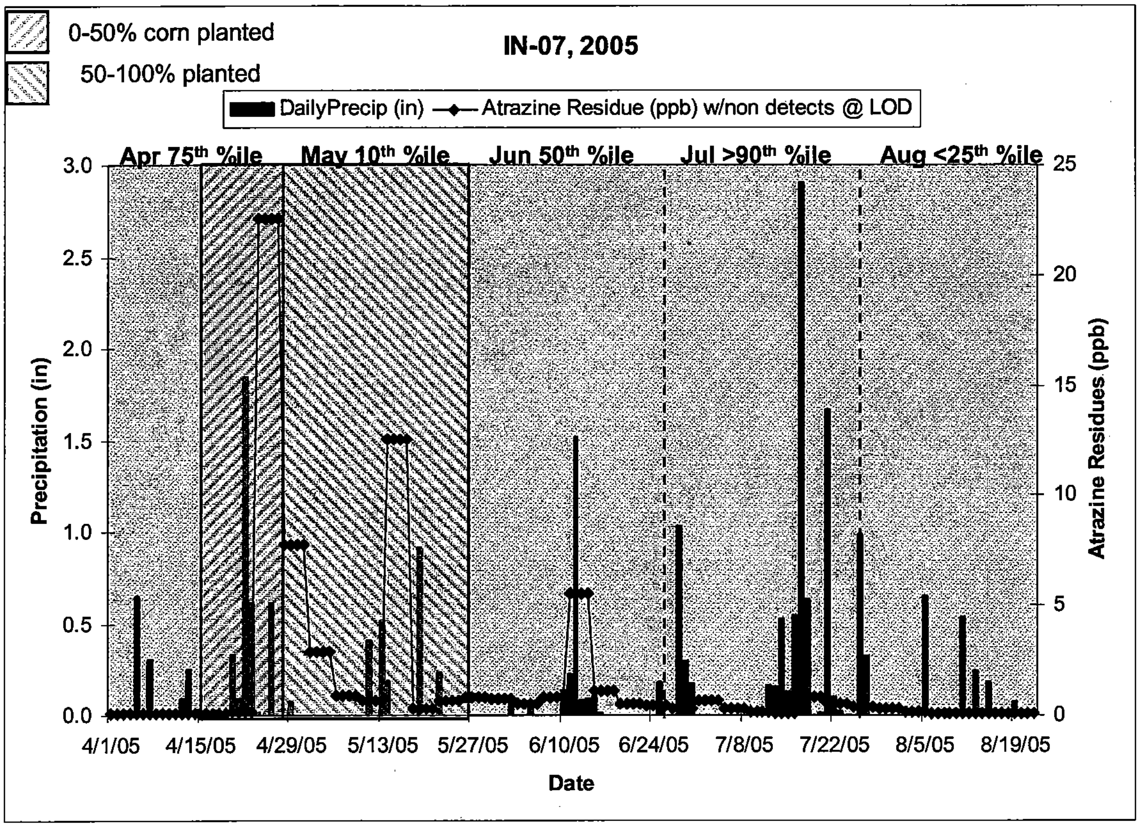
Watershed Location: White River Watershed, IN
NWS Weather Station:

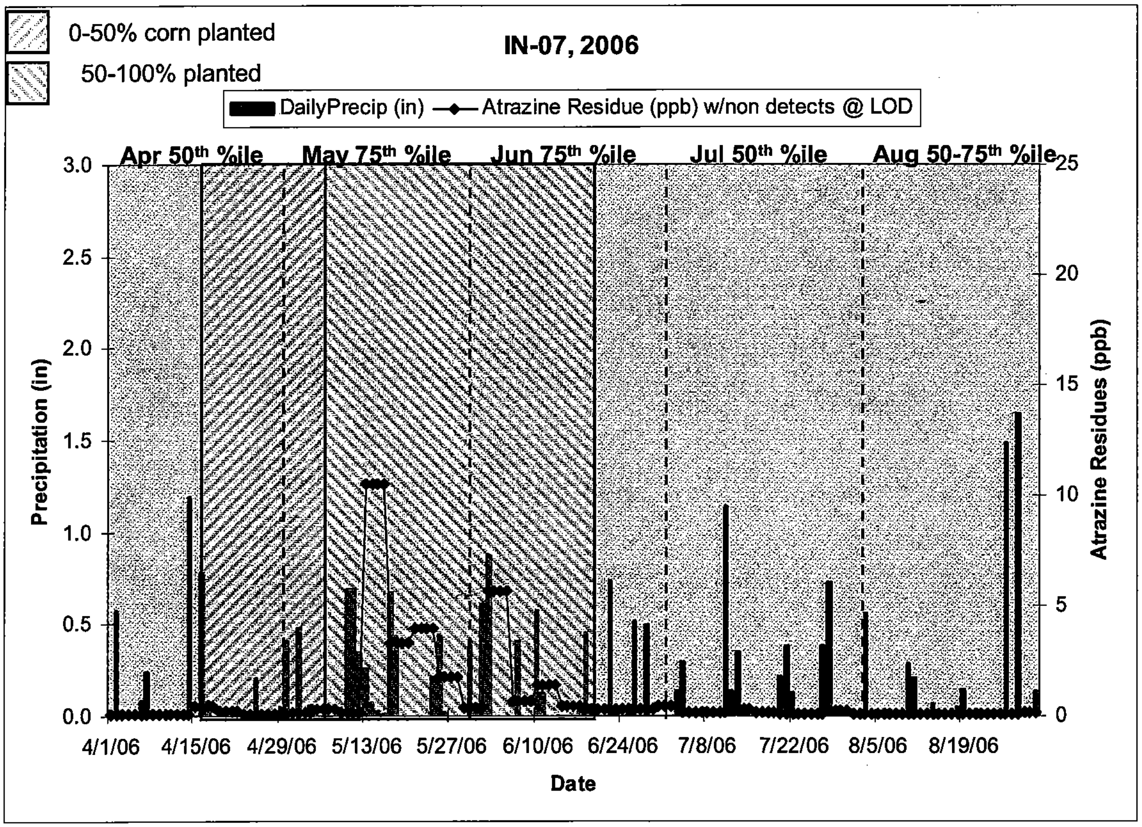
	April Total (in)	May Total (in)	June Total (in)	July Total (in)	August Total (in)	Apr-Aug Total (in)
Historical precipitation summaries, 1948-2001						
Max	9.45	7.17	10.55	10.66	8.63	30.58
90th %ile	5.71	6.67	6.14	6.35	5.06	24.50
75th %ile	4.89	5.00	4.77	5.30	3.78	21.78
50th %ile	3.68	3.81	3.66	3.78	3.14	19.39
25th %ile	2.78	2.89	2.31	2.77	2.20	15.87
10th %ile	2.09	2.19	1.71	1.70	1.50	14.74
Min	1.01	0.89	0.98	0.23	0.41	9.61
Monthly totals during the monitoring study						
2005	4.86	2.25	3.98	8.11	1.73	20.93
2006	3.64	4.86	4.9	3.88	4.59	21.87

Monthly precipitation for 2005 was at or above the median except for May, which was at the 10th percentile. (NOTE: precipitation wasn't recorded for the full month of August in 2005). In 2006, monthly precipitation totals were at or above the median in all months.



The following figures show the daily precipitation and atrazine residues in water for 2005 and 2006. The planting season is shaded to provide a point of reference for the likely timing of applications in the watershed.


0-50% corn planted
50-100% planted
IN-07, 2005
▬ DailyPrecip (in) —◆— Atrazine Residue (ppb) w/non detects @ LOD
Apr 75th %ile
May 10th %ile
Jun 50th %ile
Jul >90th %ile
Aug <25th %ile
Precipitation (in)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Atrazine Residues (ppb)
25
20
15
10
5
0
4/1/05
4/15/05
4/29/05
5/13/05
5/27/05
6/10/05
6/24/05
7/8/05
7/22/05
8/5/05
8/19/05
Date

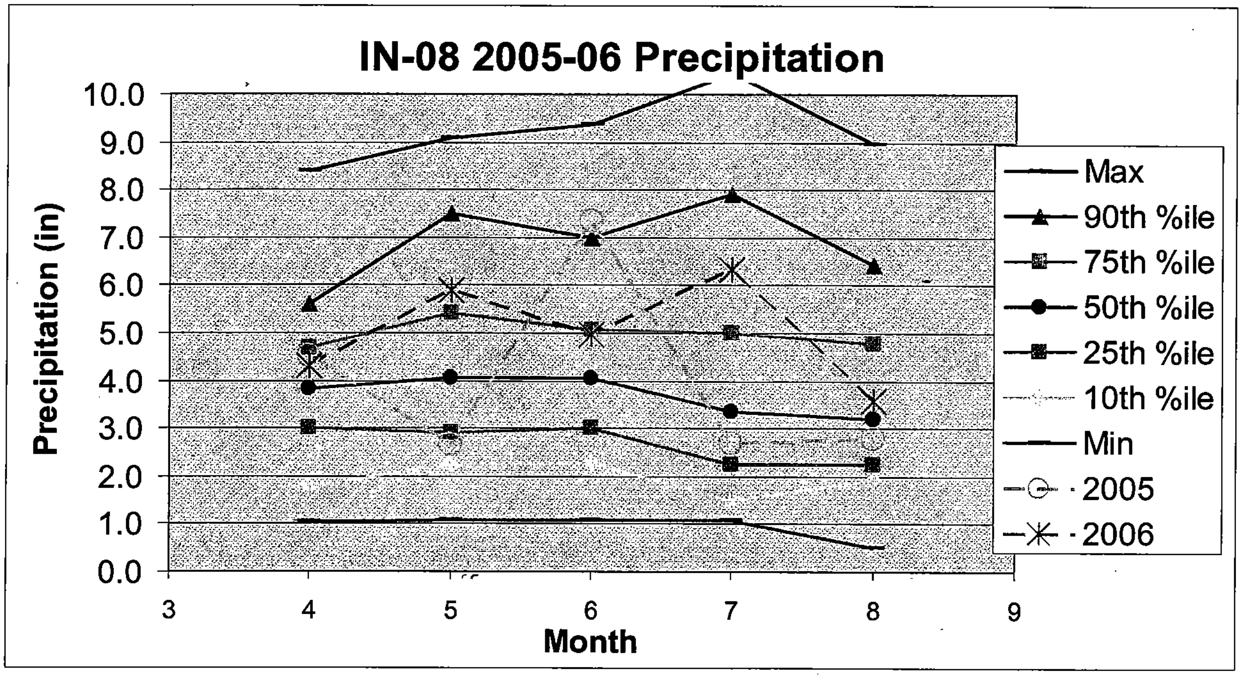

0-50% corn planted
50-100% planted
IN-07, 2006
▬ DailyPrecip (in) —◆— Atrazine Residue (ppb) w/non detects @ LOD
Apr 50th %ile
May 75th %ile
Jun 75th %ile
Jul 50th %ile
Aug 50-75th %ile
Precipitation (in)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Atrazine Residues (ppb)
25
20
15
10
5
0
4/1/06
4/15/06
4/29/06
5/13/06
5/27/06
6/10/06
6/24/06
7/8/06
7/22/06
8/5/06
8/19/06
Date

19. IN-08 2005-06

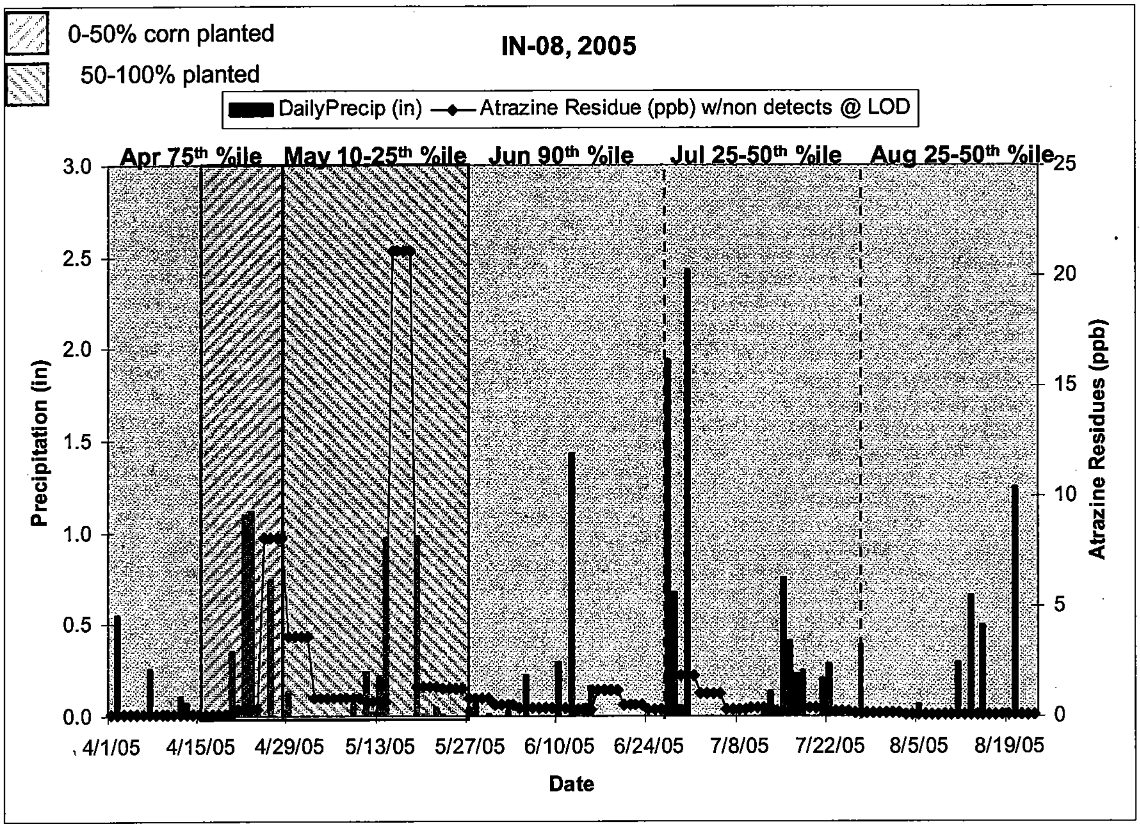
Watershed Location: Whitewater, Nolans Fork Watershed, IN
NWS Weather Station:

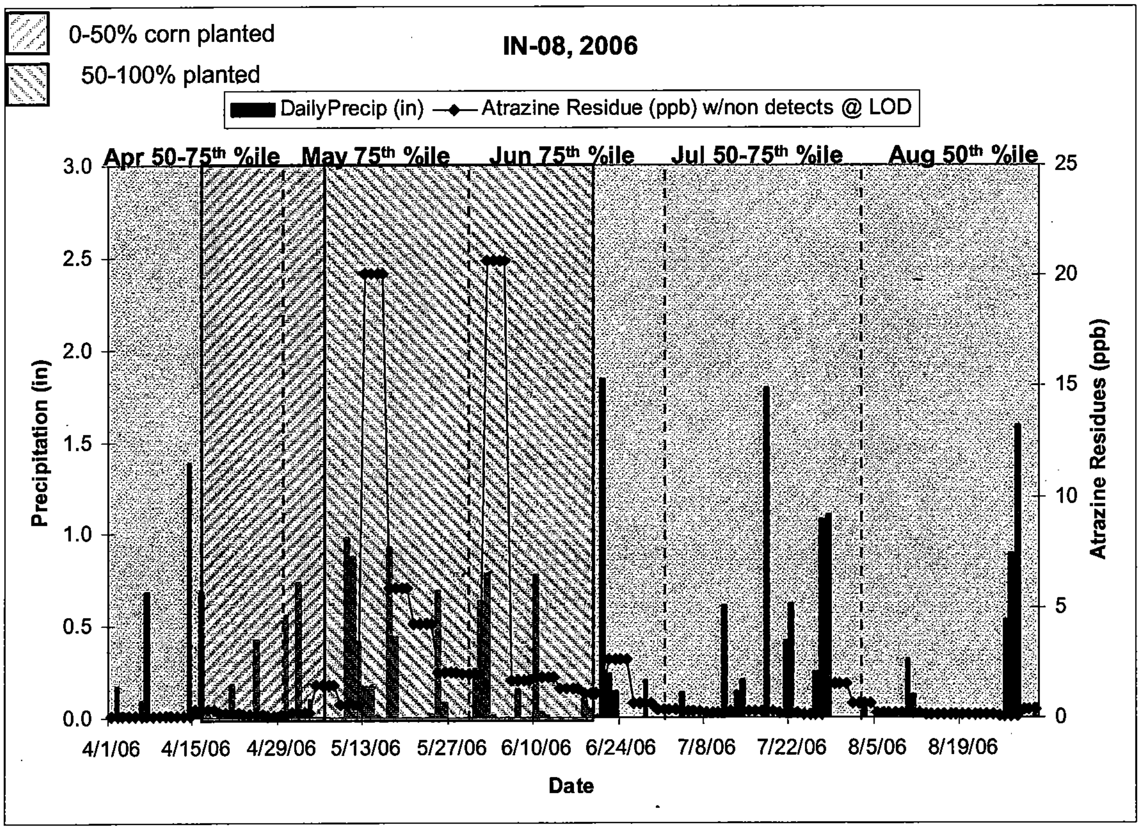
	April Total (in)	May Total (in)	June Total (in)	July Total (in)	August Total (in)	Apr-Aug Total (in)
Historical precipitation summaries, 1969-2001						
Max	8.38	9.09	9.38	10.45	8.95	31.10
90th %ile	5.61	7.51	6.99	7.91	6.41	25.72
75th %ile	4.67	5.41	5.07	4.99	4.79	24.09
50th %ile	3.82	4.04	4.06	3.34	3.19	21.07
25th %ile	3.00	2.90	3.00	2.24	2.26	16.65
10th %ile	1.76	2.24	2.29	1.48	1.94	14.66
Min	1.03	1.08	1.09	1.09	0.52	10.85
Monthly totals during the monitoring study						
2005	4.53	2.67	7.33	2.7	2.8	20.03
2006	4.31	5.88	4.97	6.34	3.58	25.08

Monthly precipitation for 2005 was above the median in April, below the 25th percentile in May, above the 90th percentile in June, and below the median for the rest of the sample period (NOTE: precipitation wasn't recorded for the full month of August in 2005). In 2006, monthly precipitation totals were at or above the median in all months.



The following figures show the daily precipitation and atrazine residues in water for 2005 and 2006. The planting season is shaded to provide a point of reference for the likely timing of applications in the watershed.


0-50% corn planted
50-100% planted
IN-08, 2005
DailyPrecip (in)
Atrazine Residue (ppb) w/non detects @ LOD
Apr 75th %ile
May 10-25th %ile
Jun 90th %ile
Jul 25-50th %ile
Aug 25-50th %ile
Precipitation (in)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Atrazine Residues (ppb)
25
20
15
10
5
0
4/1/05
4/15/05
4/29/05
5/13/05
5/27/05
6/10/05
6/24/05
7/8/05
7/22/05
8/5/05
8/19/05
Date

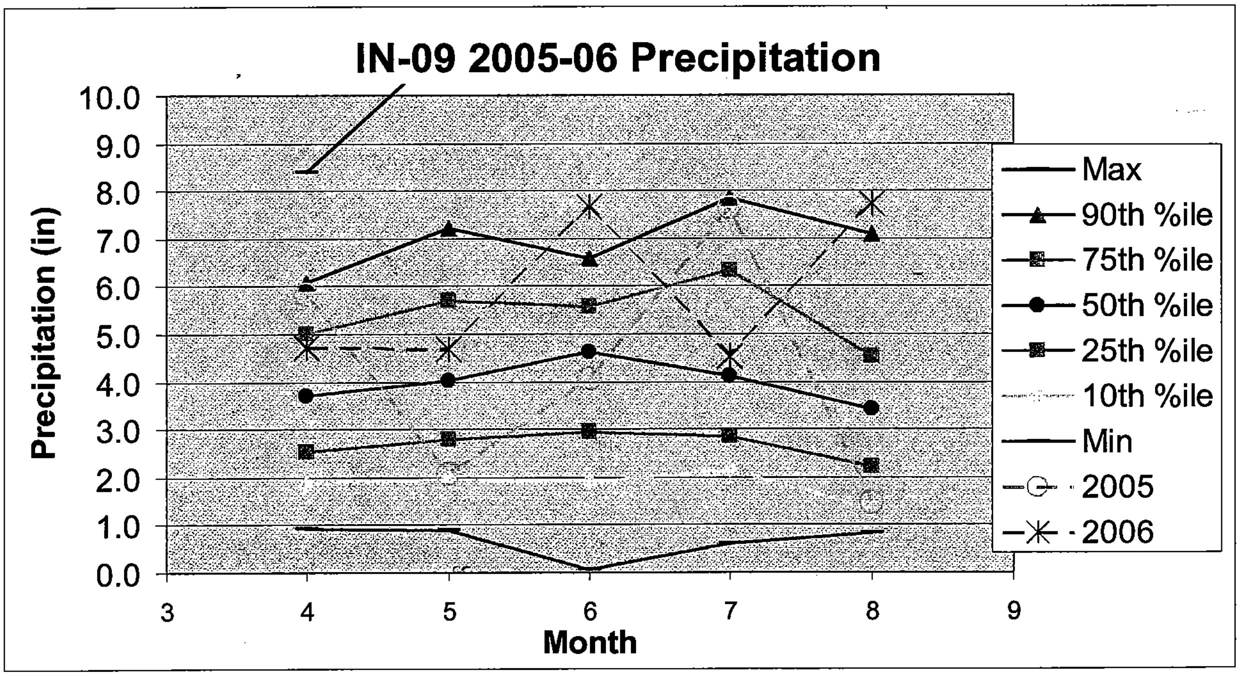

0-50% corn planted
50-100% planted
IN-08, 2006
DailyPrecip (in)
Atrazine Residue (ppb) w/non detects @ LOD
Apr 50-75th %ile
May 75th %ile
Jun 75th %ile
Jul 50-75th %ile
Aug 50th %ile
Precipitation (in)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Atrazine Residues (ppb)
25
20
15
10
5
0
4/1/06
4/15/06
4/29/06
5/13/06
5/27/06
6/10/06
6/24/06
7/8/06
7/22/06
8/5/06
8/19/06
Date

20. IN-09 2005-06

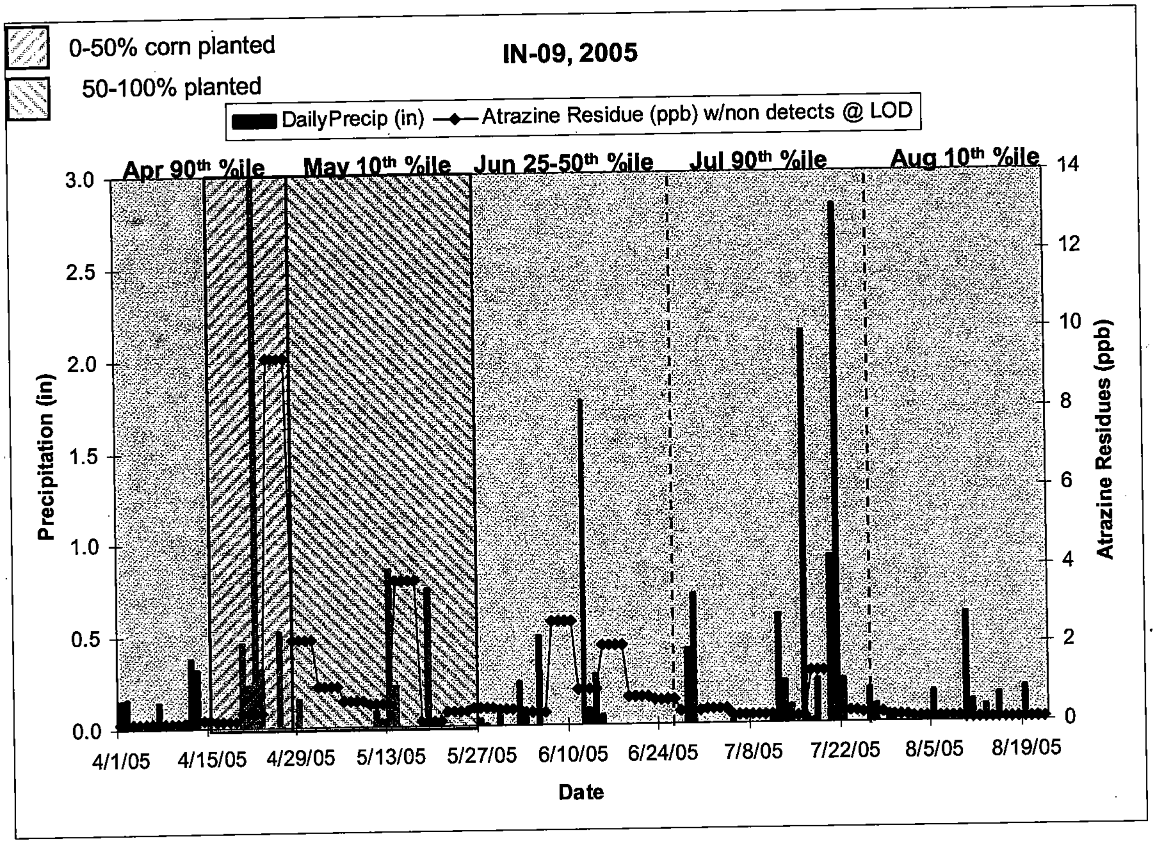
Watershed Location: Raccoon Creek Watershed, IN
NWS Weather Station:

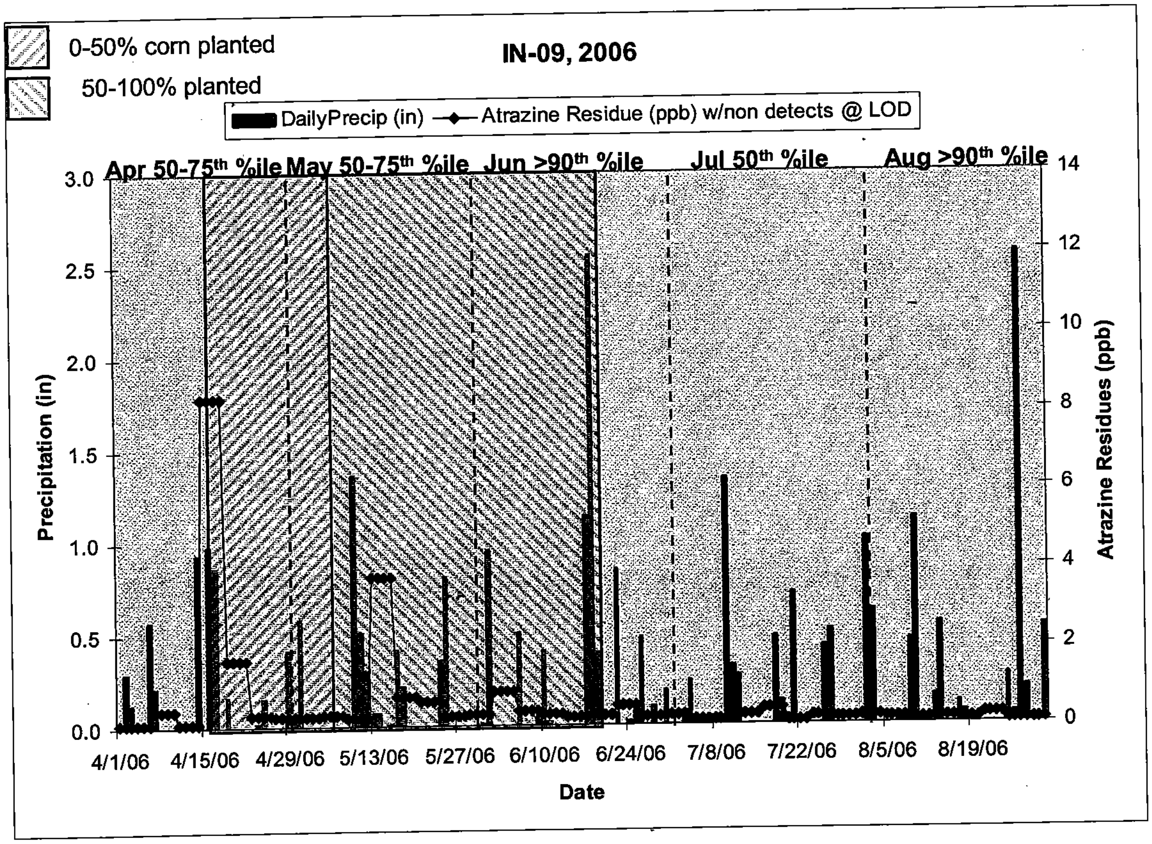
	April Total (in)	May Total (in)	June Total (in)	July Total (in)	August Total (in)	Apr-Aug Total (in)
Historical precipitation summaries, 1948-2001						
Max	8.39	11.12	10.54	11.80	11.22	36.45
90th %ile	6.06	7.22	6.58	7.85	7.07	26.55
75th %ile	4.99	5.69	5.56	6.34	4.54	24.20
50th %ile	3.70	4.01	4.63	4.13	3.42	21.19
25th %ile	2.52	2.79	2.94	2.83	2.20	18.22
10th %ile	1.85	1.97	1.89	2.16	1.33	16.35
Min	0.92	0.90	0.05	0.59	0.83	12.76
Monthly totals during the monitoring study						
2005	5.83	2.07	4.05	7.61	1.45	21.02
2006	4.72	4.69	7.66	4.51	7.72	29.30

Monthly precipitation for 2005 was above the median in April, below the 25th percentile in May, near the 90th percentile in July, and below the median for the rest of the sample period (NOTE: precipitation wasn't recorded for the full month of August in 2005). In 2006, monthly precipitation totals were at or above the median in all months.



The following figures show the daily precipitation and atrazine residues in water for 2005 and 2006. The planting season is shaded to provide a point of reference for the likely timing of applications in the watershed.


0-50% corn planted
50-100% planted
IN-09, 2005
DailyPrecip (in)
Atrazine Residue (ppb) w/non detects @ LOD
Apr 90th %ile
May 10th %ile
Jun 25-50th %ile
Jul 90th %ile
Aug 10th %ile
Precipitation (in)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Atrazine Residues (ppb)
14
12
10
8
6
4
2
0
4/1/05
4/15/05
4/29/05
5/13/05
5/27/05
6/10/05
6/24/05
7/8/05
7/22/05
8/5/05
8/19/05
Date

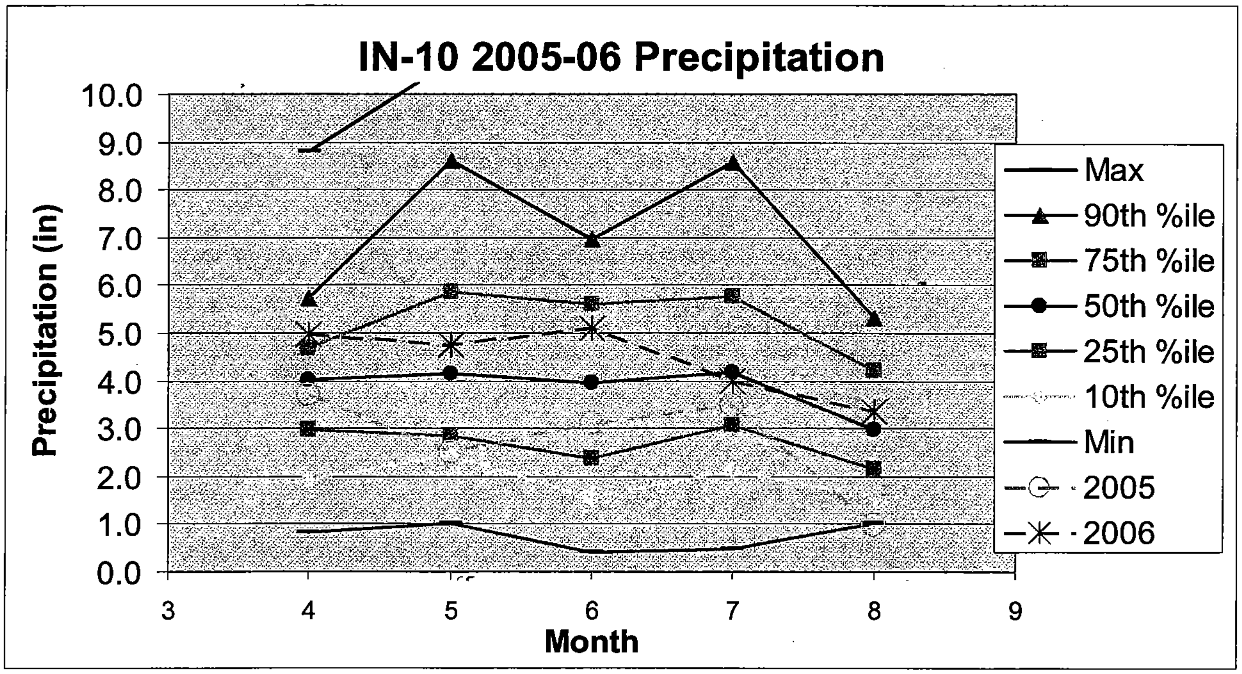

0-50% corn planted
50-100% planted
IN-09, 2006
DailyPrecip (in)
Atrazine Residue (ppb) w/non detects @ LOD
Apr 50-75th %ile
May 50-75th %ile
Jun >90th %ile
Jul 50th %ile
Aug >90th %ile
Precipitation (in)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Atrazine Residues (ppb)
14
12
10
8
6
4
2
0
4/1/06
4/15/06
4/29/06
5/13/06
5/27/06
6/10/06
6/24/06
7/8/06
7/22/06
8/5/06
8/19/06
Date

21. IN-10 2005-06

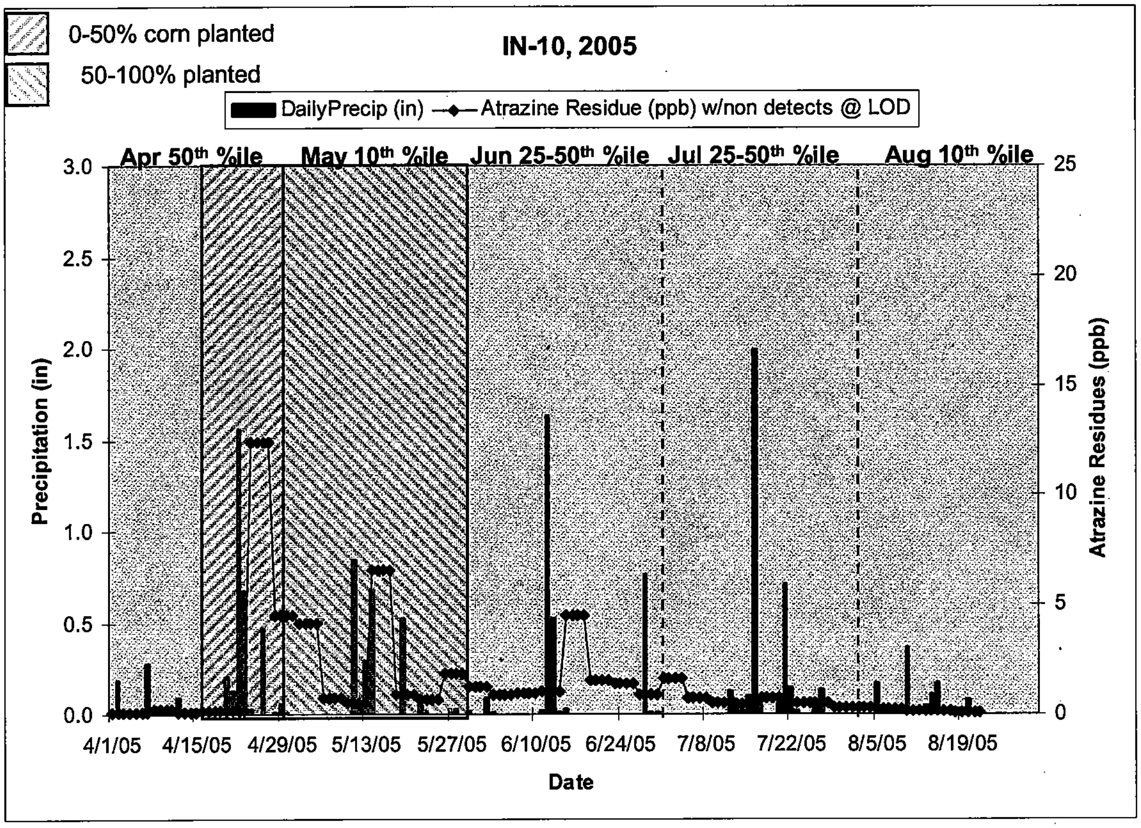
Watershed Location: Brandywine Creek Watershed, IN
NWS Weather Station:

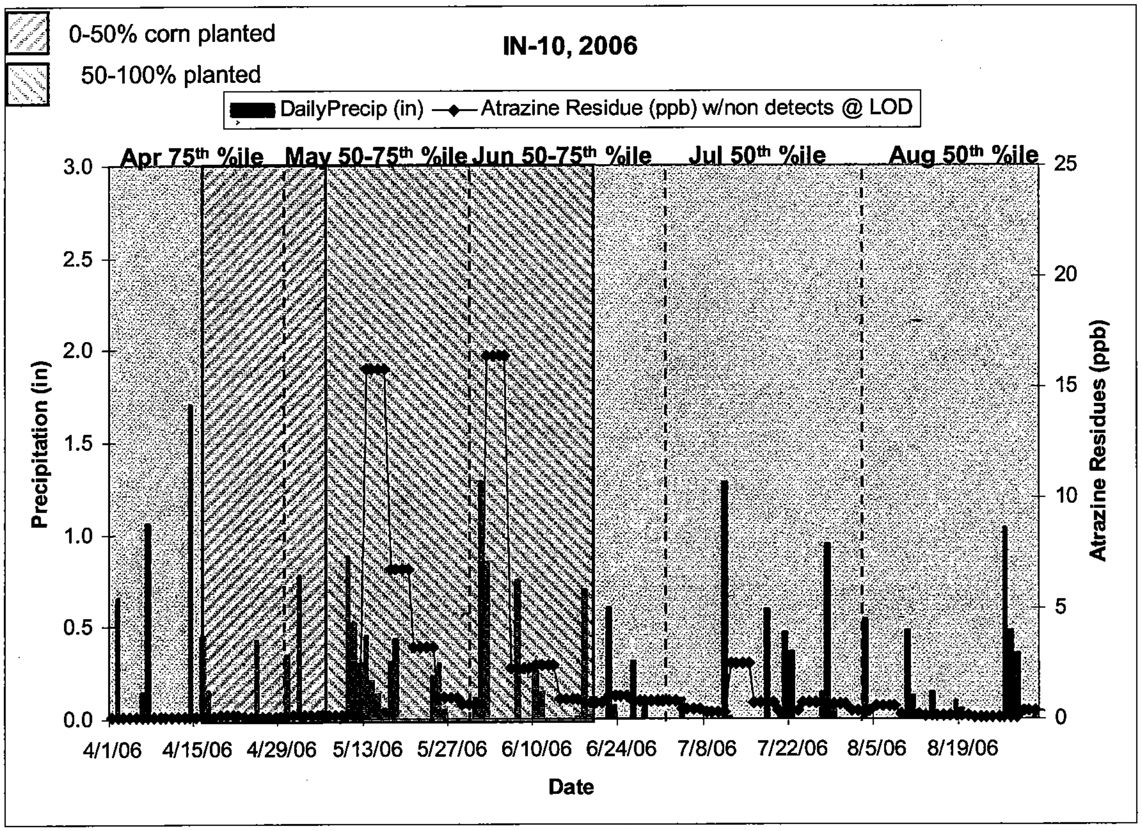
	April Total (in)	May Total (in)	June Total (in)	July Total (in)	August Total (in)	Apr-Aug Total (in)
Historical precipitation summaries, 1948-2001						
Max	8.80	10.70	10.93	11.45	11.25	32.26
90th %ile	5.73	8.60	6.95	8.57	5.32	29.52
75th %ile	4.68	5.87	5.59	5.77	4.20	24.64
50th %ile	4.02	4.16	3.96	4.19	2.98	20.77
25th %ile	2.97	2.86	2.39	3.07	2.17	17.43
10th %ile	1.93	2.43	1.54	2.11	1.55	15.30
Min	0.82	1.00	0.40	0.49	1.00	12.68
Monthly totals during the monitoring study						
2005	3.71	2.49	3.09	3.49	0.98	13.76
2006	4.96	4.76	5.11	4	3.35	22.18

Except for May, which fell to near the 10th percentile, monthly precipitation for 2005 fell between the median and the 25th percentile (NOTE: precipitation wasn't recorded for the full month of August in 2005). In 2006, monthly precipitation totals were at or above the median in all months.



The following figures show the daily precipitation and atrazine residues in water for 2005 and 2006. The planting season is shaded to provide a point of reference for the likely timing of applications in the watershed.


0-50% corn planted
50-100% planted
IN-10, 2005
DailyPrecip (in)
Atrazine Residue (ppb) w/non detects @ LOD
Apr 50th %ile
May 10th %ile
Jun 25-50th %ile
Jul 25-50th %ile
Aug 10th %ile
Precipitation (in)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Atrazine Residues (ppb)
25
20
15
10
5
0
4/1/05
4/15/05
4/29/05
5/13/05
5/27/05
6/10/05
6/24/05
7/8/05
7/22/05
8/5/05
8/19/05
Date

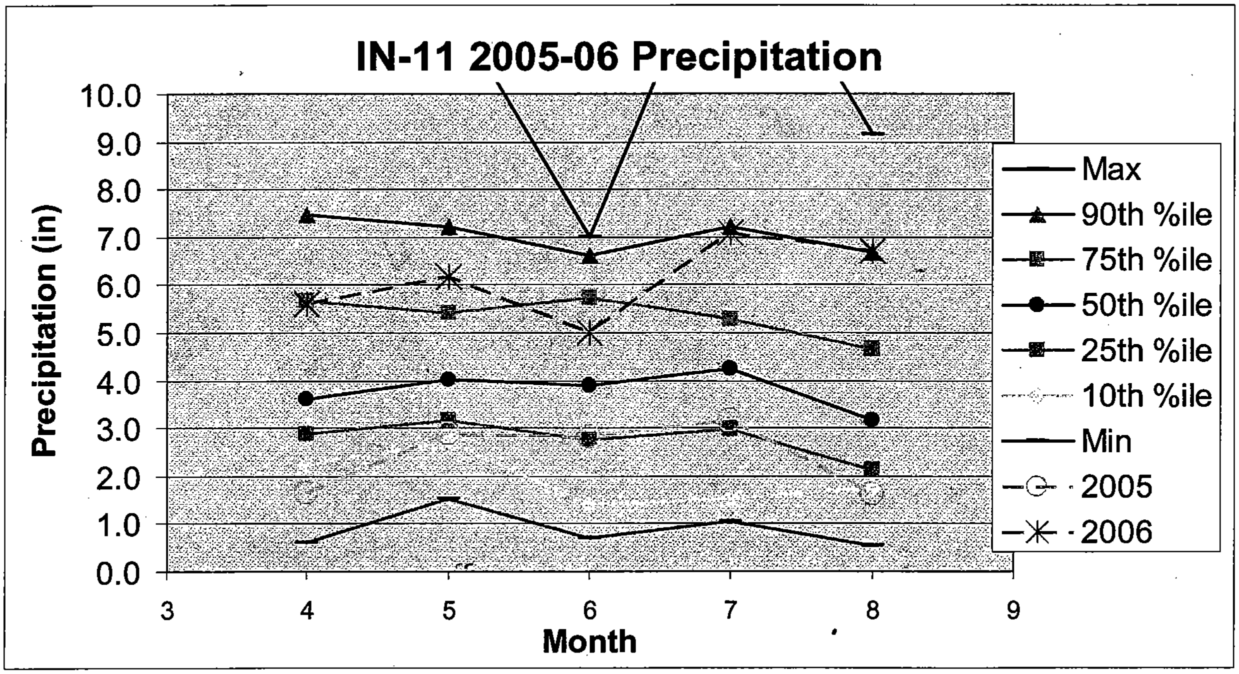

0-50% corn planted
50-100% planted
IN-10, 2006
DailyPrecip (in)
Atrazine Residue (ppb) w/non detects @ LOD
Apr 75th %ile
May 50-75th %ile
Jun 50-75th %ile
Jul 50th %ile
Aug 50th %ile
Precipitation (in)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Atrazine Residues (ppb)
25
20
15
10
5
0
4/1/06
4/15/06
4/29/06
5/13/06
5/27/06
6/10/06
6/24/06
7/8/06
7/22/06
8/5/06
8/19/06
Date

22. IN-11 2005-06

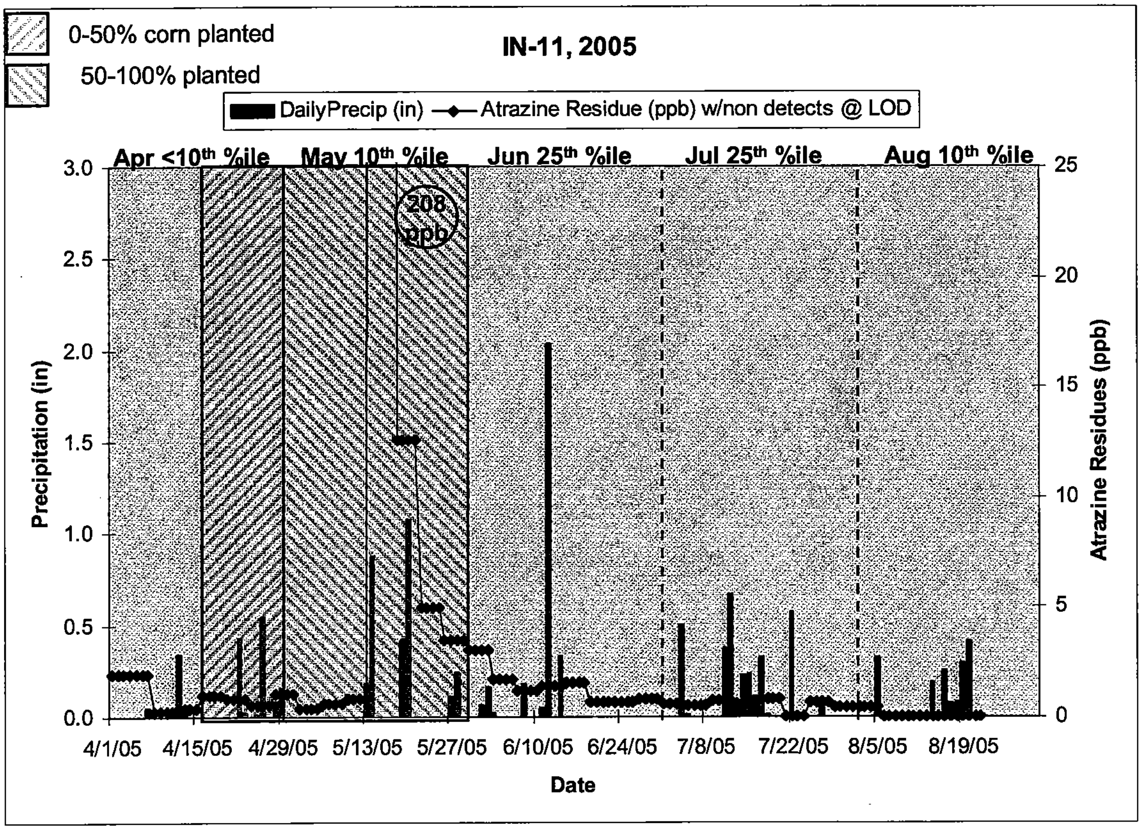
Watershed Location: Little Pigeon Creek Watershed, IN
NWS Weather Station:

	April Total (in)	May Total (in)	June Total (in)	July Total (in)	August Total (in)	Apr-Aug Total (in)
Historical precipitation summaries, 1960-2001						
Max	10.36	11.93	7.00	14.10	9.16	39.97
90th %ile	7.46	7.22	6.61	7.21	6.66	26.88
75th %ile	5.66	5.40	5.74	5.28	4.66	23.44
50th %ile	3.62	4.01	3.90	4.24	3.18	20.18
25th %ile	2.88	3.16	2.76	2.96	2.13	18.12
10th %ile	2.24	2.71	1.40	1.53	1.76	16.20
Min	0.61	1.53	0.71	1.06	0.55	10.75
Monthly totals during the monitoring study						
2005	1.65	2.89	2.82	3.15	1.62	12.13
2006	5.6	6.16	5	7.09	6.71	30.56

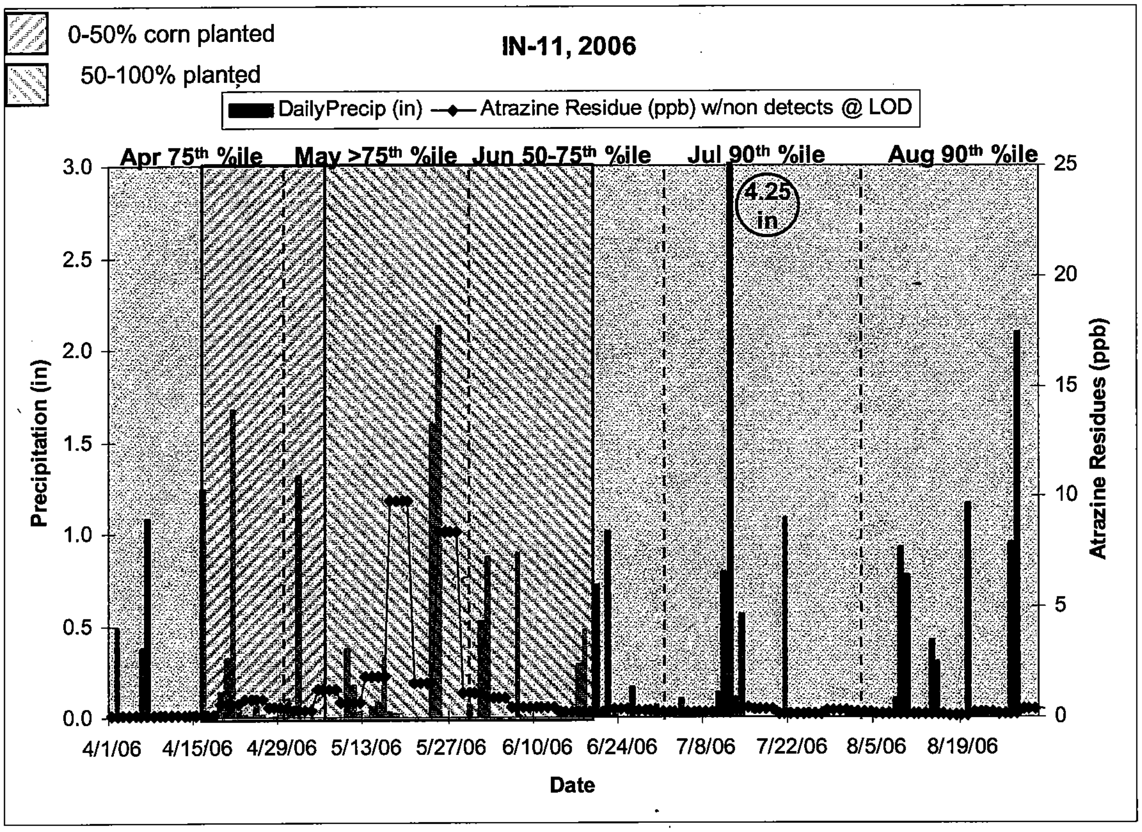
Monthly precipitation for 2005 fell at or below the 25th percentile (NOTE: precipitation wasn't recorded for the full month of August in 2005). In 2006, monthly precipitation totals were above the median in all months – in April and May, they were greater than the 75th percentile; in July and August they were near the 90th percentile



The following figures show the daily precipitation and atrazine residues in water for 2005 and 2006. The planting season is shaded to provide a point of reference for the likely timing of applications in the watershed.



0-50% corn planted
50-100% planted
IN-11, 2005
DailyPrecip (in)
Atrazine Residue (ppb) w/non detects @ LOD
Apr <10th %ile
May 10th %ile
Jun 25th %ile
Jul 25th %ile
Aug 10th %ile
208 ppb
Precipitation (in)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Atrazine Residues (ppb)
25
20
15
10
5
0
4/1/05
4/15/05
4/29/05
5/13/05
5/27/05
6/10/05
6/24/05
7/8/05
7/22/05
8/5/05
8/19/05
Date



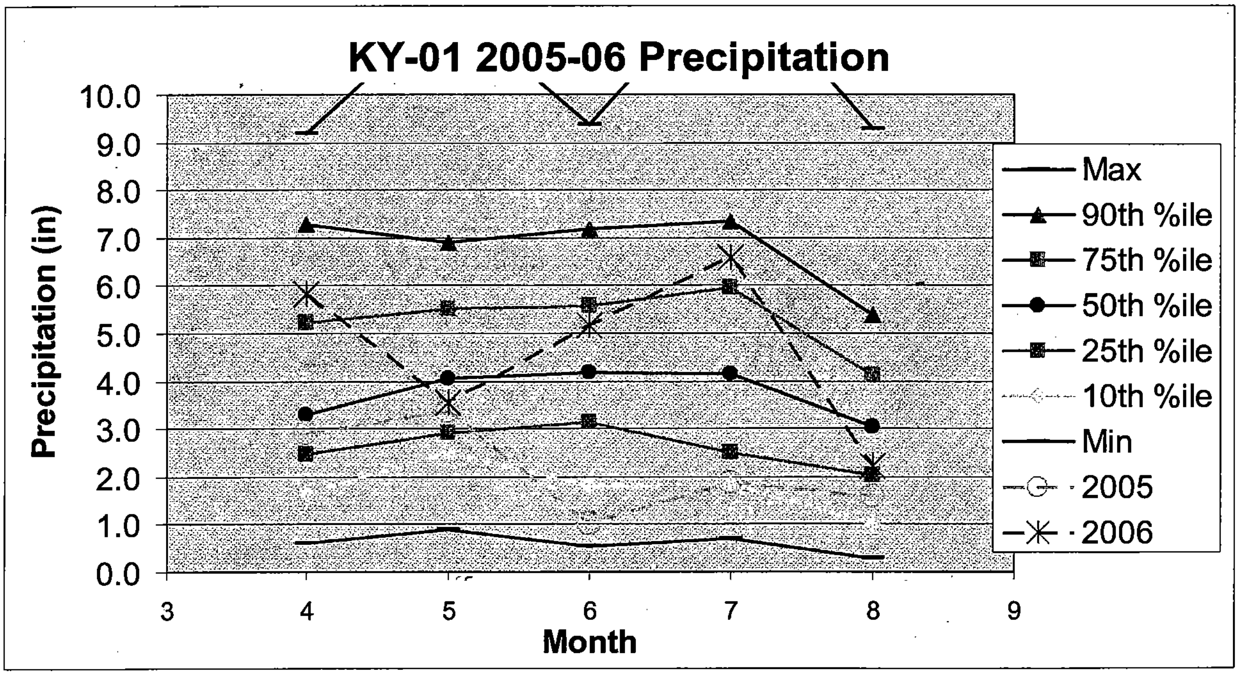
0-50% corn planted
50-100% planted
IN-11, 2006
DailyPrecip (in)
Atrazine Residue (ppb) w/non detects @ LOD
Apr 75th %ile
May >75th %ile
Jun 50-75th %ile
Jul 90th %ile
Aug 90th %ile
4.25 in
Precipitation (in)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Atrazine Residues (ppb)
25
20
15
10
5
0
4/1/06
4/15/06
4/29/06
5/13/06
5/27/06
6/10/06
6/24/06
7/8/06
7/22/06
8/5/06
8/19/06
Date

23. KY-01 2005-06

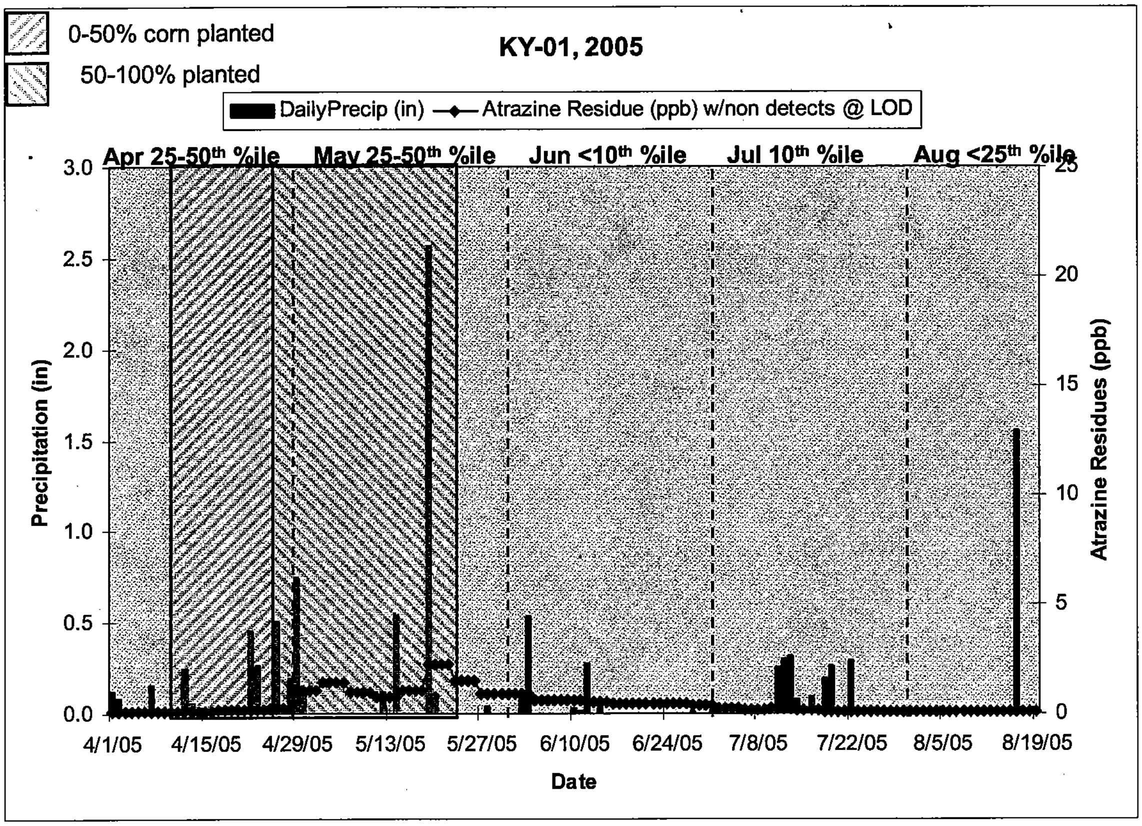
Watershed Location: Brashears Creek Watershed, KY
NWS Weather Station:

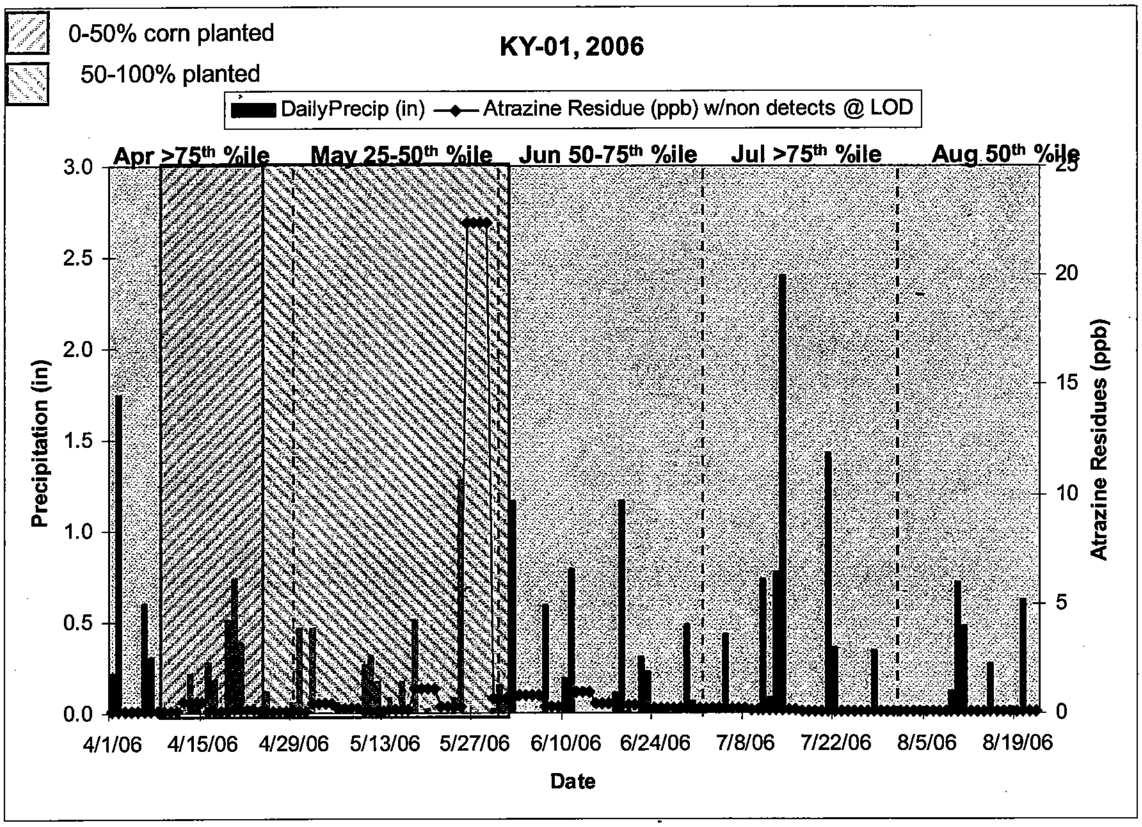
	April Total (in)	May Total (in)	June Total (in)	July Total (in)	August Total (in)	Apr-Aug Total (in)
Historical precipitation summaries, 1949-2001						
Max	9.19	11.91	9.37	12.65	9.26	31.84
90th %ile	7.27	6.88	7.18	7.34	5.39	27.47
75th %ile	5.23	5.50	5.57	5.94	4.10	23.10
50th %ile	3.28	4.04	4.18	4.14	3.04	20.07
25th %ile	2.48	2.93	3.12	2.50	2.02	17.09
10th %ile	1.65	2.49	1.80	1.82	1.03	15.24
Min	0.61	0.89	0.54	0.71	0.30	13.68
Monthly totals during the monitoring study						
2005	2.91	3.37	1.02	1.87	1.57	10.74
2006	5.83	3.53	5.17	6.58	2.22	23.33

Monthly precipitation totals in April and May of 2005 fell between the median and the 25th percentile; the remaining months were below the 25th percentile (NOTE: precipitation wasn't recorded for the full month of August in 2005). In 2006, monthly precipitation totals were generally above the median.



The following figures show the daily precipitation and atrazine residues in water for 2005 and 2006. The planting season is shaded to provide a point of reference for the likely timing of applications in the watershed.


0-50% corn planted
50-100% planted
KY-01, 2005
DailyPrecip (in)
Atrazine Residue (ppb) w/non detects @ LOD
Apr 25-50th %ile
May 25-50th %ile
Jun <10th %ile
Jul 10th %ile
Aug <25th %ile
Precipitation (in)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Atrazine Residues (ppb)
25
20
15
10
5
0
4/1/05
4/15/05
4/29/05
5/13/05
5/27/05
6/10/05
6/24/05
7/8/05
7/22/05
8/5/05
8/19/05
Date

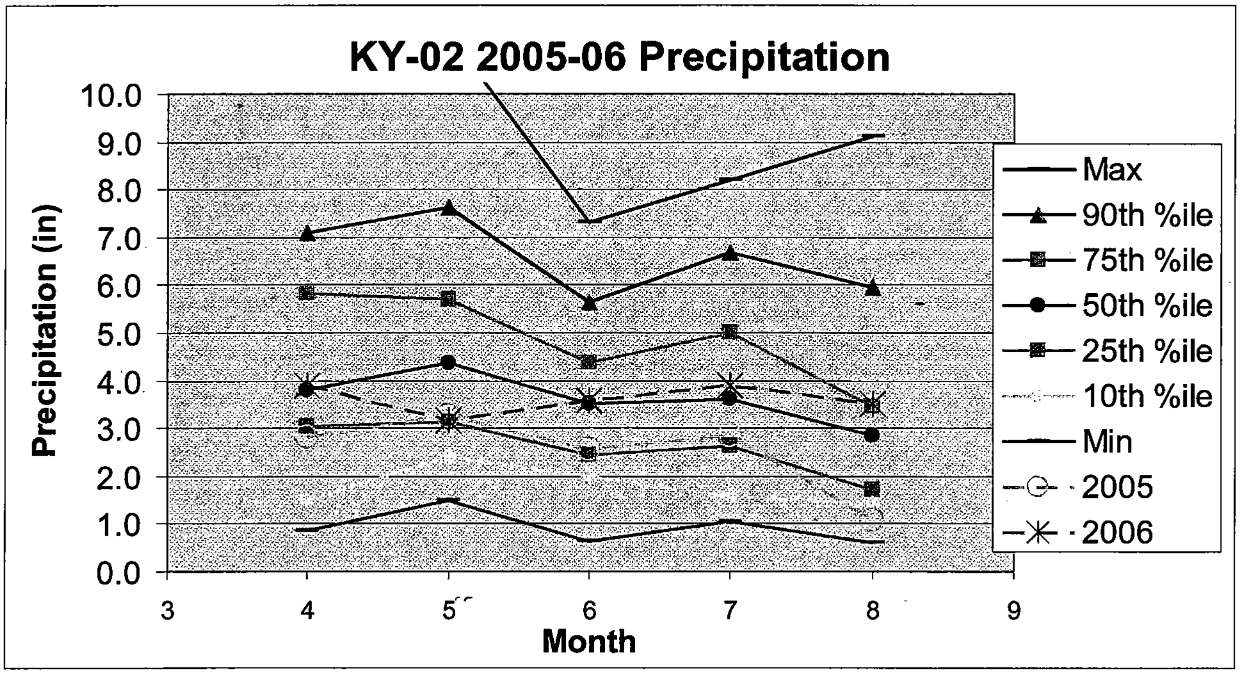

0-50% corn planted
50-100% planted
KY-01, 2006
DailyPrecip (in)
Atrazine Residue (ppb) w/non detects @ LOD
Apr >75th %ile
May 25-50th %ile
Jun 50-75th %ile
Jul >75th %ile
Aug 50th %ile
Precipitation (in)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Atrazine Residues (ppb)
25
20
15
10
5
0
4/1/06
4/15/06
4/29/06
5/13/06
5/27/06
6/10/06
6/24/06
7/8/06
7/22/06
8/5/06
8/19/06
Date

24. KY-02 2005-06

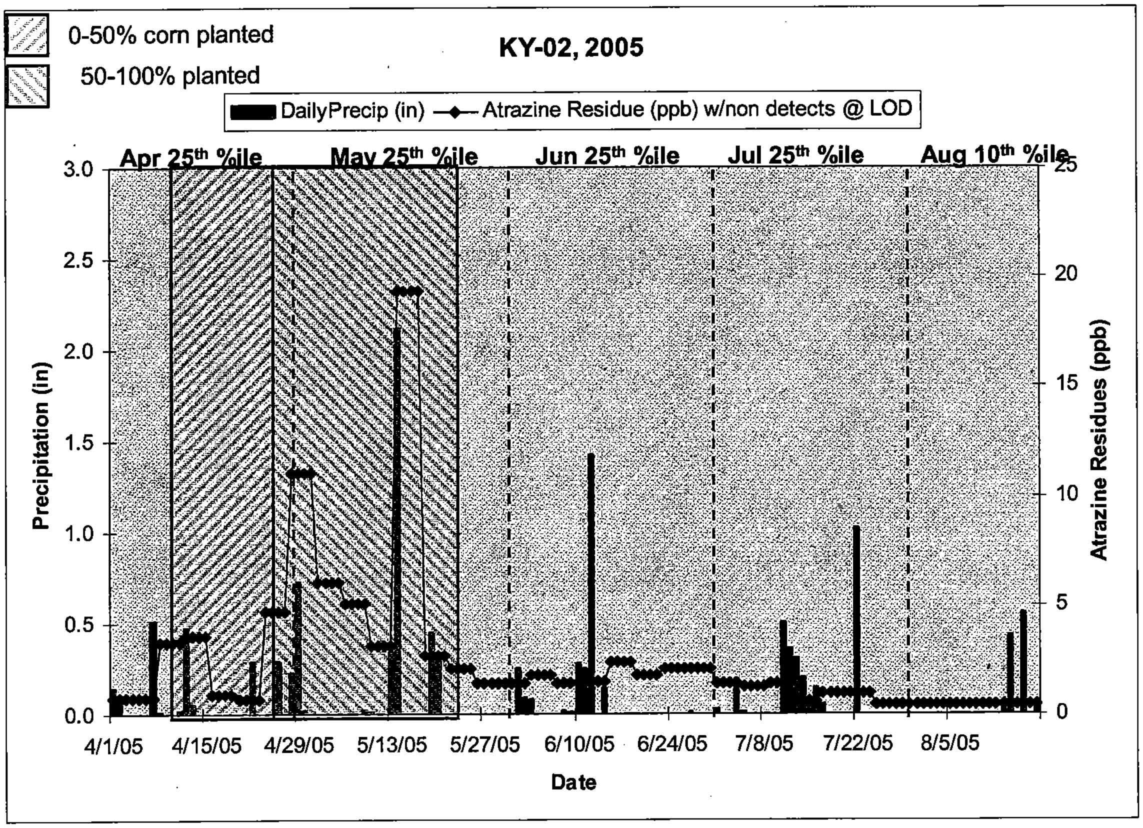
Watershed Location: Twomile Creek Watershed, KY
NWS Weather Station:

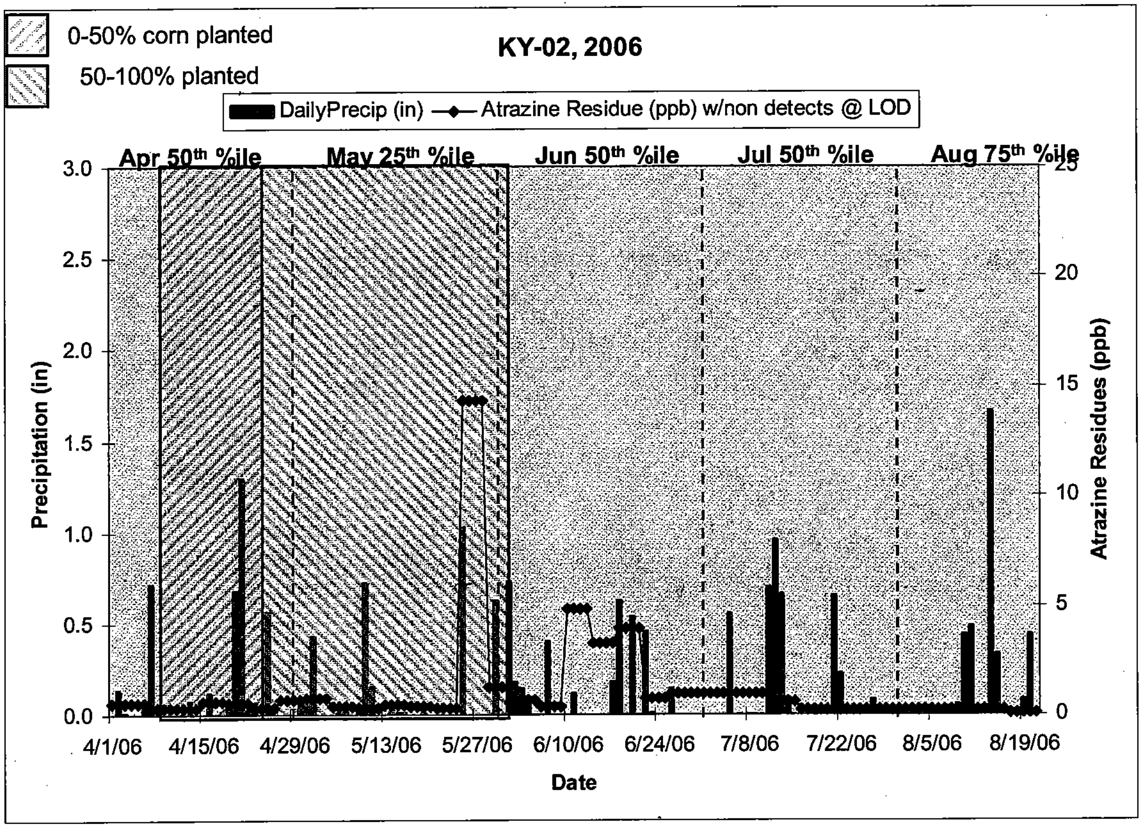
	April Total (in)	May Total (in)	June Total (in)	July Total (in)	August Total (in)	Apr-Aug Total (in)
Historical precipitation summaries, 1957-2001						
Max	12.95	11.22	7.31	8.19	9.11	32.68
90th %ile	7.09	7.62	5.62	6.67	5.94	27.02
75th %ile	5.81	5.71	4.37	4.99	3.45	23.05
50th %ile	3.79	4.37	3.50	3.61	2.84	18.75
25th %ile	3.05	3.13	2.45	2.61	1.70	15.66
10th %ile	1.50	2.40	1.98	1.58	1.44	14.59
Min	0.87	1.48	0.64	1.03	0.61	12.72
Monthly totals during the monitoring study						
2005	2.81	3.26	2.55	2.85	1.07	12.54
2006	3.89	3.18	3.59	3.89	3.5	18.05

Monthly precipitation totals for 2005 fell at or below the 25th percentile (NOTE: precipitation wasn't recorded for the full month of August in 2005). In 2006, monthly precipitation totals were generally around the median, with the exception of May, which was close to the 25th percentile.



The following figures show the daily precipitation and atrazine residues in water for 2005 and 2006. The planting season is shaded to provide a point of reference for the likely timing of applications in the watershed.


0-50% corn planted
50-100% planted
KY-02, 2005
DailyPrecip (in)
Atrazine Residue (ppb) w/non detects @ LOD
Apr 25th %ile
May 25th %ile
Jun 25th %ile
Jul 25th %ile
Aug 10th %ile
Precipitation (in)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Atrazine Residues (ppb)
25
20
15
10
5
0
4/1/05
4/15/05
4/29/05
5/13/05
5/27/05
6/10/05
6/24/05
7/8/05
7/22/05
8/5/05
Date

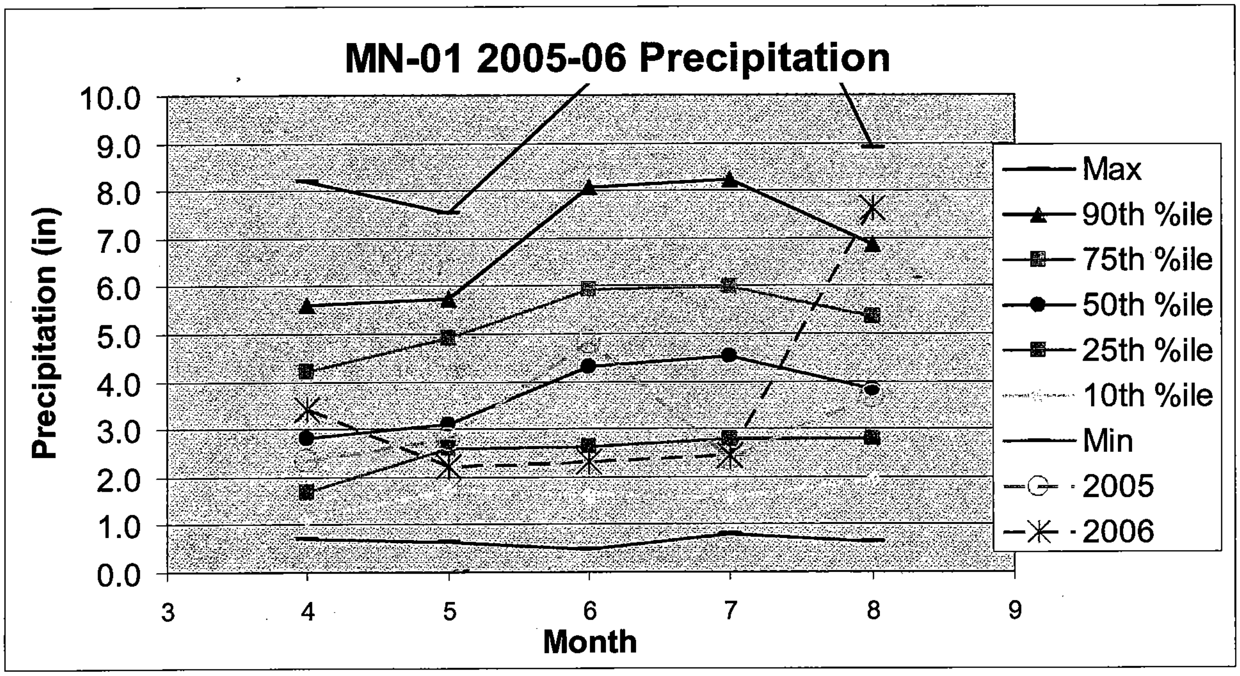

0-50% corn planted
50-100% planted
KY-02, 2006
DailyPrecip (in)
Atrazine Residue (ppb) w/non detects @ LOD
Apr 50th %ile
May 25th %ile
Jun 50th %ile
Jul 50th %ile
Aug 75th %ile
Precipitation (in)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Atrazine Residues (ppb)
25
20
15
10
5
0
4/1/06
4/15/06
4/29/06
5/13/06
5/27/06
6/10/06
6/24/06
7/8/06
7/22/06
8/5/06
8/19/06
Date

25. MN-01 2005-06

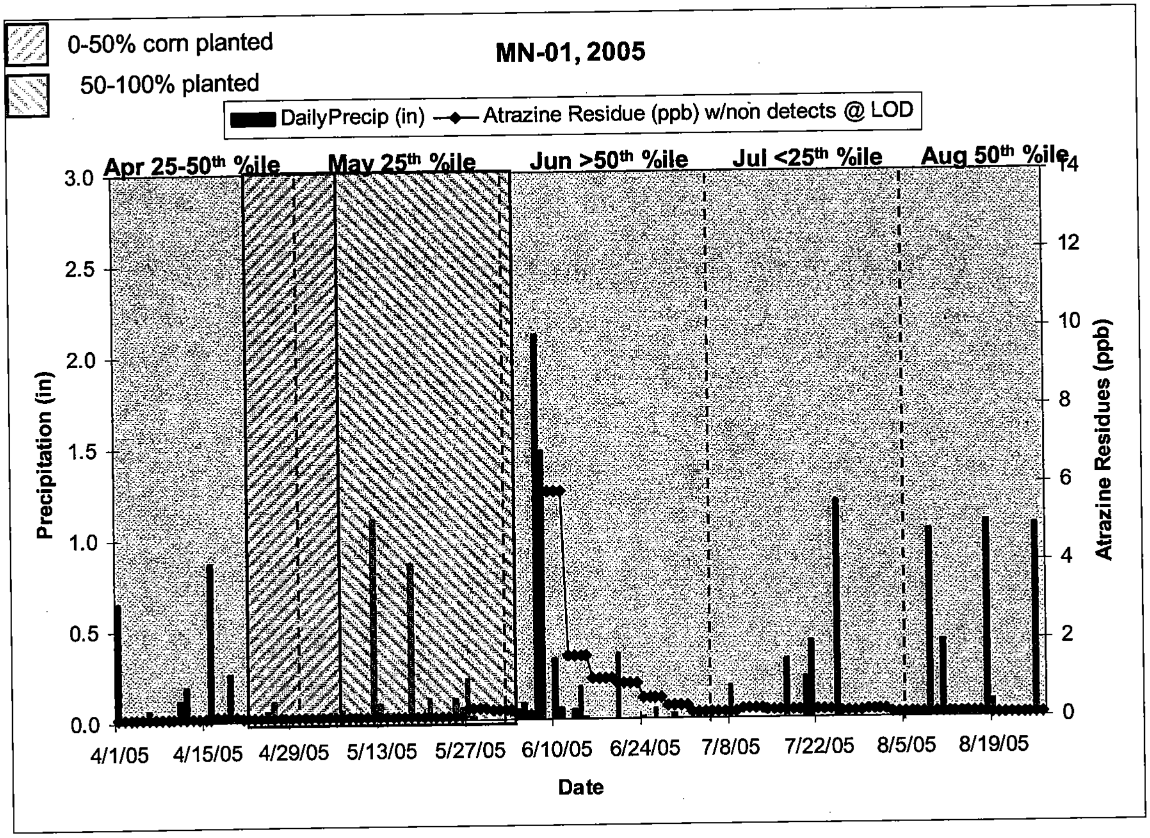
Watershed Location: Whitewater, North Fork Watershed, MN
NWS Weather Station:

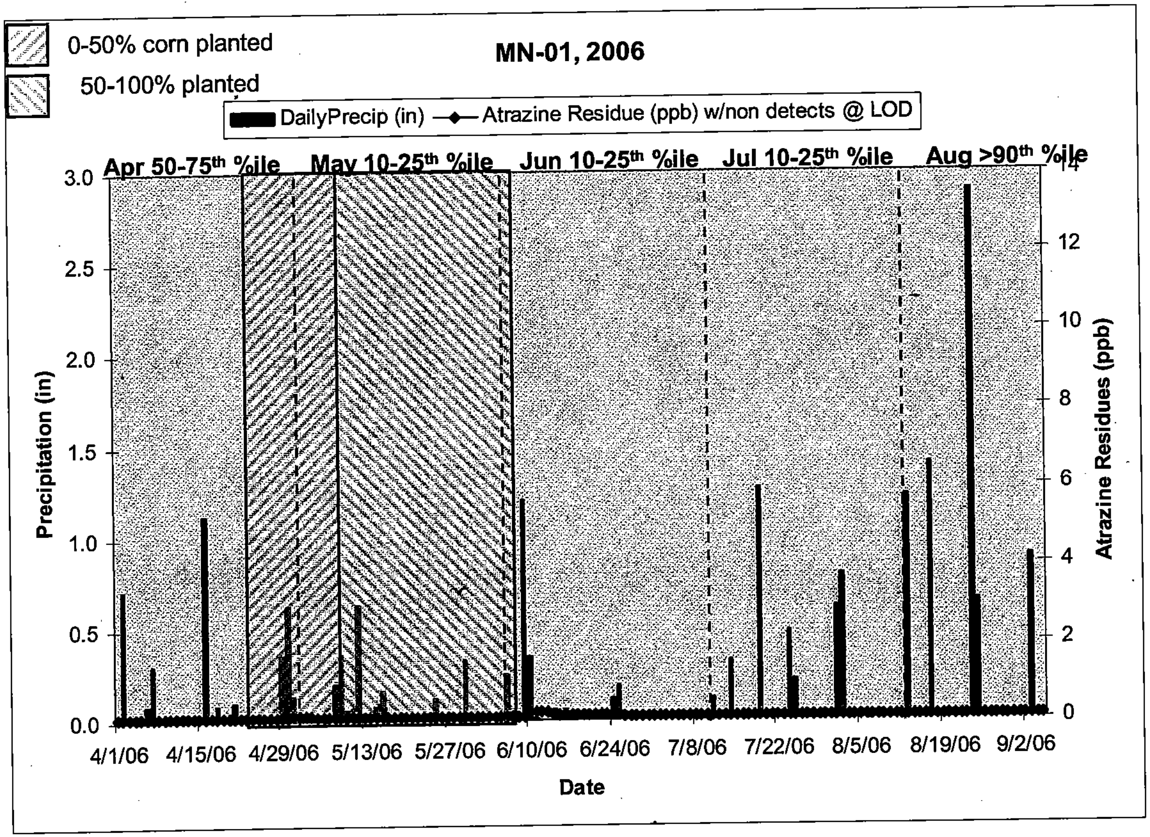
	April Total (in)	May Total (in)	June Total (in)	July Total (in)	August Total (in)	Apr-Aug Total (in)
Historical precipitation summaries, 1948-2001						
Max	8.19	7.53	10.25	15.04	8.88	31.93
90th %ile	5.61	5.73	8.07	8.22	6.86	25.30
75th %ile	4.20	4.91	5.93	5.98	5.35	23.46
50th %ile	2.83	3.12	4.29	4.53	3.82	19.68
25th %ile	1.69	2.59	2.63	2.78	2.78	16.14
10th %ile	1.14	1.71	1.61	1.56	1.94	13.72
Min	0.71	0.64	0.46	0.79	0.62	9.57
Monthly totals during the monitoring study						
2005	2.33	2.8	4.8	2.37	3.66	15.96
2006	3.42	2.22	2.31	2.43	7.62	18

Monthly precipitation totals for 2005 were generally between the median and the 25th percentile (NOTE: precipitation wasn't recorded for the full month of August in 2005). While rainfall in April of 2006 was above the median, monthly precipitation totals for May through July were lower than the 25th percentile.



The following figures show the daily precipitation and atrazine residues in water for 2005 and 2006. The planting season is shaded to provide a point of reference for the likely timing of applications in the watershed.


0-50% corn planted
50-100% planted
MN-01, 2005
DailyPrecip (in)
Atrazine Residue (ppb) w/non detects @ LOD
Apr 25-50th %ile
May 25th %ile
Jun >50th %ile
Jul <25th %ile
Aug 50th %ile
Precipitation (in)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Atrazine Residues (ppb)
14
12
10
8
6
4
2
0
4/1/05
4/15/05
4/29/05
5/13/05
5/27/05
6/10/05
6/24/05
7/8/05
7/22/05
8/5/05
8/19/05
Date

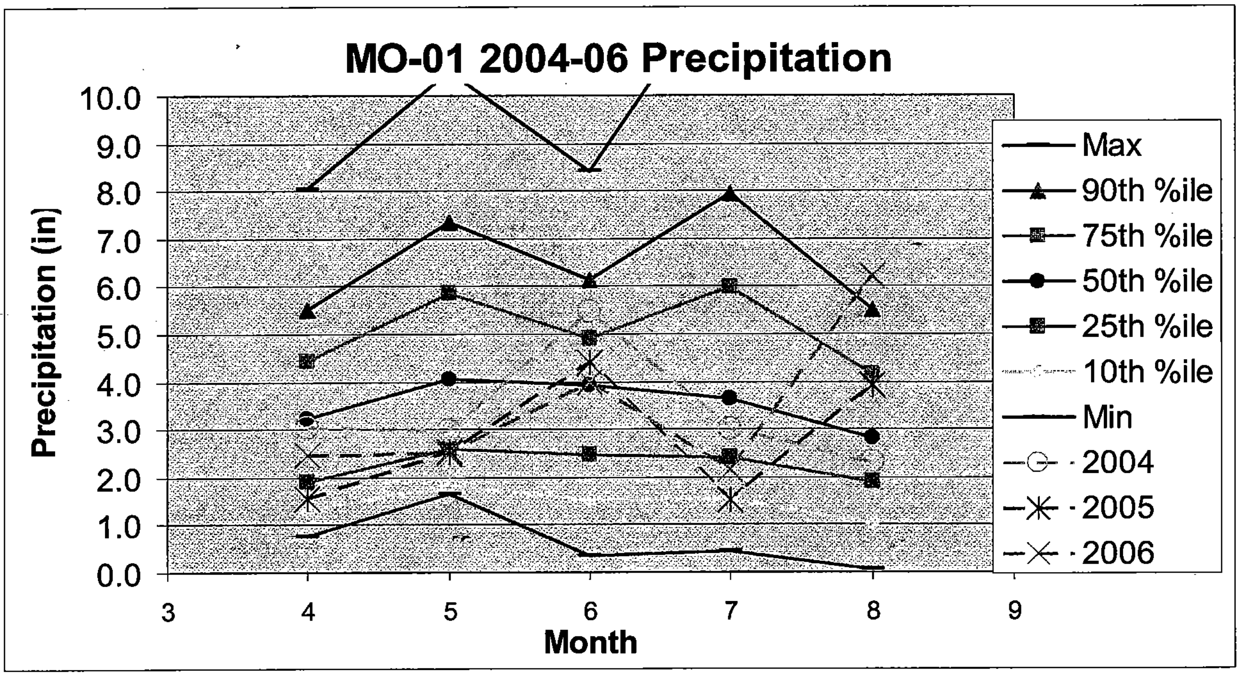

0-50% corn planted
50-100% planted
MN-01, 2006
DailyPrecip (in)
Atrazine Residue (ppb) w/non detects @ LOD
Apr 50-75th %ile
May 10-25th %ile
Jun 10-25th %ile
Jul 10-25th %ile
Aug >90th %ile
Precipitation (in)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Atrazine Residues (ppb)
14
12
10
8
6
4
2
0
4/1/06
4/15/06
4/29/06
5/13/06
5/27/06
6/10/06
6/24/06
7/8/06
7/22/06
8/5/06
8/19/06
9/2/06
Date

26. MO-01, 2004-06

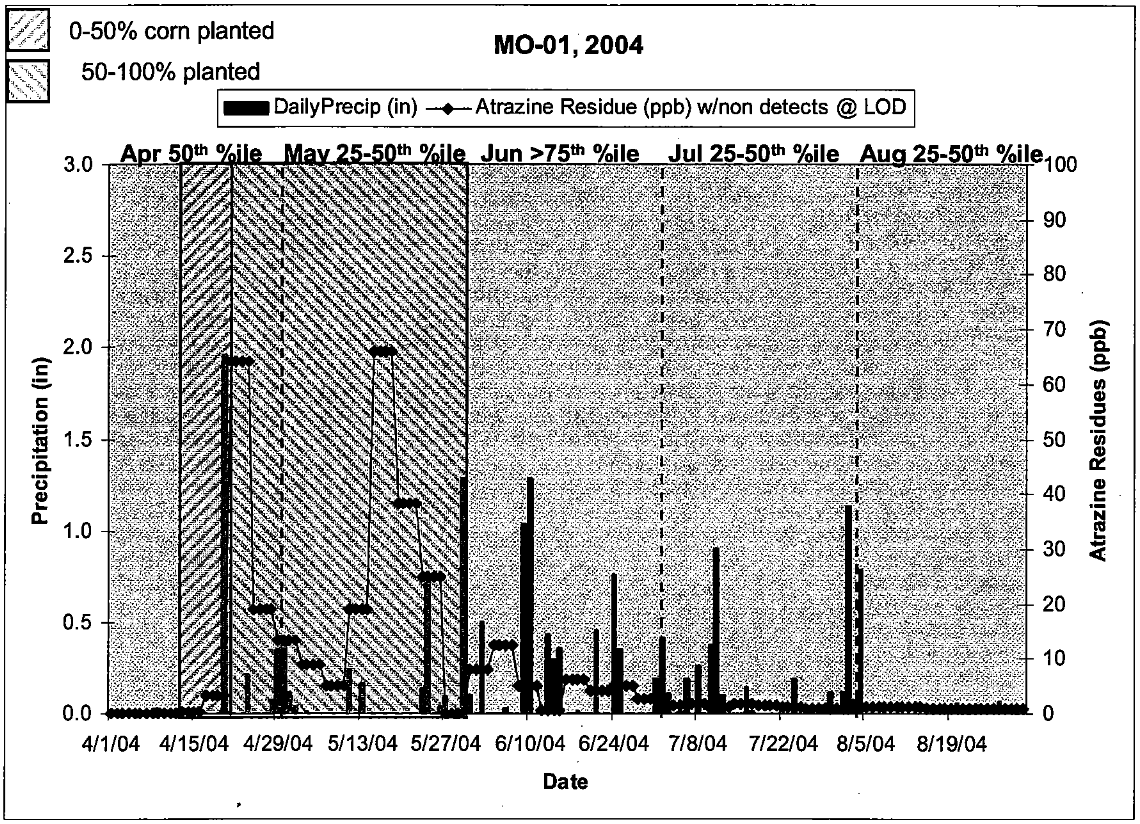
Watershed Location: South Fabius River Watershed, MO
NWS Weather Station:

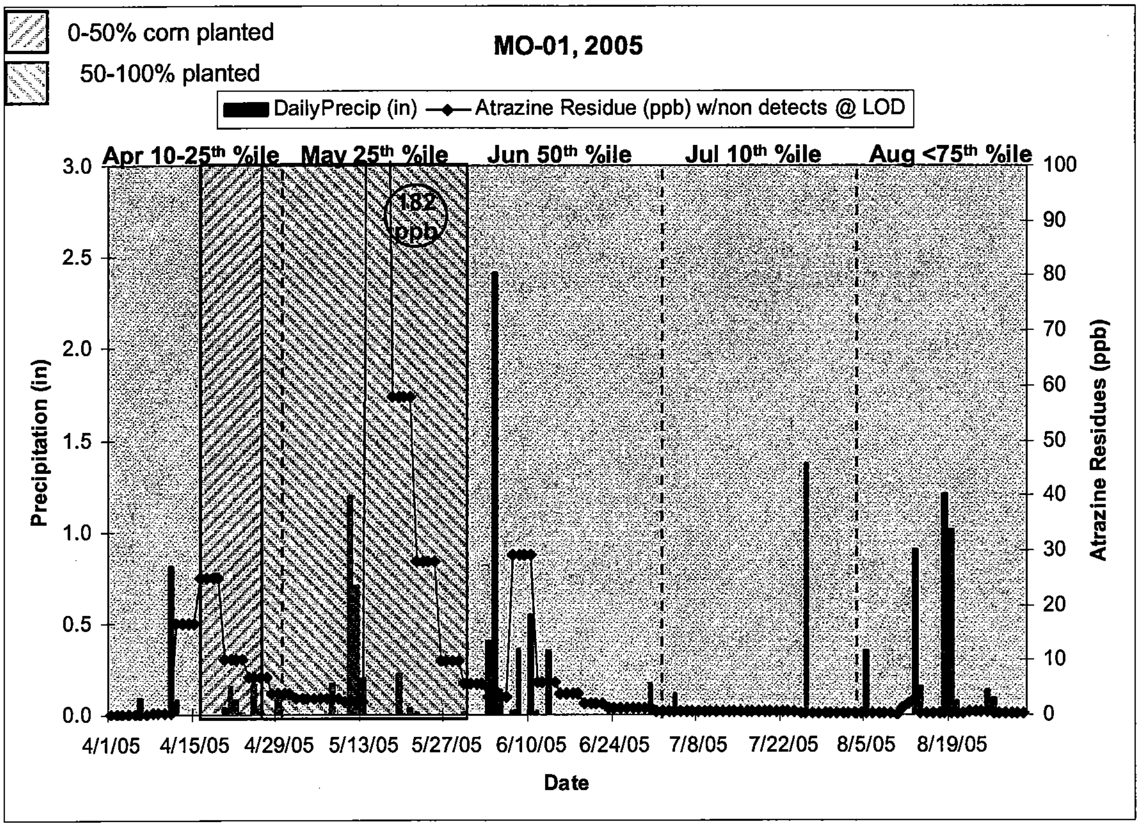
	April Total (in)	May Total (in)	June Total (in)	July Total (in)	August Total (in)	Apr-Aug Total (in)
Historical precipitation summaries, 1948-2001						
Max	8.04	10.51	8.43	12.70	14.67	32.81
90th %ile	5.52	7.34	6.14	7.95	5.51	26.03
75th %ile	4.43	5.85	4.92	5.98	4.16	21.77
50th %ile	3.22	4.04	3.93	3.63	2.81	18.08
25th %ile	1.90	2.61	2.46	2.41	1.90	16.06
10th %ile	1.29	1.84	1.52	1.51	1.04	14.58
Min	0.76	1.66	0.35	0.44	0.05	8.64
Monthly totals during the monitoring study						
2004	3.05	2.99	5.49	3.02	2.31	16.86
2005	1.55	2.54	4.4	1.52	3.91	13.92
2006	2.48	2.51	3.98	2.14	6.19	17.3

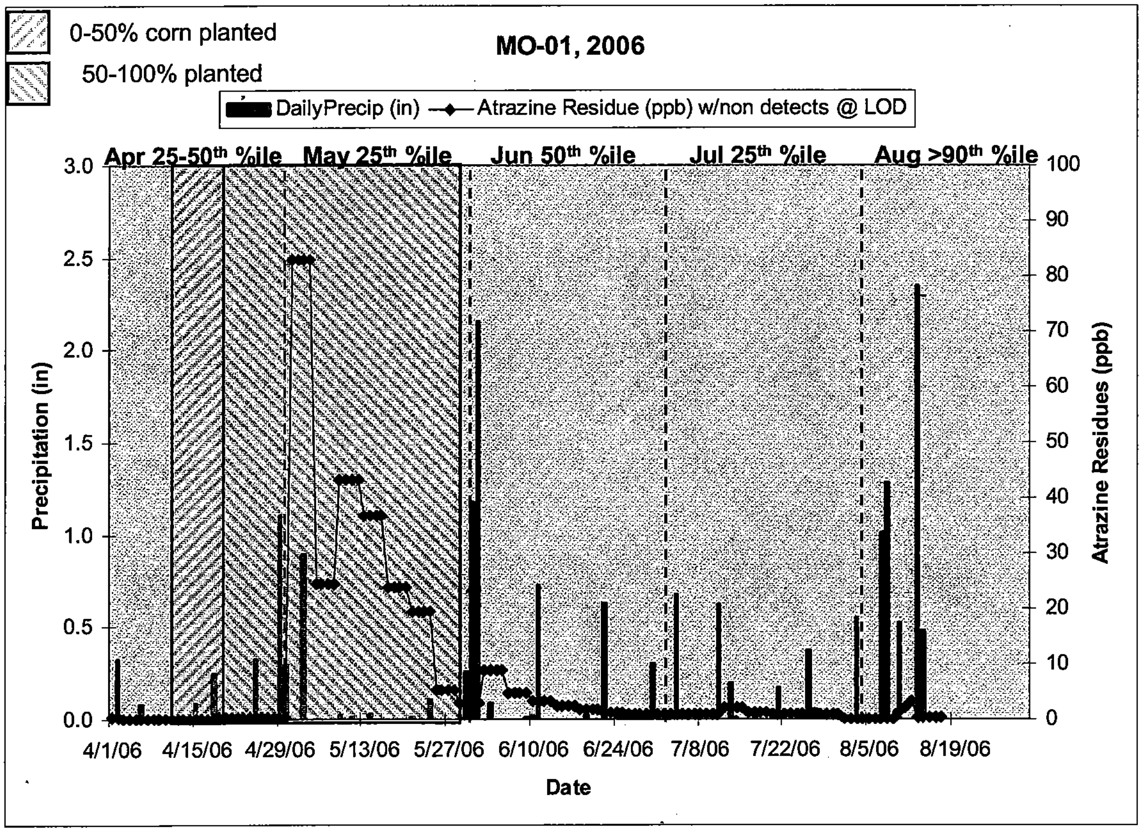
Monthly precipitation in 2004 was between the median and 25th percentile throughout the sampling period except for June, when it exceeded the 75th percentile. In 2005, monthly precipitation was low (<25th percentile) in April, May and July. In 2006, monthly precipitation totals were low (<25th percentile) in May and July.



The following figures show the daily precipitation and atrazine residues in water for 2004, 2005 and 2006. The planting season is shaded to provide a point of reference for the likely timing of applications in the watershed.




0-50% corn planted
50-100% planted
MO-01, 2005
DailyPrecip (in)
Atrazine Residue (ppb) w/non detects @ LOD
Apr 10-25th %ile
May 25th %ile
Jun 50th %ile
Jul 10th %ile
Aug <75th %ile
182 ppb
Precipitation (in)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Atrazine Residues (ppb)
100
90
80
70
60
50
40
30
20
10
0
4/1/05
4/15/05
4/29/05
5/13/05
5/27/05
6/10/05
6/24/05
7/8/05
7/22/05
8/5/05
8/19/05
Date

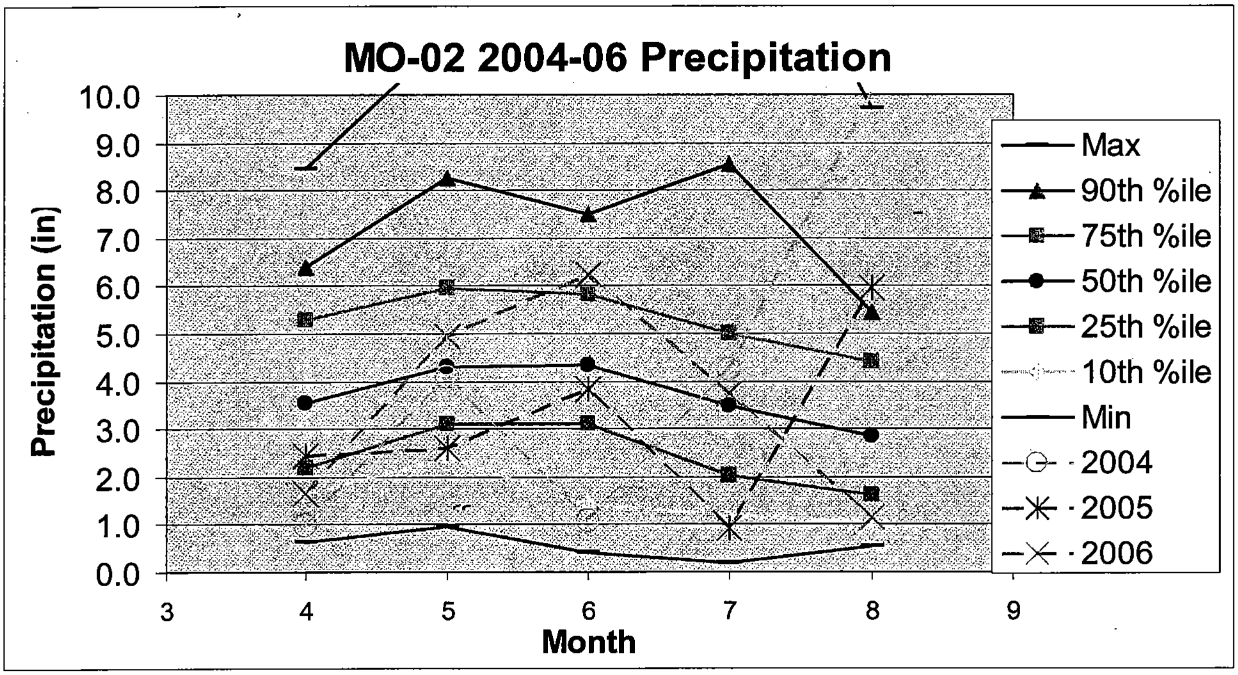

0-50% corn planted
50-100% planted
MO-01, 2006
DailyPrecip (in)
Atrazine Residue (ppb) w/non detects @ LOD
Apr 25-50th %ile
May 25th %ile
Jun 50th %ile
Jul 25th %ile
Aug >90th %ile
Precipitation (in)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Atrazine Residues (ppb)
100
90
80
70
60
50
40
30
20
10
0
4/1/06
4/15/06
4/29/06
5/13/06
5/27/06
6/10/06
6/24/06
7/8/06
7/22/06
8/5/06
8/19/06
Date

27. MO-02, 2004-06

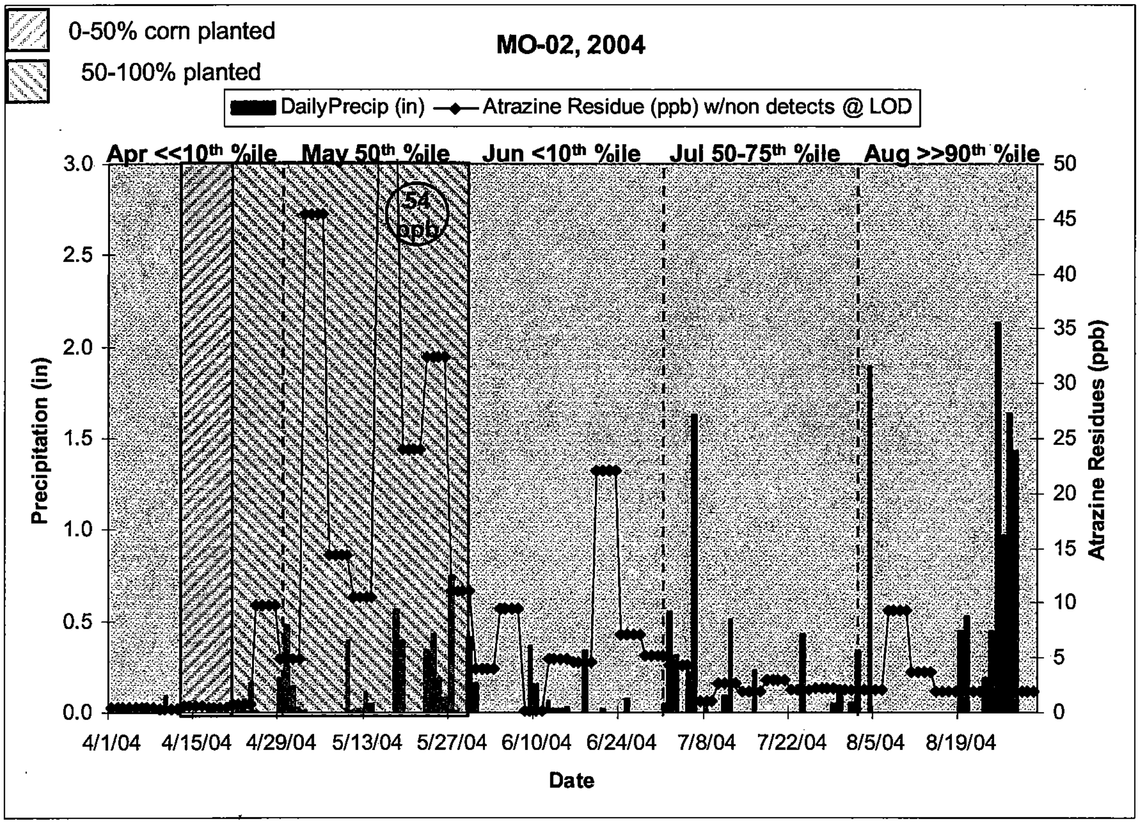
Watershed Location: Youngs Creek Watershed, MO
NWS Weather Station:

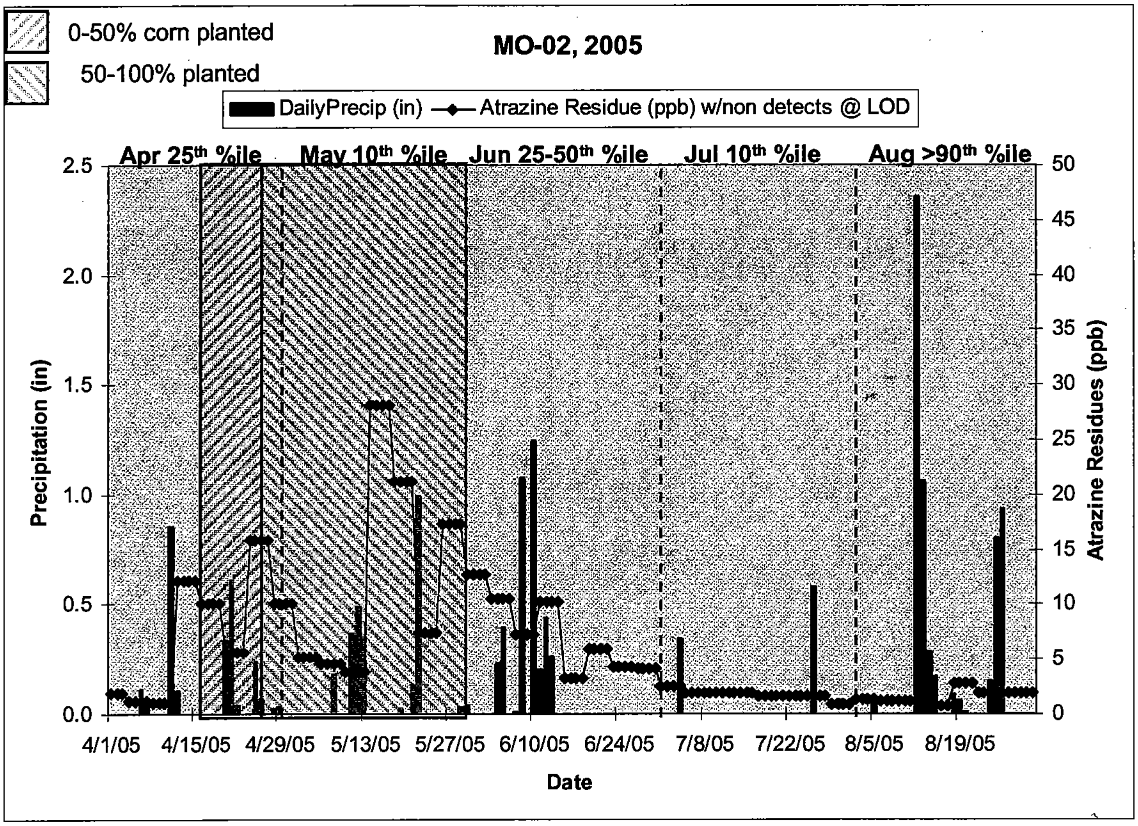
	April Total (in)	May Total (in)	June Total (in)	July Total (in)	August Total (in)	Apr-Aug Total (in)
Historical precipitation summaries, 1948-2001						
Max	8.44	11.20	10.86	15.22	9.73	38.47
90th %ile	6.38	8.26	7.51	8.56	5.43	28.24
75th %ile	5.29	5.94	5.82	5.01	4.41	24.58
50th %ile	3.55	4.30	4.33	3.48	2.85	20.33
25th %ile	2.19	3.09	3.11	2.02	1.60	16.83
10th %ile	1.63	2.40	1.41	1.19	1.04	13.00
Min	0.64	0.94	0.42	0.20	0.55	9.79
Monthly totals during the monitoring study						
2004	0.97	4.07	1.07	4.24	10.03	20.38
2005	2.44	2.59	3.84	0.92	5.95	15.74
2006	1.65	4.94	6.22	3.73	1.13	17.67

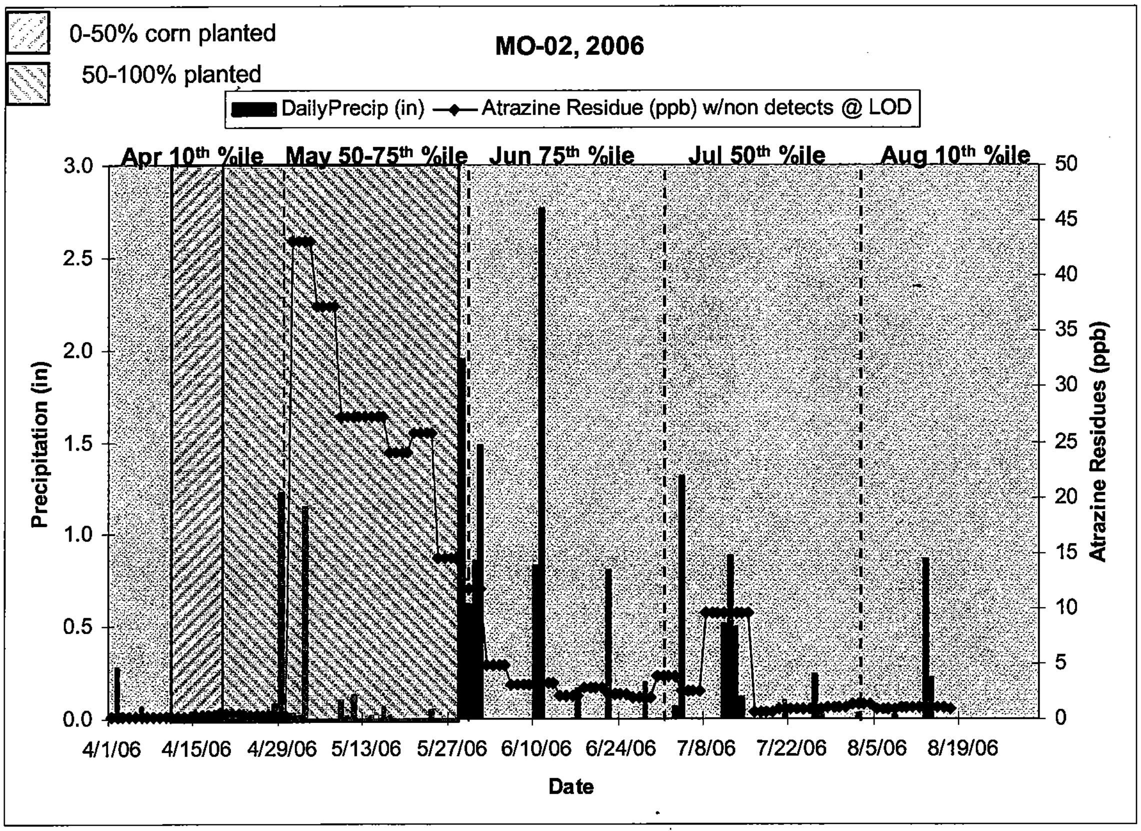
Monthly precipitation in 2004 was low (<10th percentile) in April and June throughout the and high (>90th percentile) in August. In 2005, monthly precipitation was low (<25th percentile) in April, May and July, and high (90th percentile) in August. In 2006, monthly precipitation totals were low (10th percentile) in April and August and high (75th percentile) in June.



The following figures show the daily precipitation and atrazine residues in water for 2004, 2005 and 2006. The planting season is shaded to provide a point of reference for the likely timing of applications in the watershed.




0-50% corn planted
50-100% planted
MO-02, 2005
DailyPrecip (in)
Atrazine Residue (ppb) w/non detects @ LOD
Apr 25th %ile
May 10th %ile
Jun 25-50th %ile
Jul 10th %ile
Aug >90th %ile
Precipitation (in)
2.5
2.0
1.5
1.0
0.5
0.0
Atrazine Residues (ppb)
50
45
40
35
30
25
20
15
10
5
0
4/1/05
4/15/05
4/29/05
5/13/05
5/27/05
6/10/05
6/24/05
7/8/05
7/22/05
8/5/05
8/19/05
Date

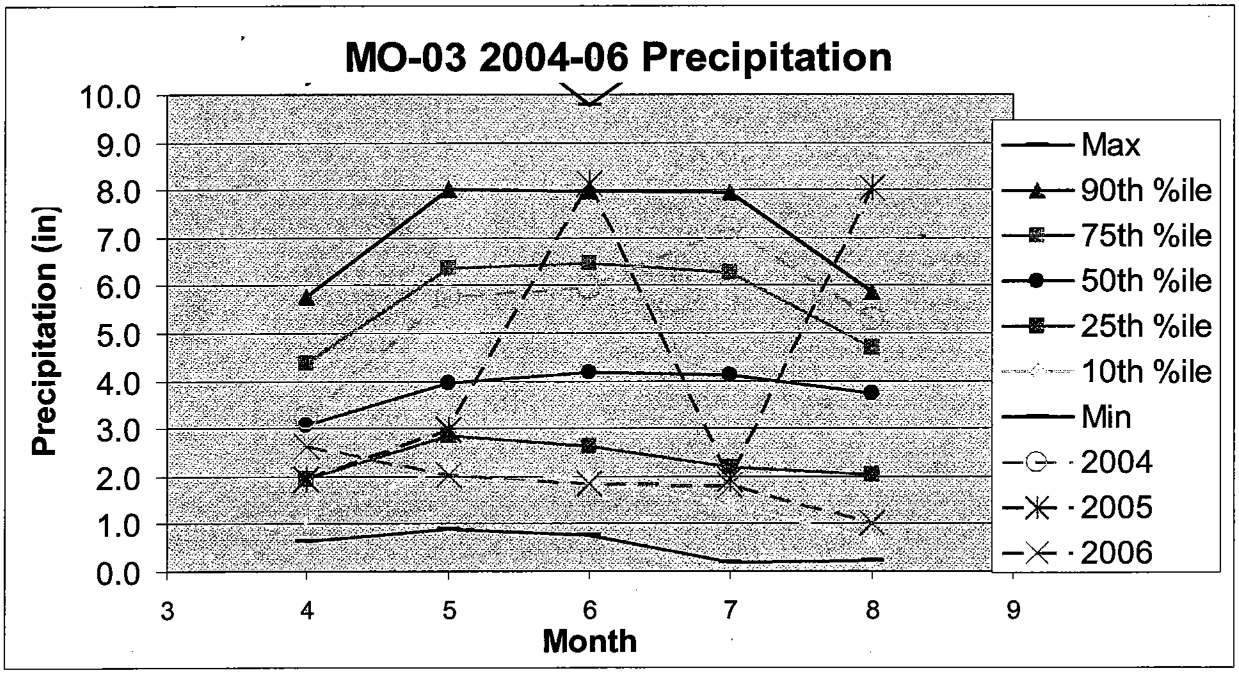

0-50% corn planted
50-100% planted
MO-02, 2006
DailyPrecip (in)
Atrazine Residue (ppb) w/non detects @ LOD
Apr 10th %ile
May 50-75th %ile
Jun 75th %ile
Jul 50th %ile
Aug 10th %ile
Precipitation (in)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Atrazine Residues (ppb)
50
45
40
35
30
25
20
15
10
5
0
4/1/06
4/15/06
4/29/06
5/13/06
5/27/06
6/10/06
6/24/06
7/8/06
7/22/06
8/5/06
8/19/06
Date

28. MO-03, 2004-06

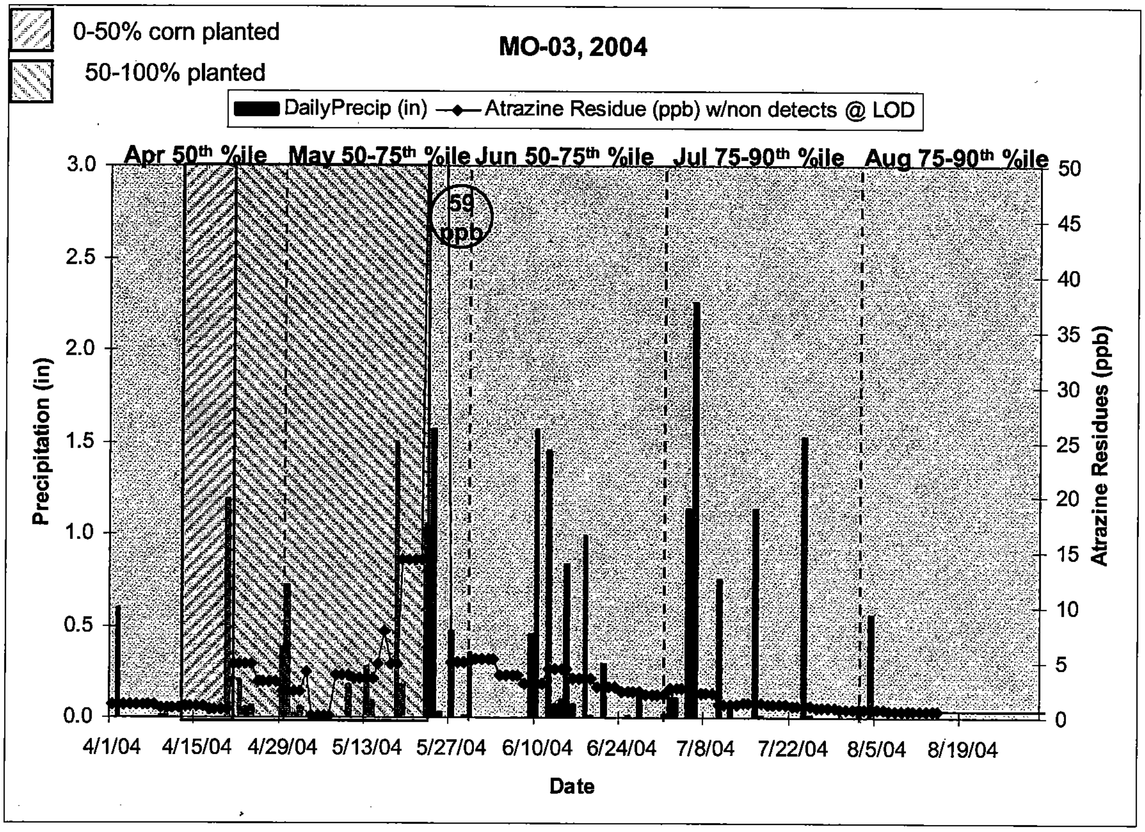
Watershed Location: Little Sni-a-Bar Creek Watershed, MO
NWS Weather Station:

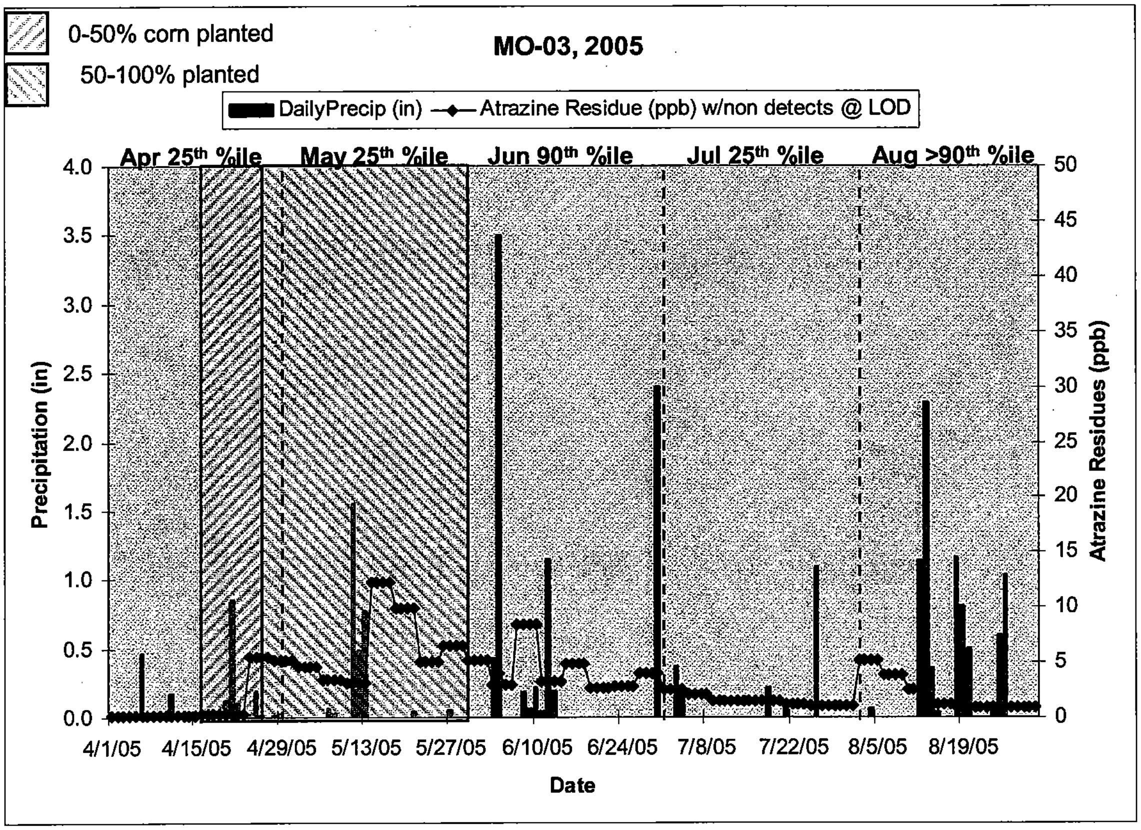
	April Total (in)	May Total (in)	June Total (in)	July Total (in)	August Total (in)	Apr-Aug Total (in)
Historical precipitation summaries, 1948-2001						
Max	10.22	12.10	9.79	11.90	10.45	36.14
90th %ile	5.76	8.01	7.97	7.93	5.87	28.17
75th %ile	4.37	6.35	6.45	6.28	4.70	24.75
50th %ile	3.09	3.95	4.19	4.11	3.75	20.86
25th %ile	1.94	2.86	2.63	2.18	2.04	16.80
10th %ile	1.13	2.18	1.93	1.38	0.67	13.49
Min	0.63	0.89	0.76	0.19	0.22	9.88
Monthly totals during the monitoring study						
2004	3.24	5.76	5.96	7.19	5.29	27.44
2005	1.92	2.96	8.13	1.92	8.04	22.97
2006	2.64	2.03	1.82	1.79	1.02	9.3

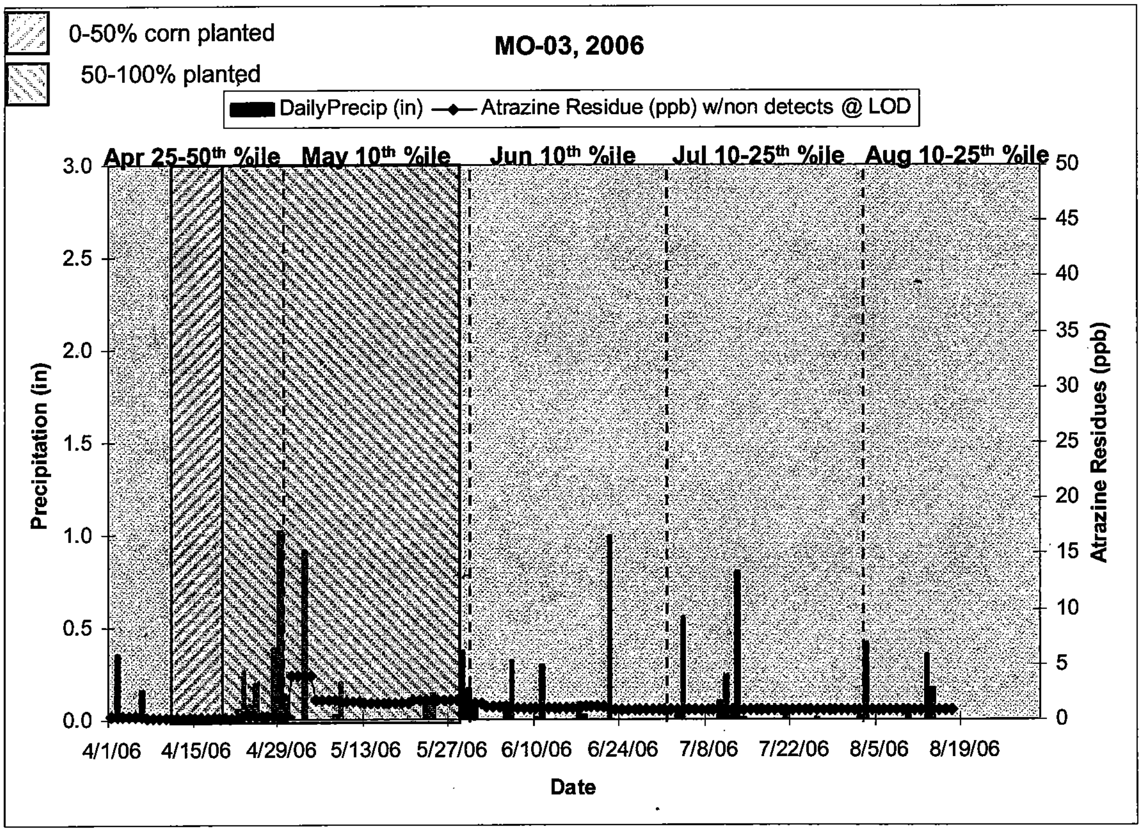
Monthly precipitation in 2004 was between the 50th and 75th percentile in April through June and above the 75th percentile in July and August. In 2005, monthly precipitation was low (25th percentile) in April, May and July, and high (90th percentile) in June and August. In 2006, monthly precipitation totals were low (at or below the 10th percentile) in May through August.



The following figures show the daily precipitation and atrazine residues in water for 2004, 2005 and 2006. The planting season is shaded to provide a point of reference for the likely timing of applications in the watershed.



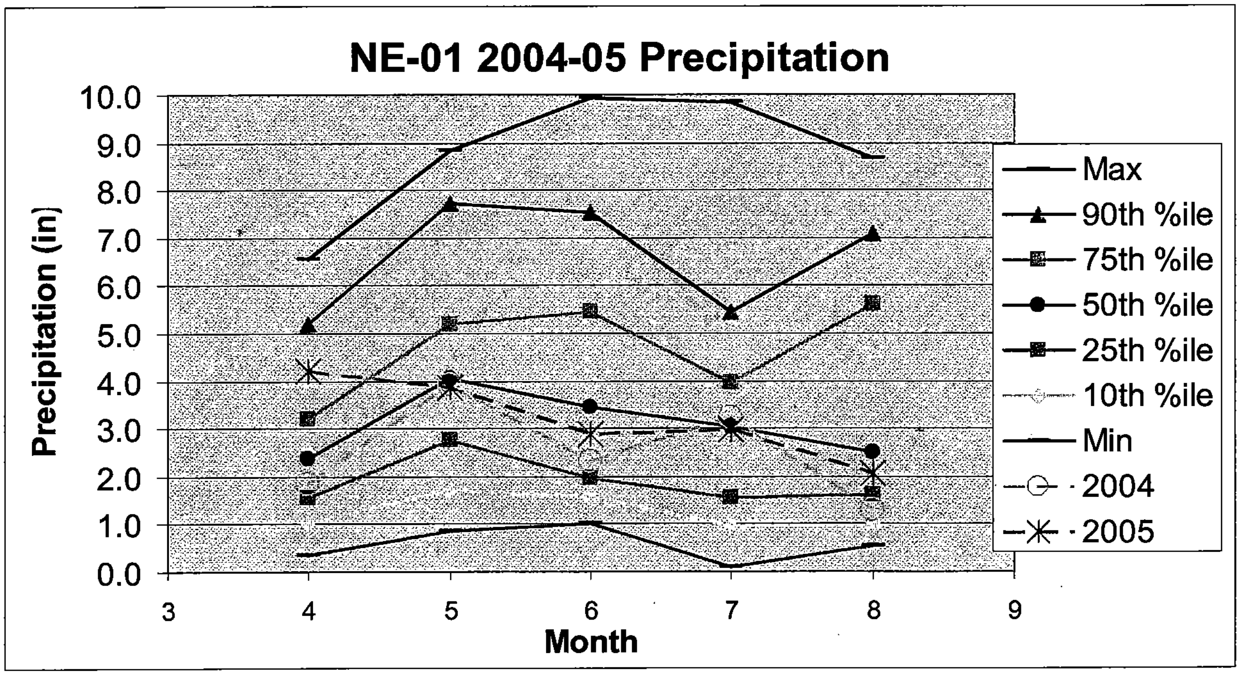

0-50% corn planted
50-100% planted
MO-03, 2005
DailyPrecip (in)
Atrazine Residue (ppb) w/non detects @ LOD
Apr 25th %ile
May 25th %ile
Jun 90th %ile
Jul 25th %ile
Aug >90th %ile
Precipitation (in)
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Atrazine Residues (ppb)
50
45
40
35
30
25
20
15
10
5
0
4/1/05
4/15/05
4/29/05
5/13/05
5/27/05
6/10/05
6/24/05
7/8/05
7/22/05
8/5/05
8/19/05
Date


0-50% corn planted
50-100% planted
MO-03, 2006
DailyPrecip (in)
Atrazine Residue (ppb) w/non detects @ LOD
Apr 25-50th %ile
May 10th %ile
Jun 10th %ile
Jul 10-25th %ile
Aug 10-25th %ile
Precipitation (in)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Atrazine Residues (ppb)
50
45
40
35
30
25
20
15
10
5
0
4/1/06
4/15/06
4/29/06
5/13/06
5/27/06
6/10/06
6/24/06
7/8/06
7/22/06
8/5/06
8/19/06
Date

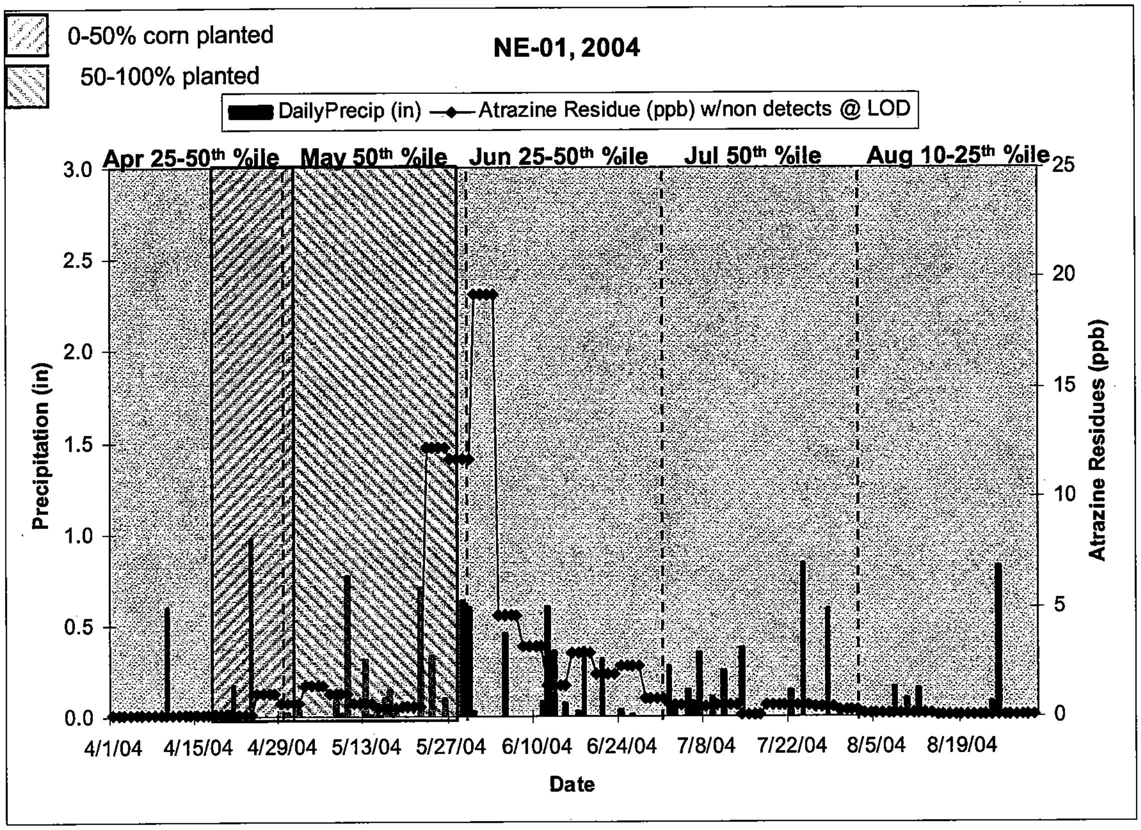
29. NE-01, 2004-2005

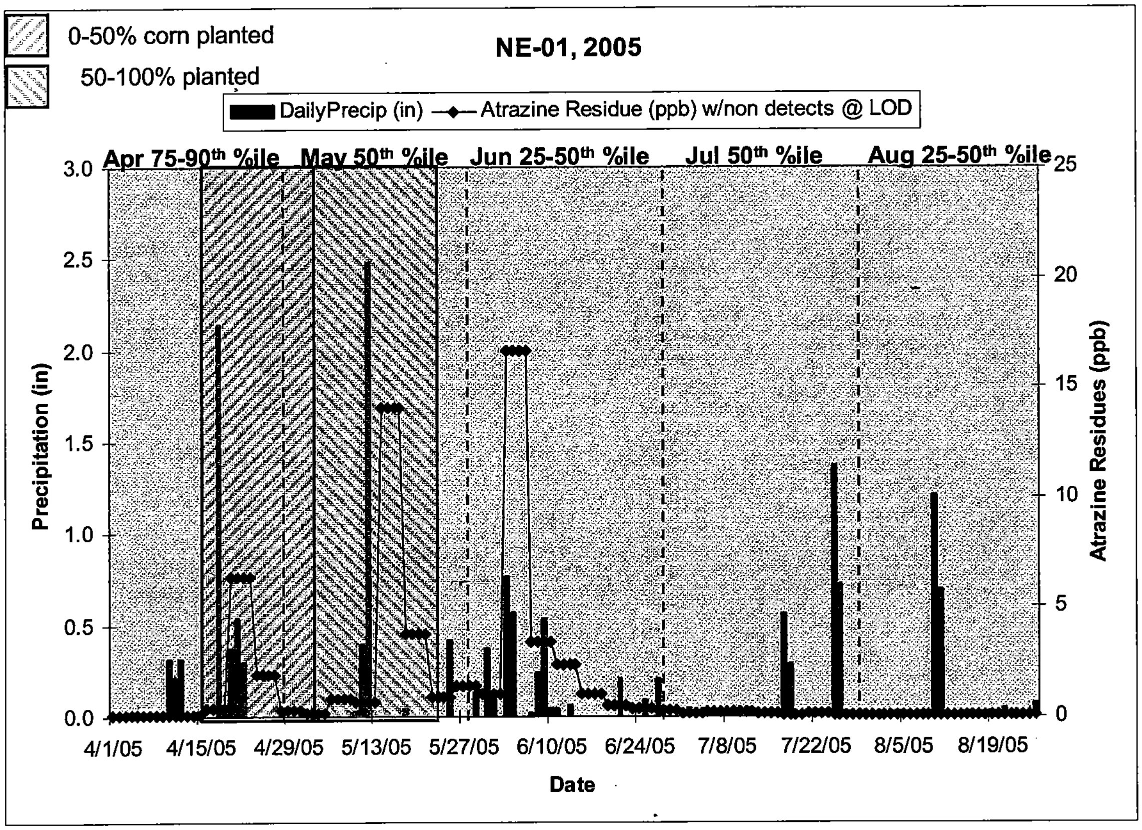
Watershed Location: Wahoo Creek, NE
NWS Weather Station:

	April Total (in)	May Total (in)	June Total (in)	July Total (in)	August Total (in)	Apr-Aug Total (in)
Historical precipitation summaries, 1969-2001						
Max	6.54	8.84	9.94	9.85	8.68	32.36
90th %ile	5.20	7.73	7.53	5.46	7.08	23.16
75th %ile	3.21	5.20	5.43	3.94	5.60	20.37
50th %ile	2.37	4.05	3.45	3.03	2.50	16.08
25th %ile	1.54	2.74	1.95	1.54	1.62	14.04
10th %ile	1.05	1.70	1.59	0.95	0.98	12.01
Min	0.34	0.85	1.02	0.11	0.53	10.02
Monthly totals during the monitoring study						
2004	1.84	3.93	2.32	3.22	1.31	12.62
2005	4.22	3.86	2.88	2.97	2.07	16



The following figures show the daily precipitation and atrazine residues in water for 2004 and 2005. The planting season is shaded to provide a point of reference for the likely timing of applications in the watershed.


0-50% corn planted
50-100% planted
NE-01, 2004
DailyPrecip (in)
Atrazine Residue (ppb) w/non detects @ LOD
Apr 25-50th %ile
May 50th %ile
Jun 25-50th %ile
Jul 50th %ile
Aug 10-25th %ile
Precipitation (in)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Atrazine Residues (ppb)
25
20
15
10
5
0
4/1/04
4/15/04
4/29/04
5/13/04
5/27/04
6/10/04
6/24/04
7/8/04
7/22/04
8/5/04
8/19/04
Date

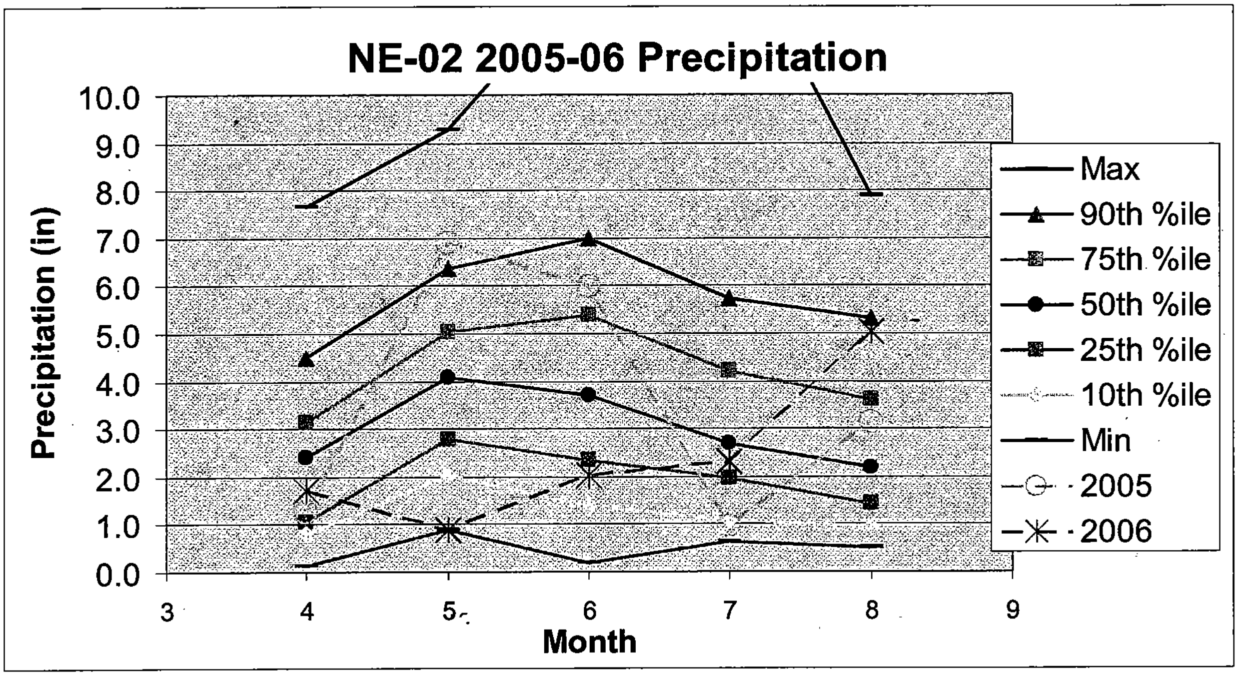

0-50% corn planted
50-100% planted
NE-01, 2005
DailyPrecip (in)
Atrazine Residue (ppb) w/non detects @ LOD
Apr 75-90th %ile
May 50th %ile
Jun 25-50th %ile
Jul 50th %ile
Aug 25-50th %ile
Precipitation (in)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Atrazine Residues (ppb)
25
20
15
10
5
0
4/1/05
4/15/05
4/29/05
5/13/05
5/27/05
6/10/05
6/24/05
7/8/05
7/22/05
8/5/05
8/19/05
Date

30. NE-02 2005-06

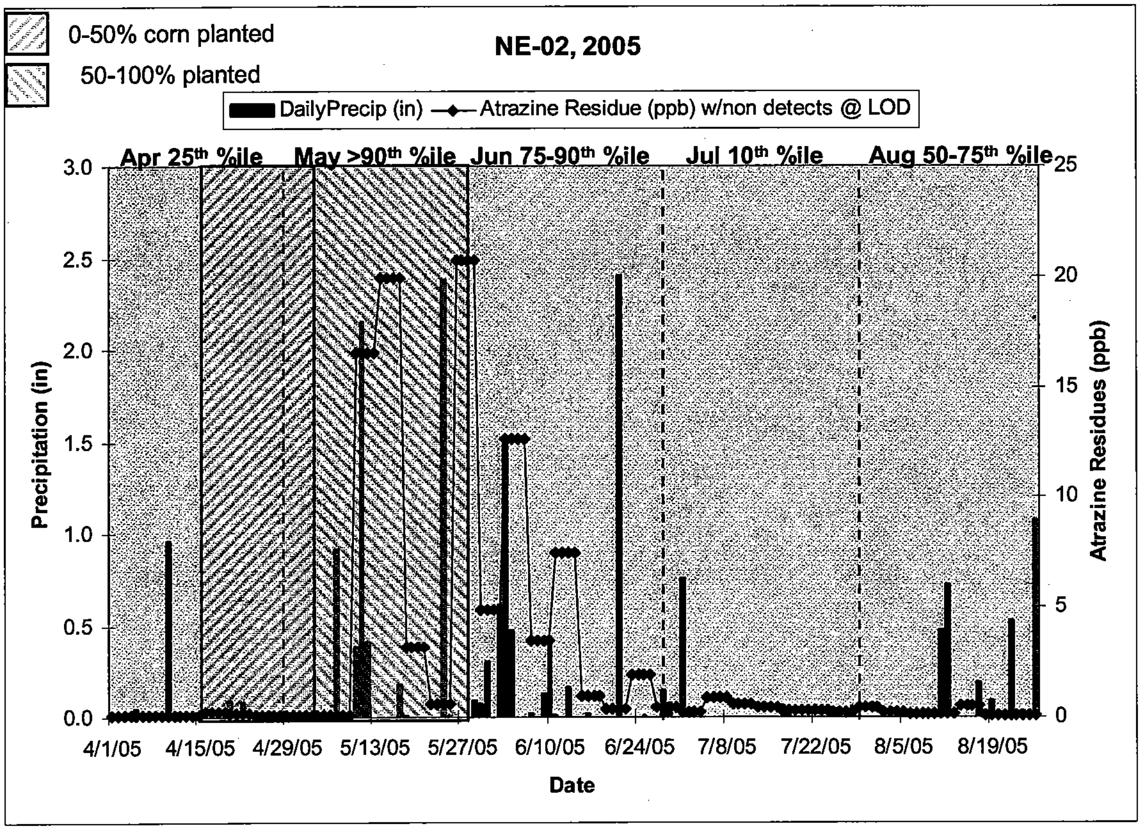
Watershed Location: Middle Loup River Watershed, NE
NWS Weather Station:

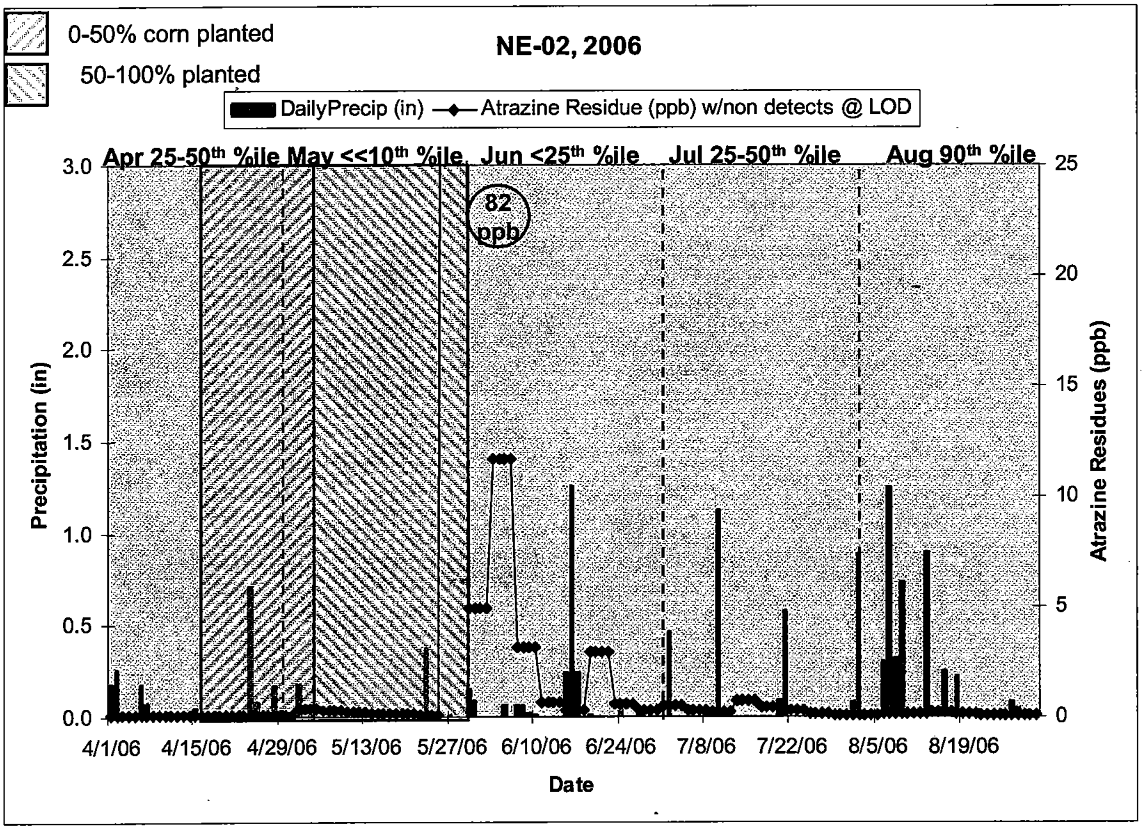
	April Total (in)	May Total (in)	June Total (in)	July Total (in)	August Total (in)	Apr-Aug Total (in)
Historical precipitation summaries, 1948-2001						
Max	7.65	9.28	12.64	13.54	7.87	24.29
90th %ile	4.49	6.37	6.98	5.73	5.33	21.62
75th %ile	3.14	5.04	5.37	4.20	3.62	19.66
50th %ile	2.39	4.09	3.70	2.68	2.18	16.56
25th %ile	1.04	2.78	2.34	1.97	1.42	14.10
10th %ile	0.80	2.03	1.39	1.08	0.96	11.69
Min	0.13	0.89	0.20	0.62	0.50	8.86
Monthly totals during the monitoring study						
2005	1.26	6.91	5.97	0.94	3.13	18.21
2006	1.7	0.89	2.01	2.3	5.04	11.94

Monthly precipitation totals for 2005 bounced between below the median/ 25th percentile for April and July to above the 75th percentile in May and June. Monthly rainfall totals in 2006 were near or below the 25th percentile from April through July.



The following figures show the daily precipitation and atrazine residues in water for 2005 and 2006. The planting season is shaded to provide a point of reference for the likely timing of applications in the watershed.

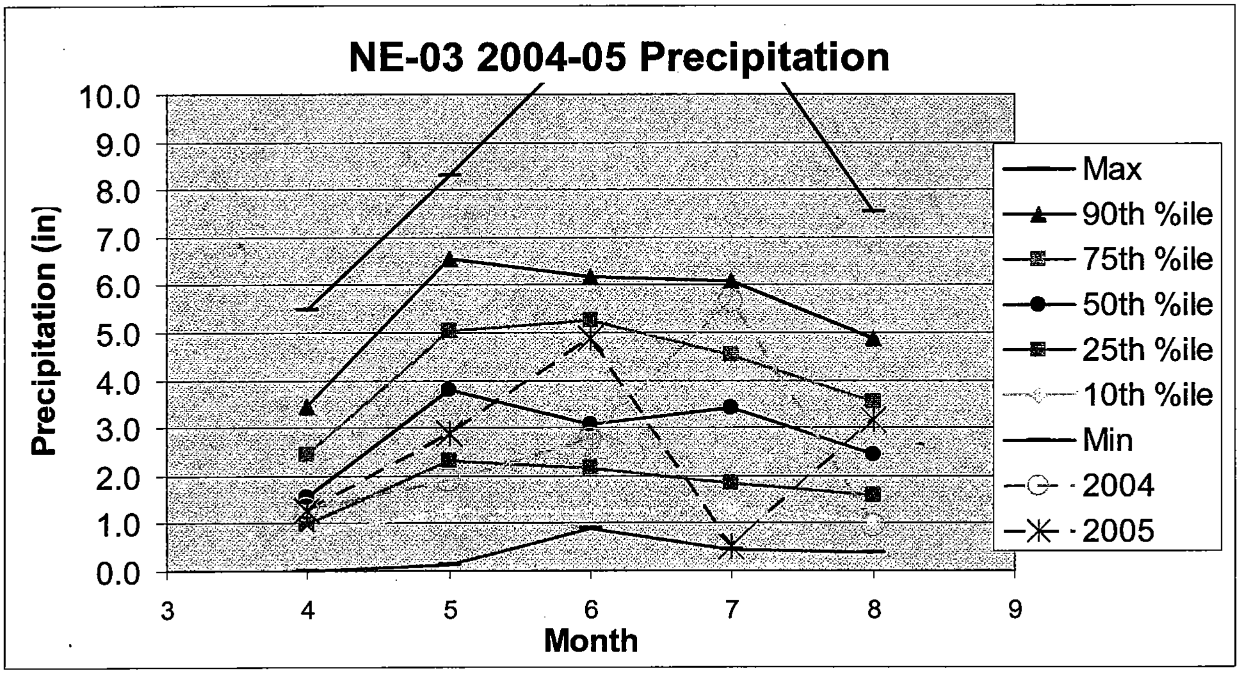

0-50% corn planted
50-100% planted
NE-02, 2005
DailyPrecip (in)
Atrazine Residue (ppb) w/non detects @ LOD
Apr 25th %ile
May >90th %ile
Jun 75-90th %ile
Jul 10th %ile
Aug 50-75th %ile
Precipitation (in)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Atrazine Residues (ppb)
25
20
15
10
5
0
4/1/05
4/15/05
4/29/05
5/13/05
5/27/05
6/10/05
6/24/05
7/8/05
7/22/05
8/5/05
8/19/05
Date


0-50% corn planted
50-100% planted
NE-02, 2006
DailyPrecip (in)
Atrazine Residue (ppb) w/non detects @ LOD
Apr 25-50th %ile
May <<10th %ile
Jun <25th %ile
Jul 25-50th %ile
Aug 90th %ile
82 ppb
Precipitation (in)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Atrazine Residues (ppb)
25
20
15
10
5
0
4/1/06
4/15/06
4/29/06
5/13/06
5/27/06
6/10/06
6/24/06
7/8/06
7/22/06
8/5/06
8/19/06
Date

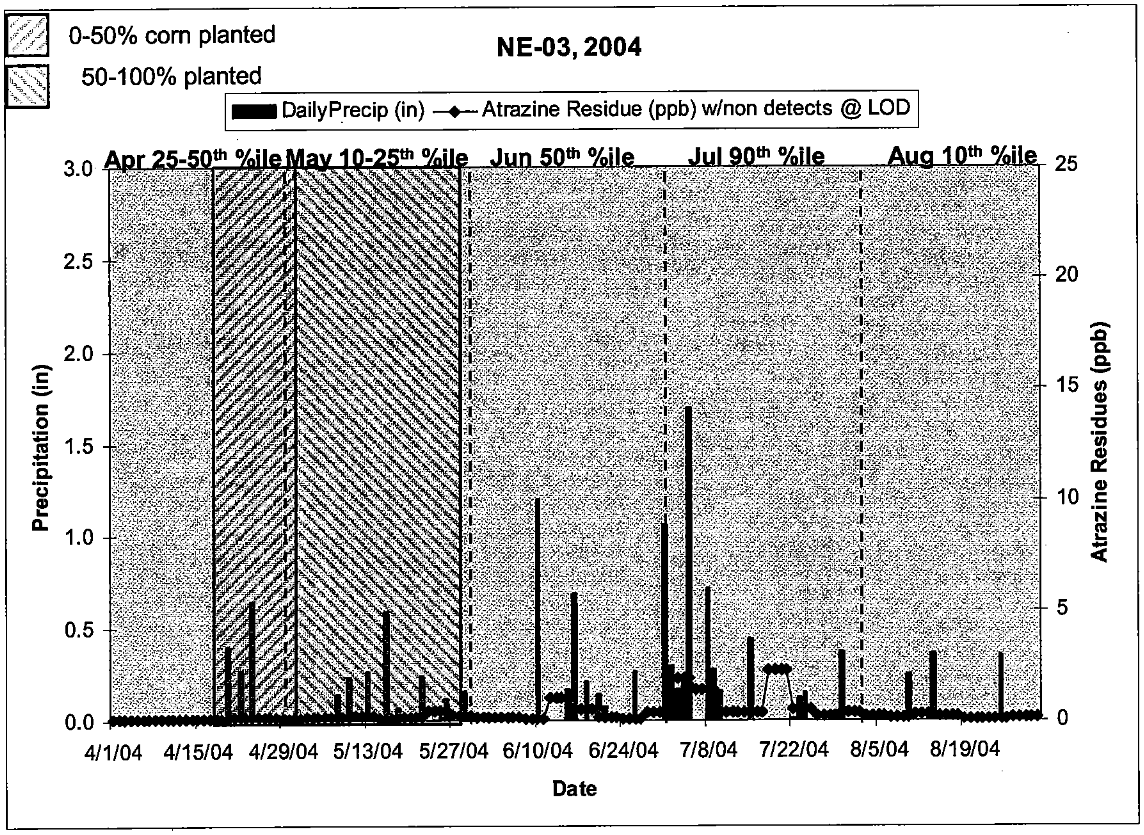
31. NE-03, 2004-2005

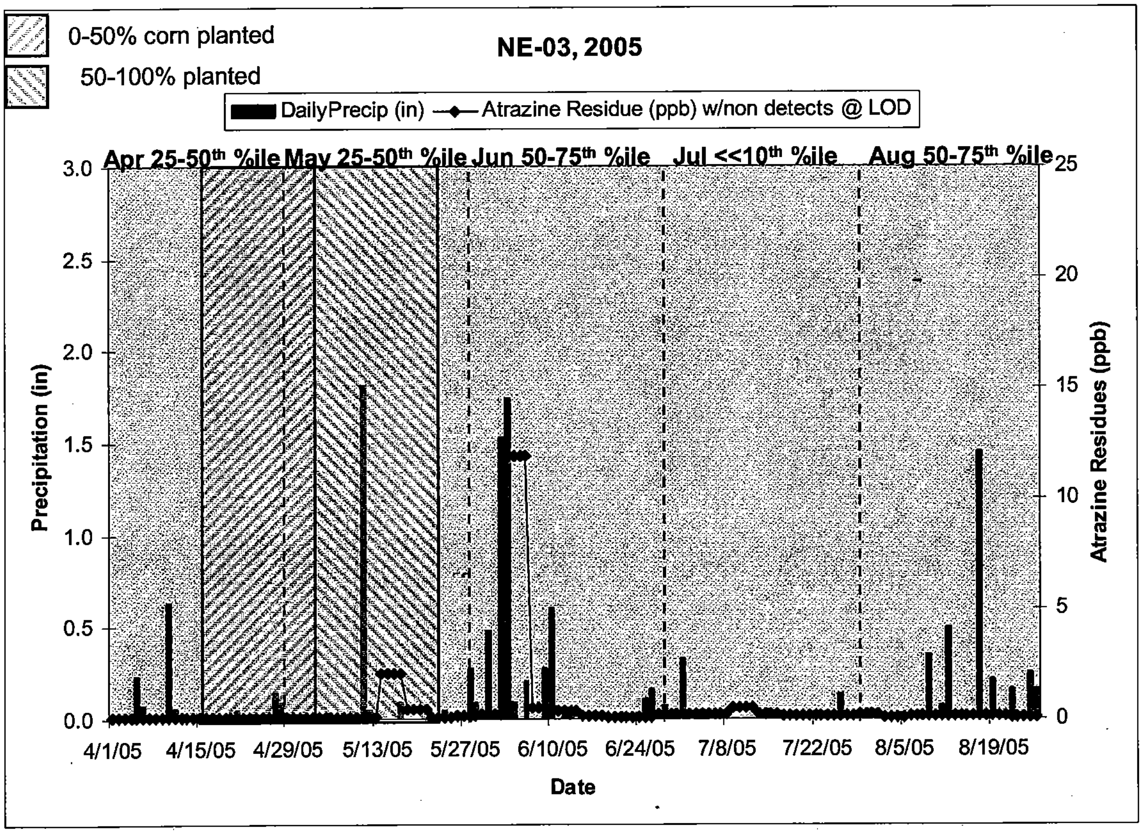
Watershed Location: Platte River, NE
NWS Weather Station:

	April Total (in)	May Total (in)	June Total (in)	July Total (in)	August Total (in)	Apr-Aug Total (in)
Historical precipitation summaries, 1948-2001						
Max	6.54	8.84	9.94	9.85	8.68	32.36
90th %ile	5.20	7.73	7.53	5.46	7.08	23.16
75th %ile	3.21	5.20	5.43	3.94	5.60	20.37
50th %ile	2.37	4.05	3.45	3.03	2.50	16.08
25th %ile	1.54	2.74	1.95	1.54	1.62	14.04
10th %ile	1.05	1.70	1.59	0.95	0.98	12.01
Min	0.34	0.85	1.02	0.11	0.53	10.02
Monthly totals during the monitoring study						
2004	1.84	3.93	2.32	3.22	1.31	12.62
2005	4.22	3.86	2.88	2.97	2.07	16



The following figures show the daily precipitation and atrazine residues in water for 2004 and 2005. The planting season is shaded to provide a point of reference for the likely timing of applications in the watershed.


0-50% corn planted
50-100% planted
NE-03, 2004
DailyPrecip (in)
Atrazine Residue (ppb) w/non detects @ LOD
Apr 25-50th %ile
May 10-25th %ile
Jun 50th %ile
Jul 90th %ile
Aug 10th %ile
Precipitation (in)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Atrazine Residues (ppb)
25
20
15
10
5
0
4/1/04
4/15/04
4/29/04
5/13/04
5/27/04
6/10/04
6/24/04
7/8/04
7/22/04
8/5/04
8/19/04
Date

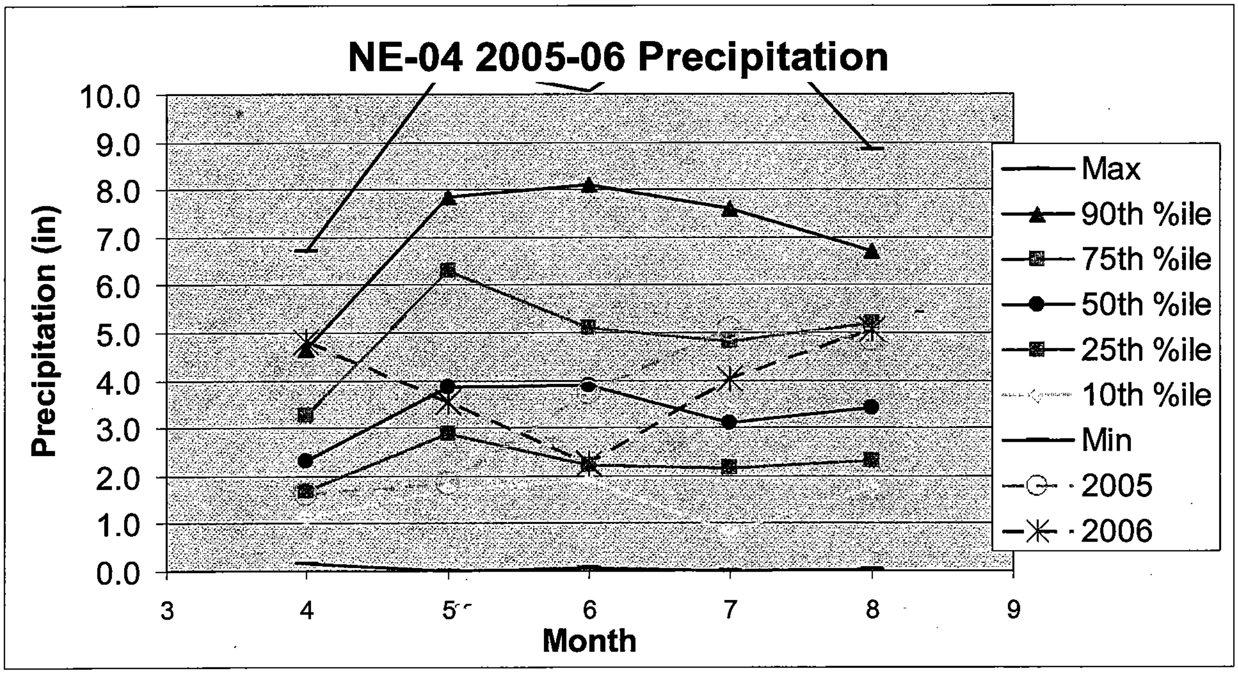

0-50% corn planted
50-100% planted
NE-03, 2005
DailyPrecip (in)
Atrazine Residue (ppb) w/non detects @ LOD
Apr 25-50th %ile
May 25-50th %ile
Jun 50-75th %ile
Jul <<10th %ile
Aug 50-75th %ile
Precipitation (in)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Atrazine Residues (ppb)
25
20
15
10
5
0
4/1/05
4/15/05
4/29/05
5/13/05
5/27/05
6/10/05
6/24/05
7/8/05
7/22/05
8/5/05
8/19/05
Date

32. NE-04 2005-06

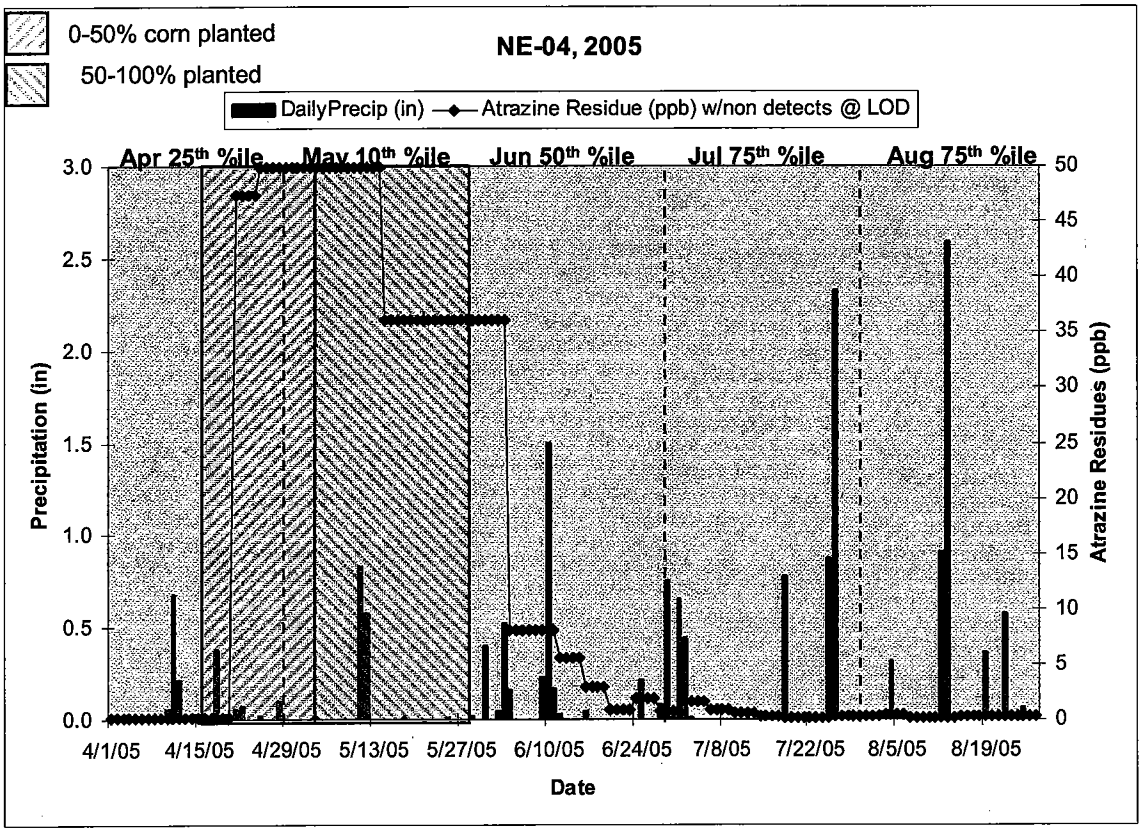
Watershed Location: Big Blue River, Upper Gage Watershed, NE
NWS Weather Station:

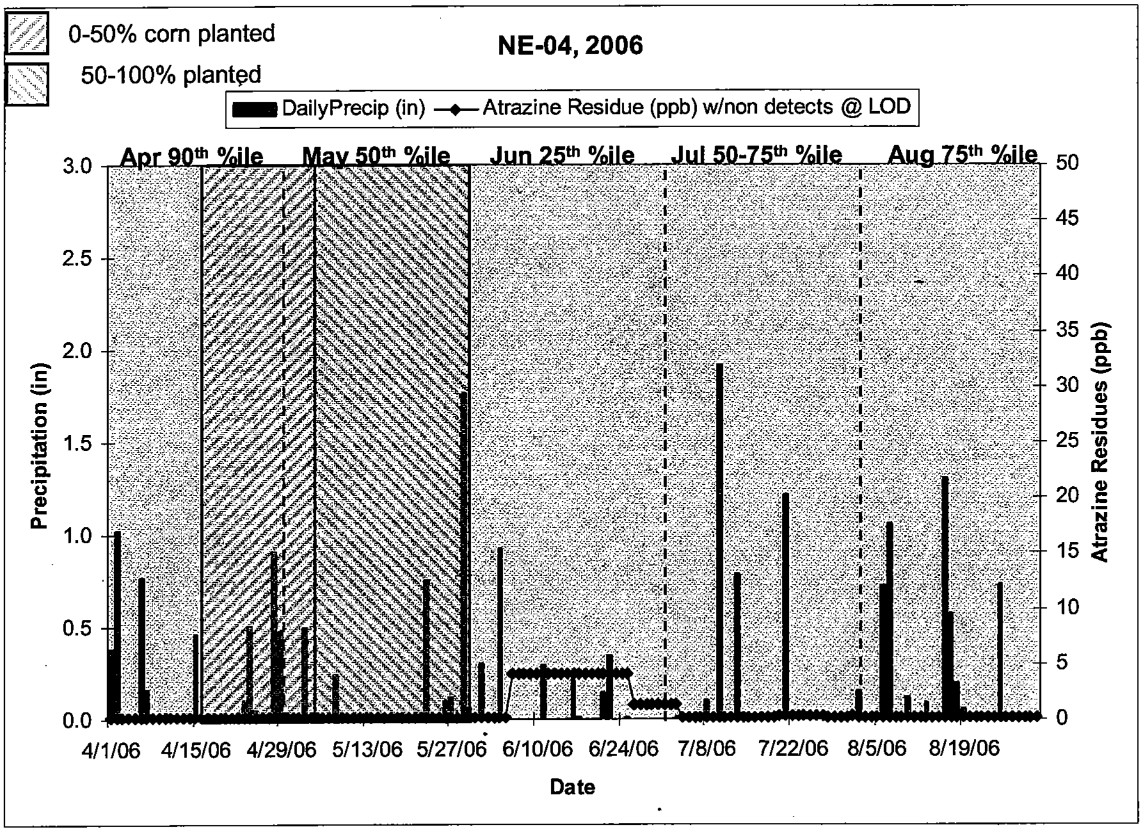
	April Total (in)	May Total (in)	June Total (in)	July Total (in)	August Total (in)	Apr-Aug Total (in)
Historical precipitation summaries, 1948-2001						
Max	6.72	10.64	10.06	12.04	8.83	33.90
90th %ile	4.65	7.86	8.09	7.60	6.70	26.22
75th %ile	3.25	6.30	5.08	4.82	5.19	23.35
50th %ile	2.32	3.87	3.90	3.11	3.41	18.40
25th %ile	1.67	2.87	2.22	2.17	2.30	14.49
10th %ile	1.11	1.72	1.90	0.83	1.75	11.83
Min	0.16	0.00	0.05	0.00	0.02	9.87
Monthly totals during the monitoring study						
2005	1.61	1.85	3.74	5.07	4.85	17.12
2006	4.8	3.55	2.26	4.03	5.05	19.69

Monthly precipitation totals for 2005 were at or below the 25th percentile for April and May, at the median in June and near the 75th percentile in July and August. Monthly rainfall totals in 2006 were at or above the median in all but June, which was near the 25th percentile.



The following figures show the daily precipitation and atrazine residues in water for 2005 and 2006. The planting season is shaded to provide a point of reference for the likely timing of applications in the watershed.


▨ 0-50% corn planted
▨ 50-100% planted
NE-04, 2005
DailyPrecip (in)
Atrazine Residue (ppb) w/non detects @ LOD
Apr 25th %ile
May 10th %ile
Jun 50th %ile
Jul 75th %ile
Aug 75th %ile
Precipitation (in)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Atrazine Residues (ppb)
50
45
40
35
30
25
20
15
10
5
0
4/1/05
4/15/05
4/29/05
5/13/05
5/27/05
6/10/05
6/24/05
7/8/05
7/22/05
8/5/05
8/19/05
Date

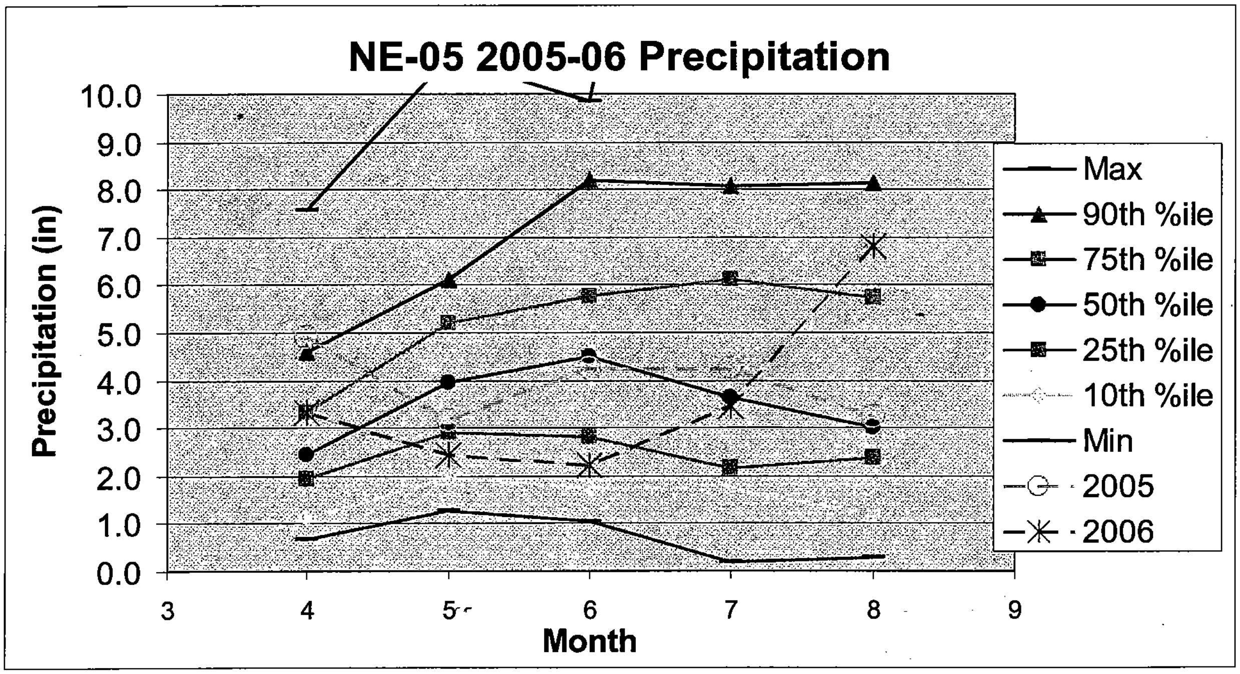

▨ 0-50% corn planted
▨ 50-100% planted
NE-04, 2006
DailyPrecip (in)
Atrazine Residue (ppb) w/non detects @ LOD
Apr 90th %ile
May 50th %ile
Jun 25th %ile
Jul 50-75th %ile
Aug 75th %ile
Precipitation (in)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Atrazine Residues (ppb)
50
45
40
35
30
25
20
15
10
5
0
4/1/06
4/15/06
4/29/06
5/13/06
5/27/06
6/10/06
6/24/06
7/8/06
7/22/06
8/5/06
8/19/06
Date

33. NE-05 2005-06

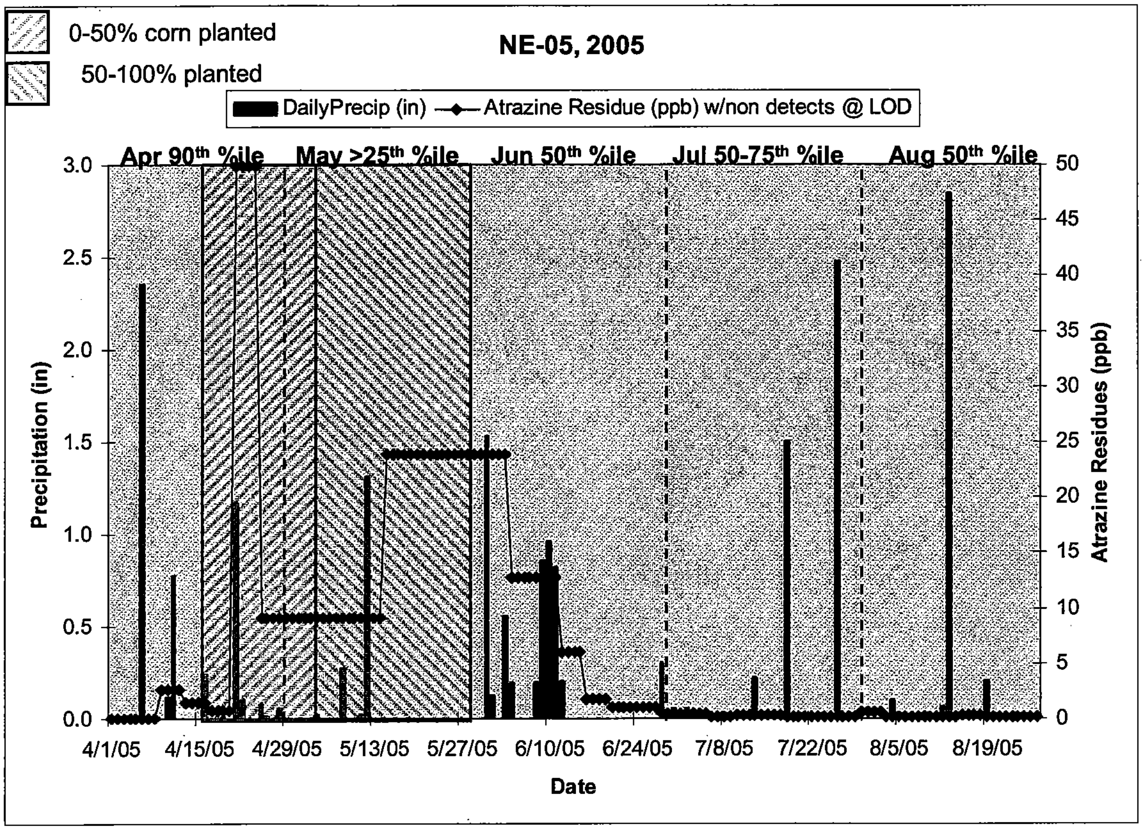
Watershed Location: Muddy Creek, Nebraska Watershed, NE
NWS Weather Station:

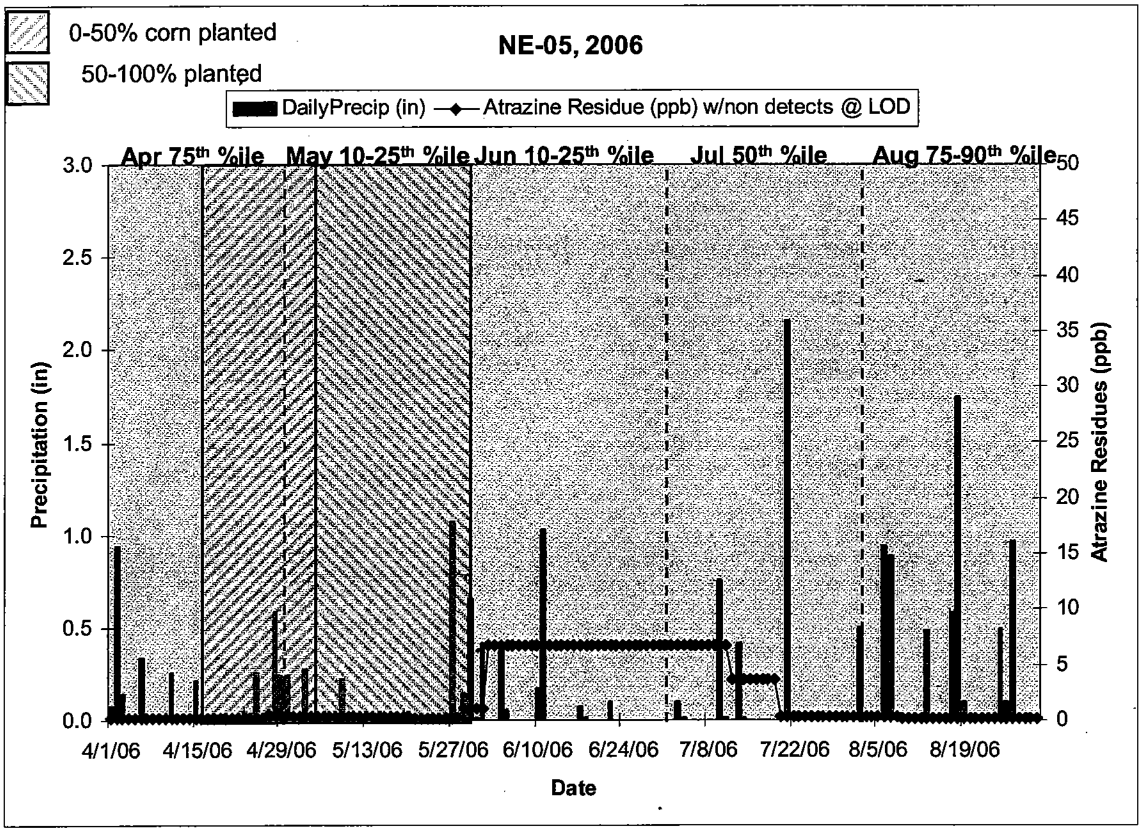
	April Total (in)	May Total (in)	June Total (in)	July Total (in)	August Total (in)	Apr-Aug Total (in)
Historical precipitation summaries, 1948-2001						
Max	7.55	10.76	9.83	26.20	12.92	42.36
90th %ile	4.59	6.11	8.20	8.06	8.13	27.11
75th %ile	3.33	5.18	5.77	6.10	5.72	22.54
50th %ile	2.43	3.97	4.50	3.65	3.02	19.92
25th %ile	1.92	2.91	2.83	2.17	2.36	16.62
10th %ile	1.12	1.95	1.75	1.72	1.21	13.76
Min	0.65	1.28	1.03	0.20	0.27	10.47
Monthly totals during the monitoring study						
2005	4.9	3.15	4.23	4.24	3.23	19.75
2006	3.32	2.44	2.23	3.44	6.8	18.23

Monthly precipitation totals for 2005 were near the median, except for April, which exceeded the 75th percentile value. Monthly rainfall totals in 2006 were below the 25th percentile in May and June and at or greater than the median in April, July, and August.



The following figures show the daily precipitation and atrazine residues in water for 2005 and 2006. The planting season is shaded to provide a point of reference for the likely timing of applications in the watershed.


0-50% corn planted
50-100% planted
NE-05, 2005
DailyPrecip (in)
Atrazine Residue (ppb) w/non detects @ LOD
Apr 90th %ile
May >25th %ile
Jun 50th %ile
Jul 50-75th %ile
Aug 50th %ile
Precipitation (in)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Atrazine Residues (ppb)
50
45
40
35
30
25
20
15
10
5
0
4/1/05
4/15/05
4/29/05
5/13/05
5/27/05
6/10/05
6/24/05
7/8/05
7/22/05
8/5/05
8/19/05
Date

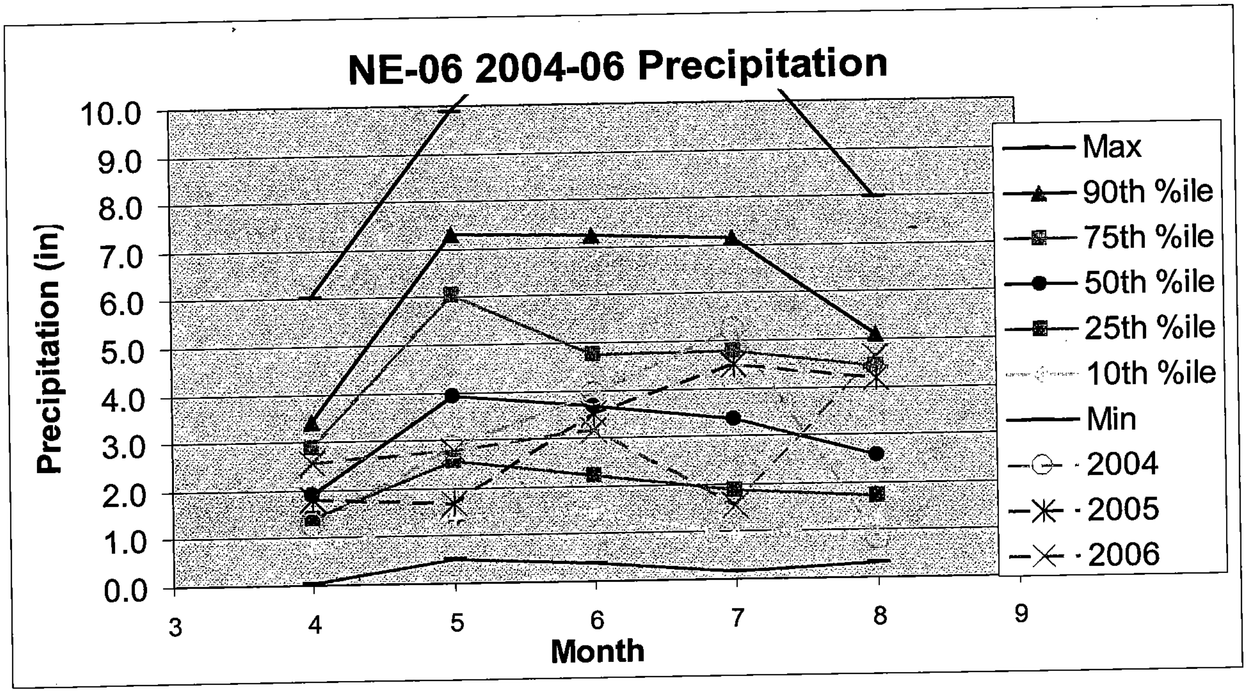

0-50% corn planted
50-100% planted
NE-05, 2006
DailyPrecip (in)
Atrazine Residue (ppb) w/non detects @ LOD
Apr 75th %ile
May 10-25th %ile
Jun 10-25th %ile
Jul 50th %ile
Aug 75-90th %ile
Precipitation (in)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Atrazine Residues (ppb)
50
45
40
35
30
25
20
15
10
5
0
4/1/06
4/15/06
4/29/06
5/13/06
5/27/06
6/10/06
6/24/06
7/8/06
7/22/06
8/5/06
8/19/06
Date

34. NE-06 2004-06

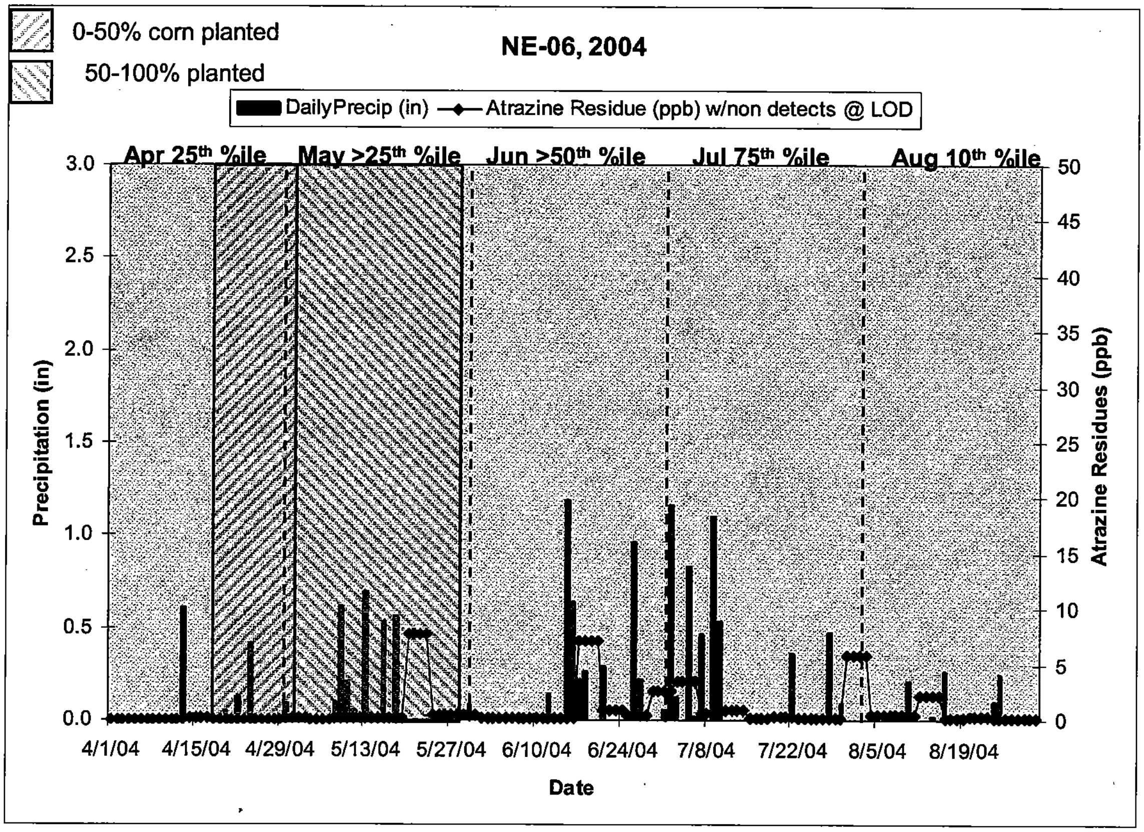
Watershed Location: Crooked Creek Watershed, NE
NWS Weather Station:

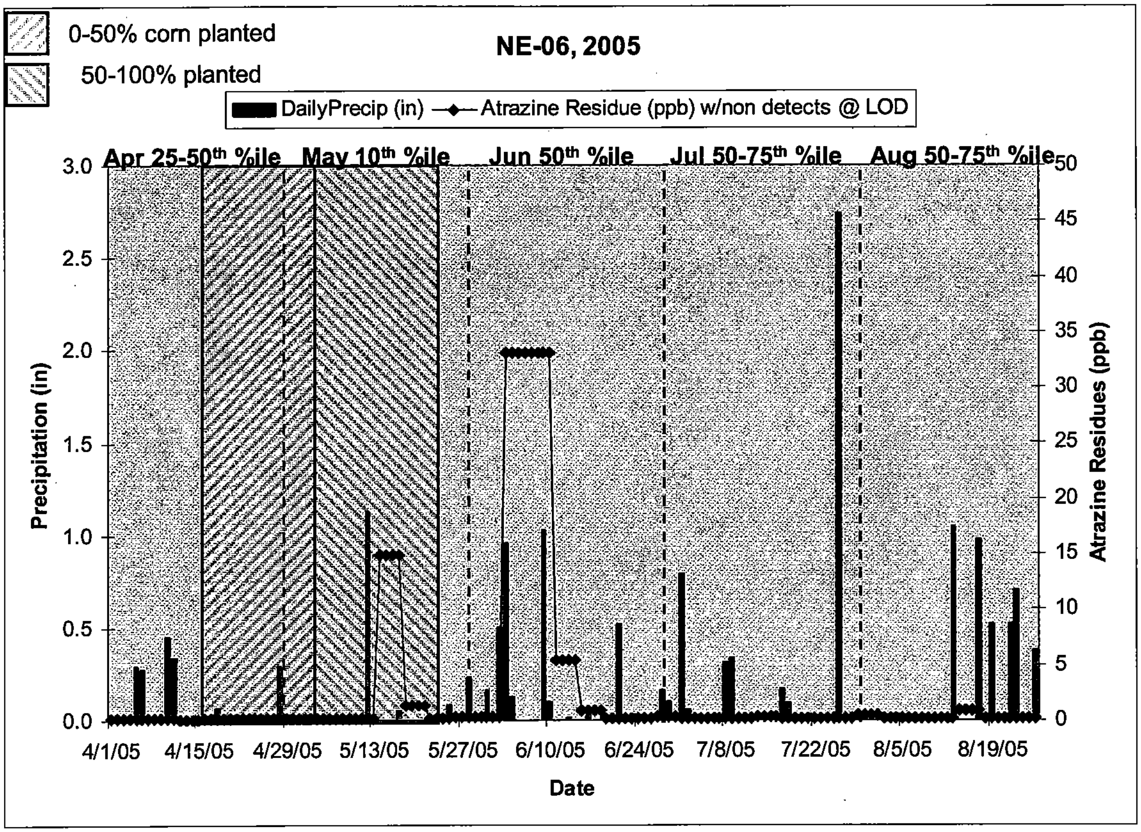
	April Total (in)	May Total (in)	June Total (in)	July Total (in)	August Total (in)	Apr-Aug Total (in)
Historical precipitation summaries, 1948-2001						
Max	6.00	9.87	12.72	11.47	7.99	28.07
90th %ile	3.43	7.31	7.25	7.16	5.09	22.66
75th %ile	2.89	6.03	4.76	4.77	4.43	19.72
50th %ile	1.89	3.94	3.69	3.36	2.56	16.78
25th %ile	1.38	2.58	2.23	1.87	1.72	13.78
10th %ile	0.75	1.39	1.46	0.90	1.18	11.98
Min	0.02	0.50	0.38	0.15	0.32	9.43
Monthly totals during the monitoring study						
2004	1.27	2.85	3.93	5.23	0.83	14.11
2005	1.79	1.67	3.52	4.49	4.18	15.65
2006	2.57	2.79	3.15	1.54	4.62	14.67

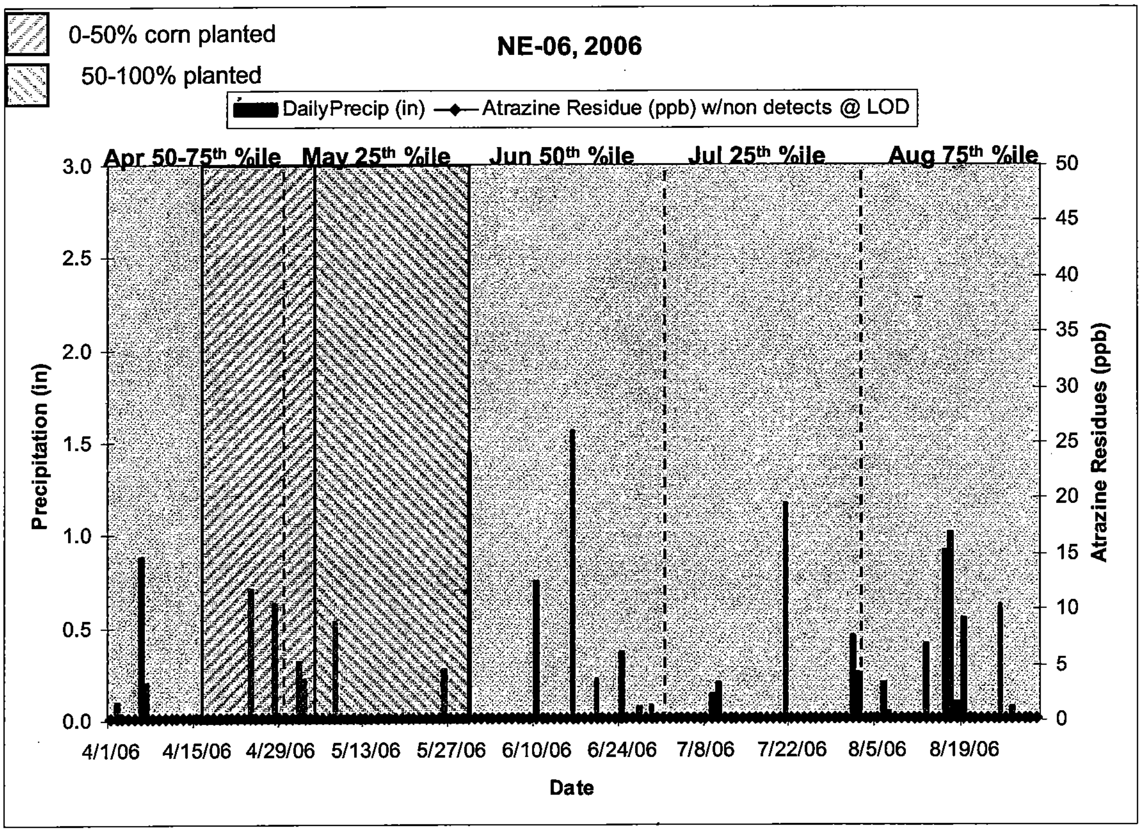
Monthly precipitation totals for 2004 were at or below the 25th percentile in April and May and above the 75th percentile in July. In 2005, monthly totals fell below the 25th percentile value in May but were at or above the 50th percentile in the other sample months. Monthly rainfall totals in 2006 were at or below the 25th percentile in May and July and near the 75th percentile in April and August.



The following figures show the daily precipitation and atrazine residues in water for 2004, 2005, and 2006. The planting season is shaded to provide a point of reference for the likely timing of applications in the watershed.




0-50% corn planted
50-100% planted
NE-06, 2005
DailyPrecip (in)
Atrazine Residue (ppb) w/non detects @ LOD
Apr 25-50th %ile
May 10th %ile
Jun 50th %ile
Jul 50-75th %ile
Aug 50-75th %ile
Precipitation (in)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Atrazine Residues (ppb)
50
45
40
35
30
25
20
15
10
5
0
4/1/05
4/15/05
4/29/05
5/13/05
5/27/05
6/10/05
6/24/05
7/8/05
7/22/05
8/5/05
8/19/05
Date

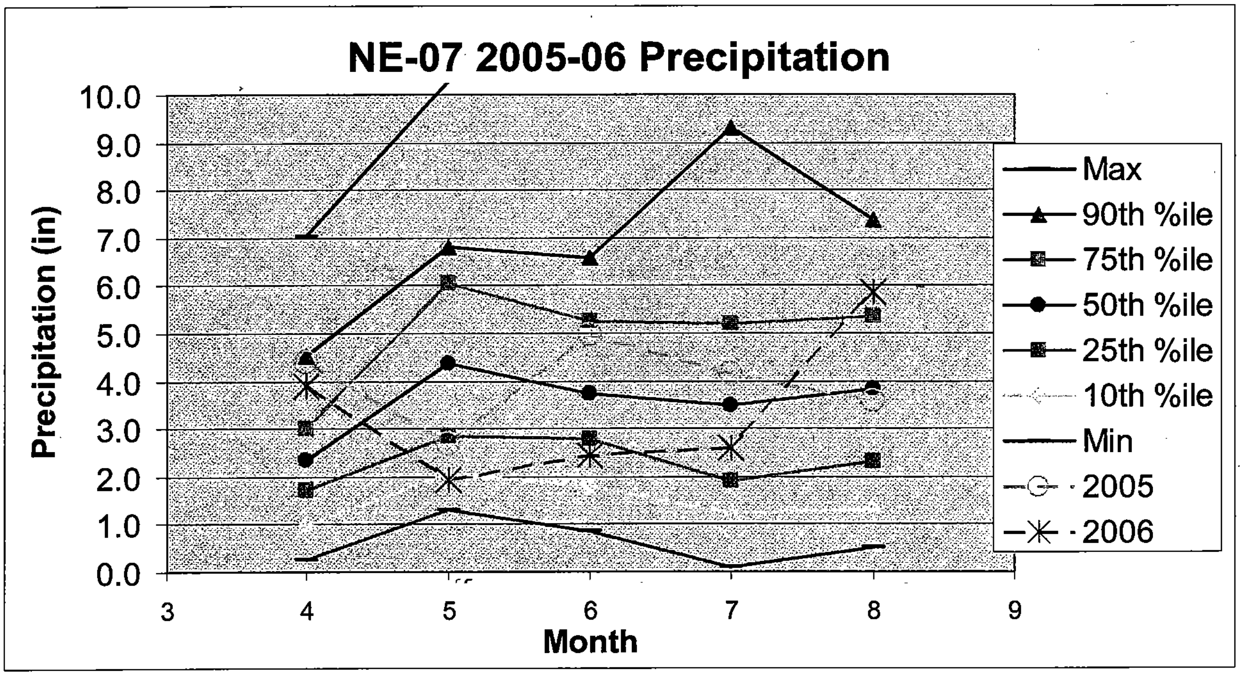

0-50% corn planted
50-100% planted
NE-06, 2006
DailyPrecip (in)
Atrazine Residue (ppb) w/non detects @ LOD
Apr 50-75th %ile
May 25th %ile
Jun 50th %ile
Jul 25th %ile
Aug 75th %ile
Precipitation (in)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Atrazine Residues (ppb)
50
45
40
35
30
25
20
15
10
5
0
4/1/06
4/15/06
4/29/06
5/13/06
5/27/06
6/10/06
6/24/06
7/8/06
7/22/06
8/5/06
8/19/06
Date

35. NE-07 2005-06

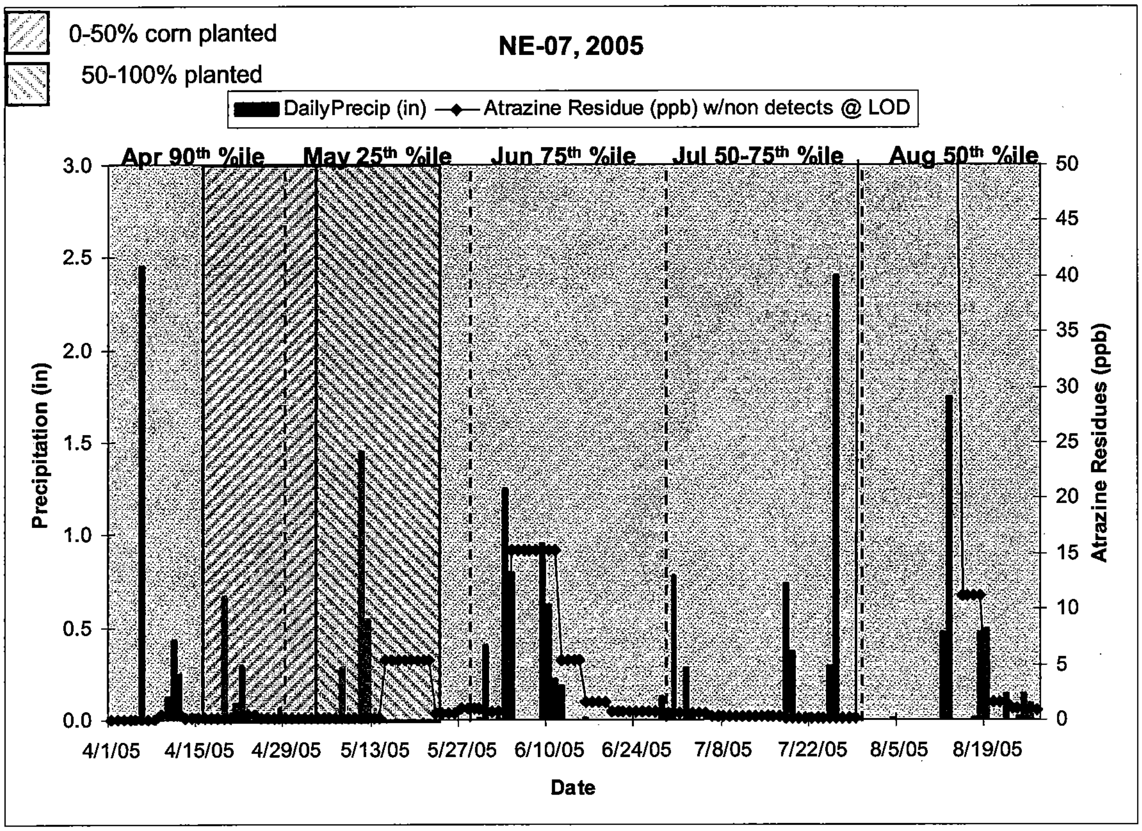
Watershed Location: Big Blue River, Lower Gage Watershed, NE
NWS Weather Station:

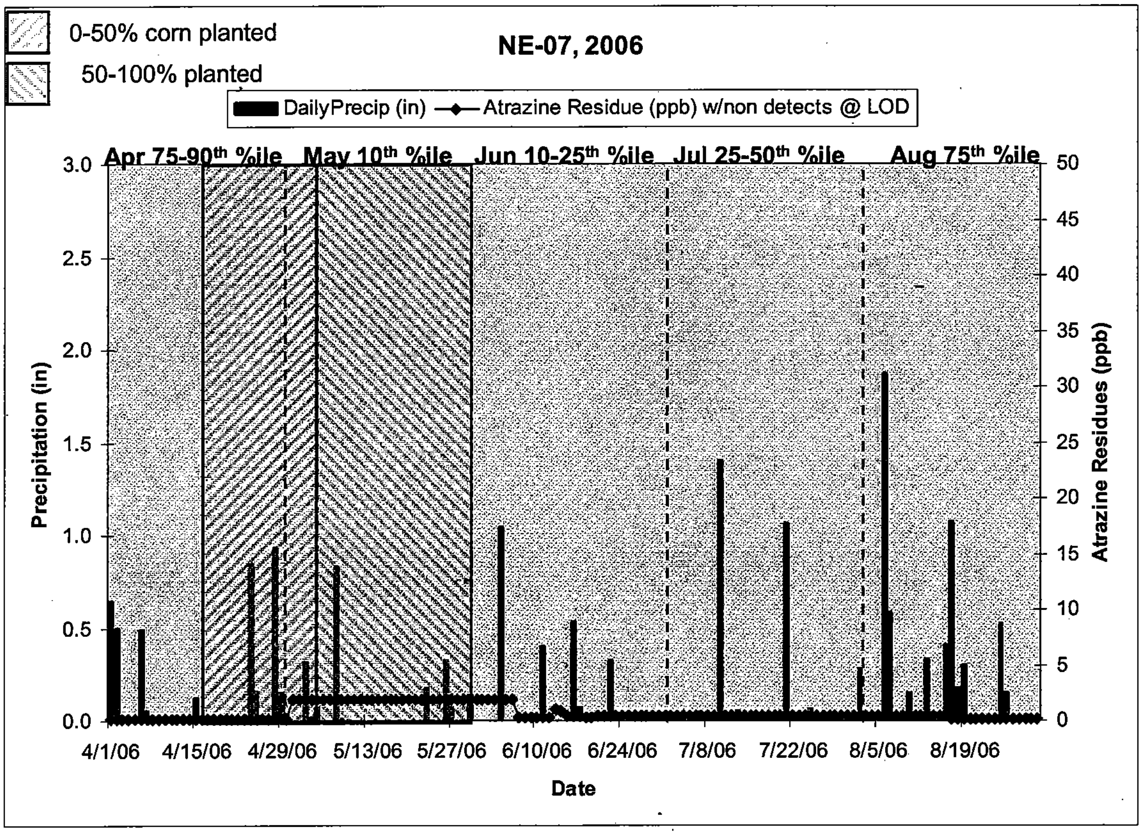
	April Total (in)	May Total (in)	June Total (in)	July Total (in)	August Total (in)	Apr-Aug Total (in)
Historical precipitation summaries, 1948-2001						
Max	7.04	10.28	11.55	17.02	11.12	35.52
90th %ile	4.54	6.80	6.59	9.30	7.38	27.49
75th %ile	3.00	6.05	5.25	5.21	5.35	22.62
50th %ile	2.33	4.36	3.72	3.49	3.82	19.03
25th %ile	1.70	2.84	2.78	1.90	2.31	16.28
10th %ile	0.99	2.05	1.79	1.24	1.30	13.45
Min	0.26	1.30	0.85	0.10	0.51	10.45
Monthly totals during the monitoring study						
2005	4.41	2.7	4.98	4.13	3.58	19.8
2006	3.88	1.94	2.44	2.61	5.87	16.74

Monthly precipitation totals for 2005 were near or above the median, except for May, which was near the 25th percentile value. Monthly rainfall totals in 2006 were below the 25th percentile in May and June, below the median in July, and greater than the 75th percentile in April and August.



The following figures show the daily precipitation and atrazine residues in water for 2005 and 2006. The planting season is shaded to provide a point of reference for the likely timing of applications in the watershed.

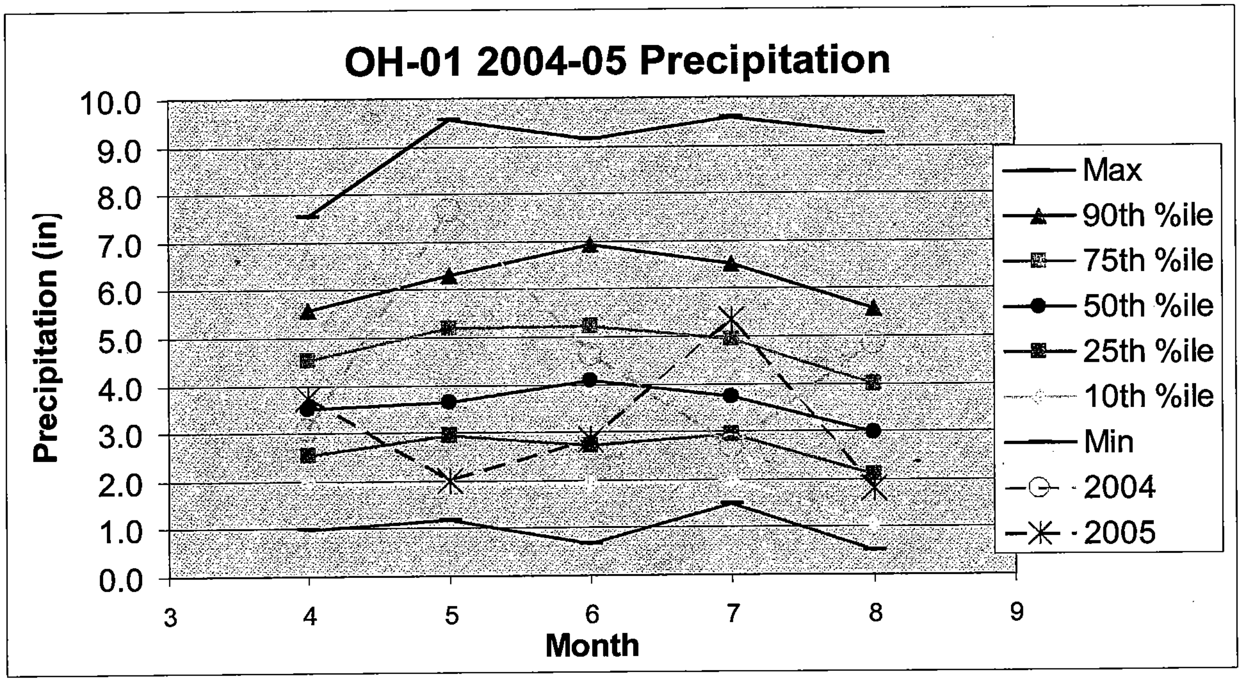

▨ 0-50% corn planted
▧ 50-100% planted
NE-07, 2005
DailyPrecip (in)
Atrazine Residue (ppb) w/non detects @ LOD
Apr 90th %ile
May 25th %ile
Jun 75th %ile
Jul 50-75th %ile
Aug 50th %ile
Precipitation (in)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Atrazine Residues (ppb)
50
45
40
35
30
25
20
15
10
5
0
4/1/05
4/15/05
4/29/05
5/13/05
5/27/05
6/10/05
6/24/05
7/8/05
7/22/05
8/5/05
8/19/05
Date


▨ 0-50% corn planted
▧ 50-100% planted
NE-07, 2006
DailyPrecip (in)
Atrazine Residue (ppb) w/non detects @ LOD
Apr 75-90th %ile
May 10th %ile
Jun 10-25th %ile
Jul 25-50th %ile
Aug 75th %ile
Precipitation (in)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Atrazine Residues (ppb)
50
45
40
35
30
25
20
15
10
5
0
4/1/06
4/15/06
4/29/06
5/13/06
5/27/06
6/10/06
6/24/06
7/8/06
7/22/06
8/5/06
8/19/06
Date

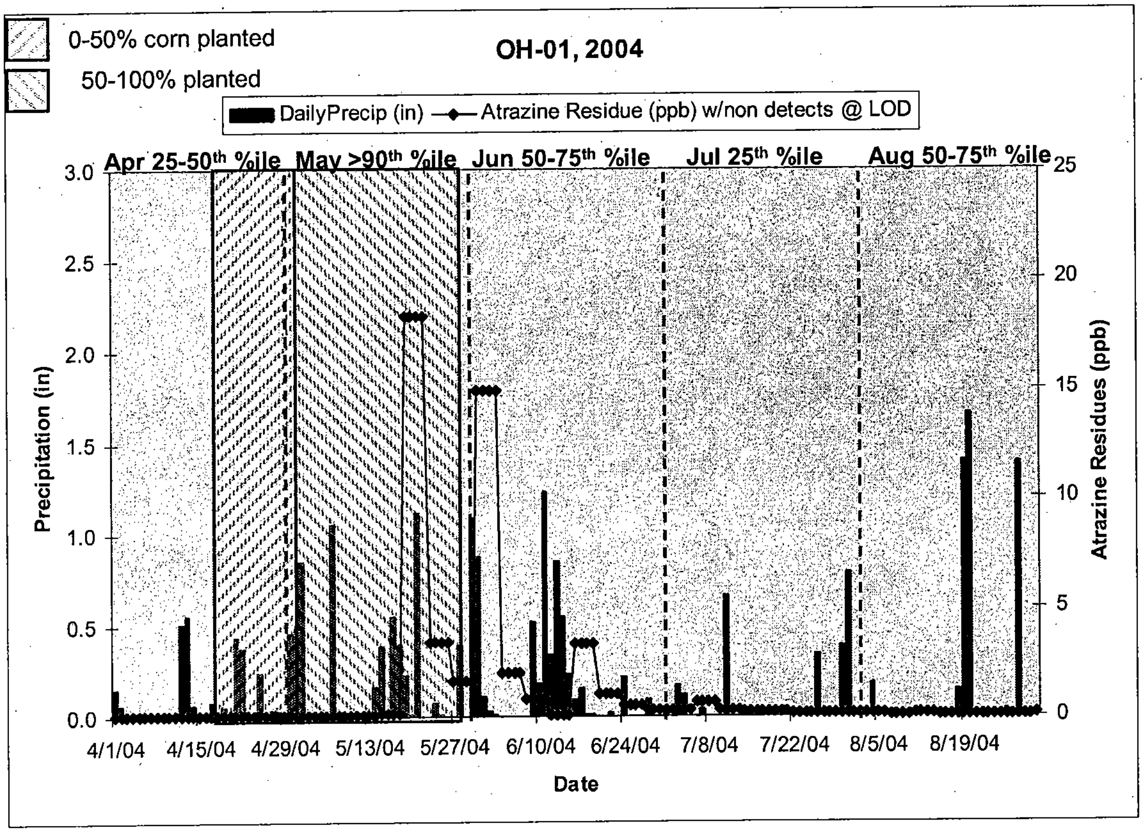
36. OH-01 2004-05

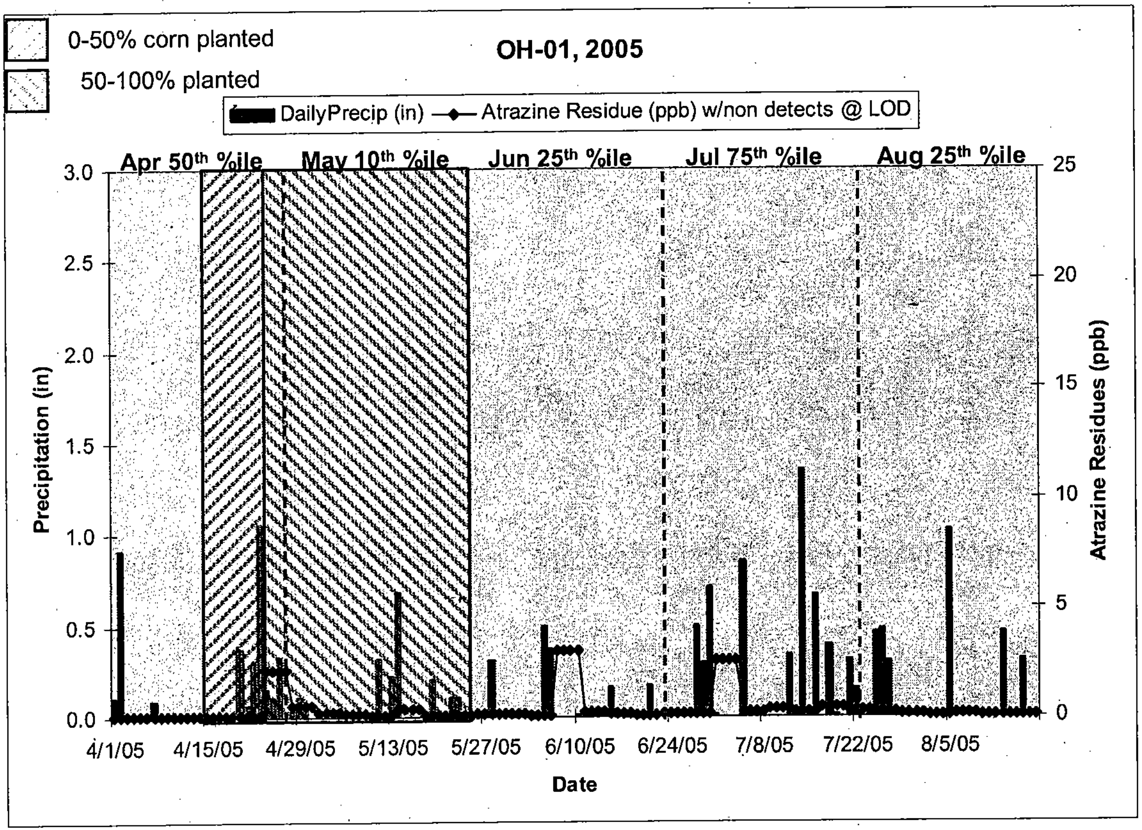
Watershed Location: Kokosing River, OH
NWS Weather Station:

	April Total (in)	May Total (in)	June Total (in)	July Total (in)	August Total (in)	Apr-Aug Total (in)
Historical precipitation summaries, 1948-2001						
Max	7.52	9.55	9.14	9.59	9.24	28.69
90th %ile	5.57	6.29	6.92	6.53	5.57	24.13
75th %ile	4.52	5.20	5.21	4.94	3.99	22.80
50th %ile	3.52	3.63	4.07	3.73	2.98	18.99
25th %ile	2.55	2.93	2.72	2.95	2.10	16.17
10th %ile	1.97	1.90	1.94	1.95	1.09	14.47
Min	0.98	1.17	0.68	1.48	0.51	12.67
Monthly totals during the monitoring study						
2004	3.06	7.65	4.62	2.68	4.83	22.84
2005	3.73	1.98	2.84	5.36	1.81	15.72



The following figures show the daily precipitation and atrazine residues in water for 2004 and 2005. The planting season is shaded to provide a point of reference for the likely timing of applications in the watershed.


▨ 0-50% corn planted
▨ 50-100% planted
OH-01, 2004
DailyPrecip (in)
Atrazine Residue (ppb) w/non detects @ LOD
Apr 25-50th %ile
May >90th %ile
Jun 50-75th %ile
Jul 25th %ile
Aug 50-75th %ile
Precipitation (in)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Atrazine Residues (ppb)
25
20
15
10
5
0
4/1/04
4/15/04
4/29/04
5/13/04
5/27/04
6/10/04
6/24/04
7/8/04
7/22/04
8/5/04
8/19/04
Date

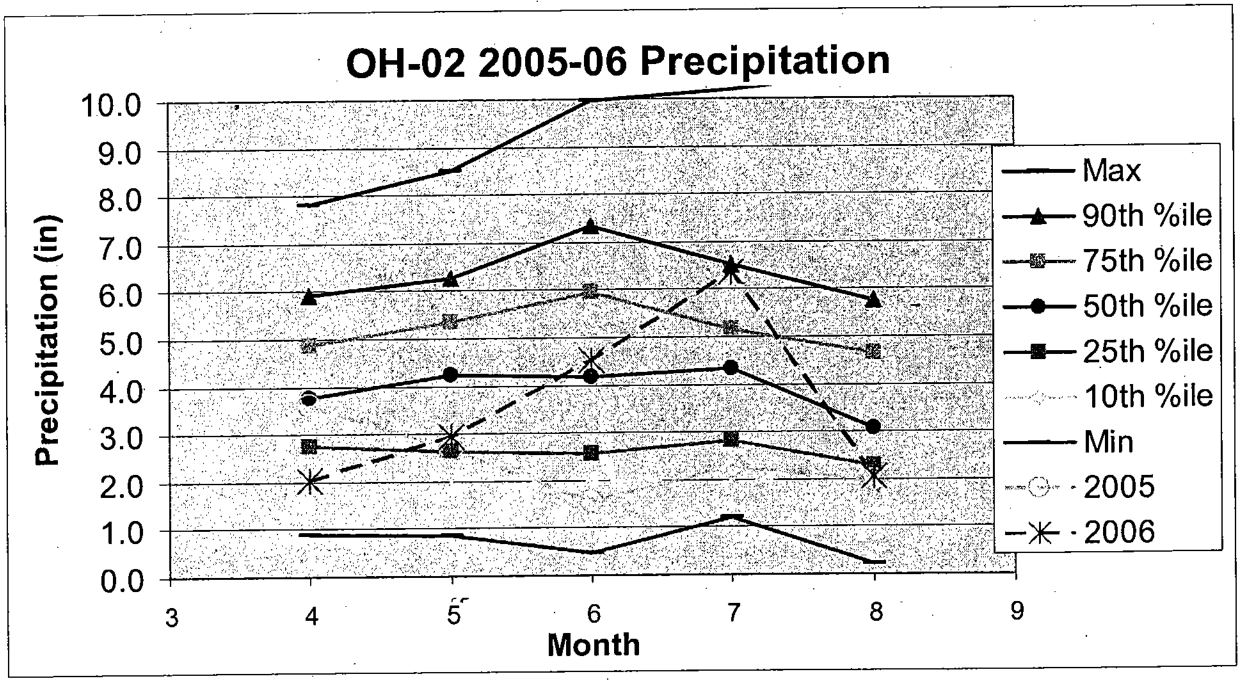

▨ 0-50% corn planted
▨ 50-100% planted
OH-01, 2005
DailyPrecip (in)
Atrazine Residue (ppb) w/non detects @ LOD
Apr 50th %ile
May 10th %ile
Jun 25th %ile
Jul 75th %ile
Aug 25th %ile
Precipitation (in)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Atrazine Residues (ppb)
25
20
15
10
5
0
4/1/05
4/15/05
4/29/05
5/13/05
5/27/05
6/10/05
6/24/05
7/8/05
7/22/05
8/5/05
Date

37. OH-02 2005-06

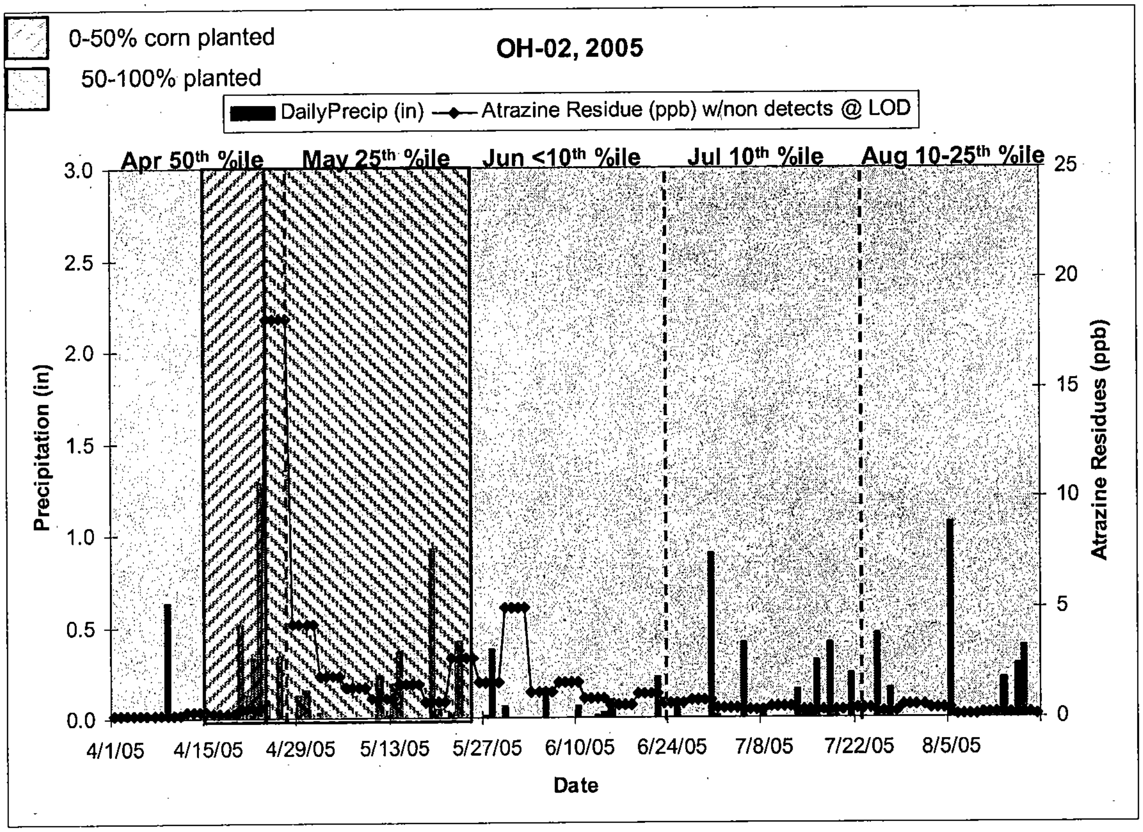
Watershed Location: Licking River, North Fork Watershed, OH
NWS Weather Station:

	April Total (in)	May Total (in)	June Total (in)	July Total (in)	August Total (in)	Apr-Aug Total (in)
Historical precipitation summaries, 1936-2001						
Max	7.81	8.52	9.96	10.19	10.50	31.79
90th %ile	5.93	6.28	7.34	6.51	5.75	26.50
75th %ile	4.89	5.35	5.95	5.17	4.64	23.03
50th %ile	3.77	4.23	4.18	4.33	3.07	20.08
25th %ile	2.76	2.63	2.57	2.83	2.28	17.34
10th %ile	1.58	1.85	1.93	2.11	1.54	15.22
Min	0.88	0.87	0.48	1.21	0.21	10.39
Monthly totals during the monitoring study						
2005	3.61	2.67	1.56	2.27	1.95	12.06
2006	2.01	2.94	4.53	6.36	2.06	17.9

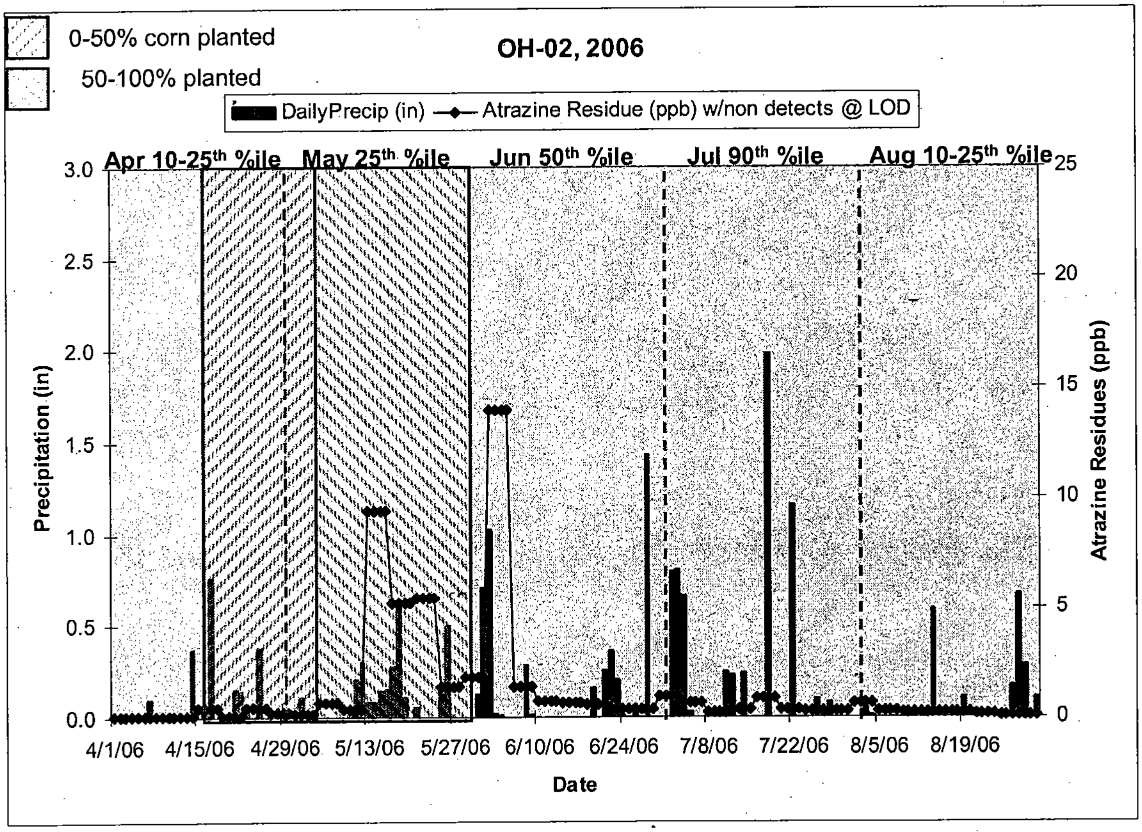
Monthly precipitation totals for 2005 were at or below the 25th percentile, except for April, which was near the median. Monthly rainfall totals in 2006 remained at or below the 25th percentile in April and May, before rising above the median in June and near the 90th percentile in July.



The following figures show the daily precipitation and atrazine residues in water for 2005 and 2006. The planting season is shaded to provide a point of reference for the likely timing of applications in the watershed.



▨ 0-50% corn planted
▨ 50-100% planted
OH-02, 2005
DailyPrecip (in)
Atrazine Residue (ppb) w/non detects @ LOD
Apr 50th %ile
May 25th %ile
Jun <10th %ile
Jul 10th %ile
Aug 10-25th %ile
Precipitation (in)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Atrazine Residues (ppb)
25
20
15
10
5
0
4/1/05
4/15/05
4/29/05
5/13/05
5/27/05
6/10/05
6/24/05
7/8/05
7/22/05
8/5/05
Date

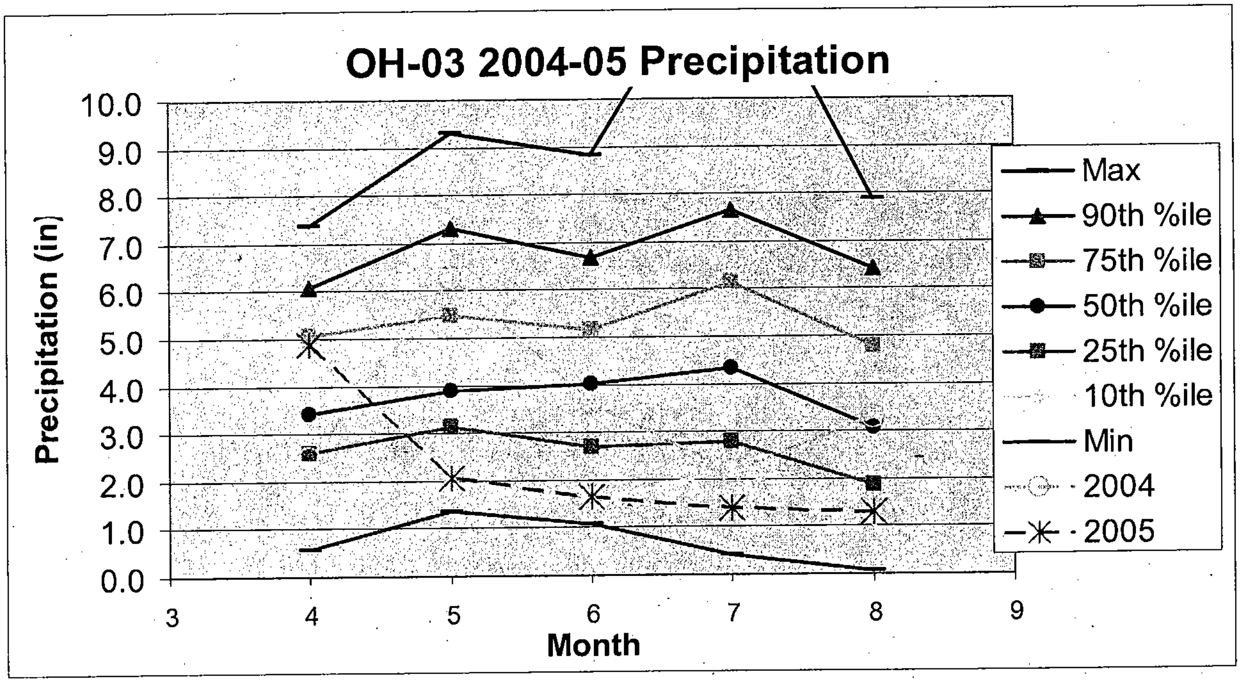


▨ 0-50% corn planted
▨ 50-100% planted
OH-02, 2006
DailyPrecip (in)
Atrazine Residue (ppb) w/non detects @ LOD
Apr 10-25th %ile
May 25th %ile
Jun 50th %ile
Jul 90th %ile
Aug 10-25th %ile
Precipitation (in)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Atrazine Residues (ppb)
25
20
15
10
5
0
4/1/06
4/15/06
4/29/06
5/13/06
5/27/06
6/10/06
6/24/06
7/8/06
7/22/06
8/5/06
8/19/06
Date

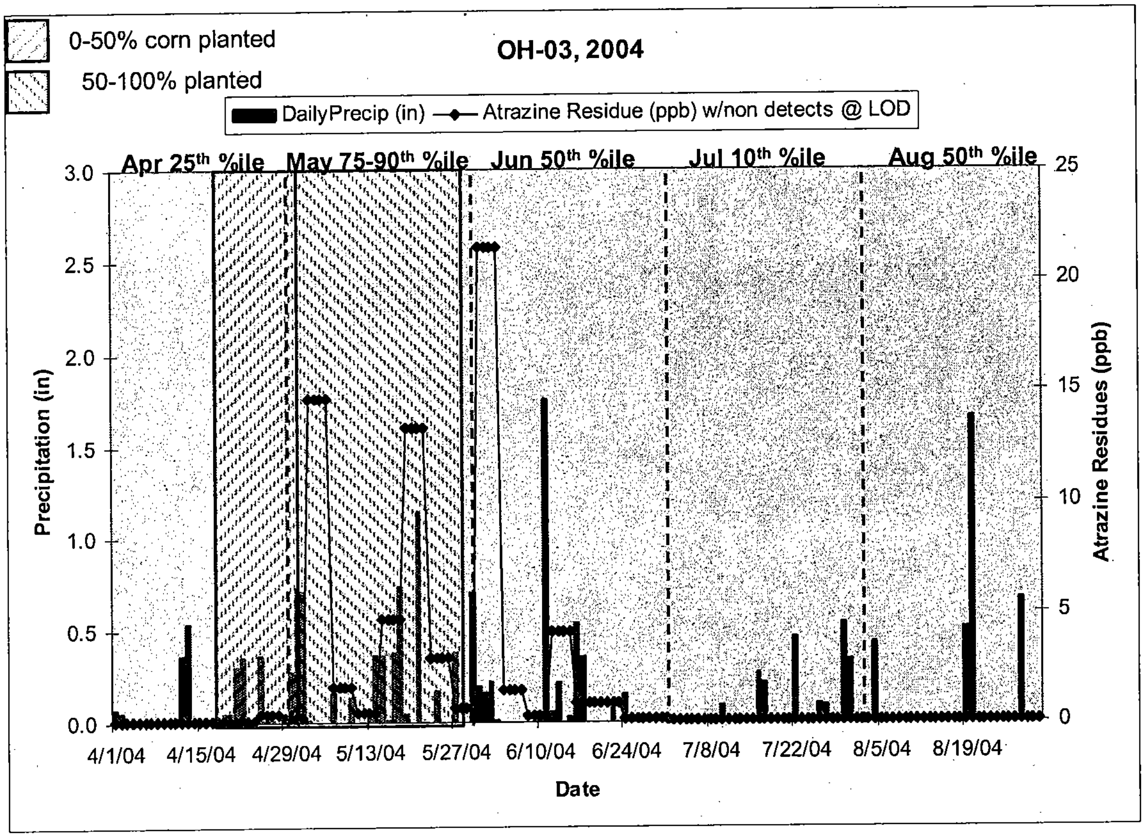
38. OH-03 2004-05

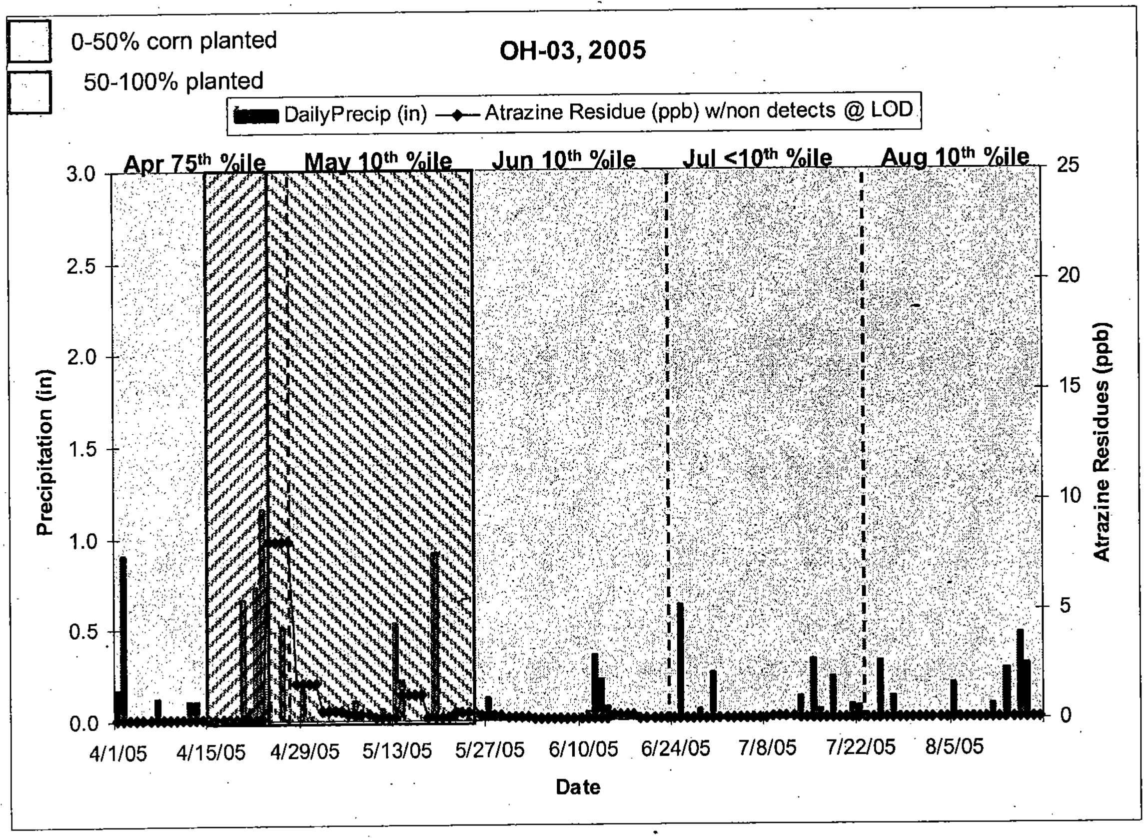
Watershed Location: Mad River, OH
NWS Weather Station:

	April Total (in)	May Total (in)	June Total (in)	July Total (in)	August Total (in)	Apr-Aug Total (in)
Historical precipitation summaries, 1948-2001						
Max	7.36	9.30	8.83	13.61	7.88	32.74
90th %ile	6.06	7.31	6.68	7.66	6.44	26.88
75th %ile	5.06	5.48	5.17	6.15	4.78	23.92
50th %ile	3.41	3.90	4.01	4.34	3.07	19.63
25th %ile	2.60	3.12	2.70	2.80	1.86	16.12
10th %ile	1.70	1.98	1.52	2.21	1.13	13.46
Min	0.58	1.35	1.07	0.41	0.05	12.07
Monthly totals during the monitoring study						
2004	2.46	6.27	3.6	2.16	3.28	17.77
2005	4.86	2.05	1.64	1.38	1.31	11.24



The following figures show the daily precipitation and atrazine residues in water for 2004 and 2005. The planting season is shaded to provide a point of reference for the likely timing of applications in the watershed.


0-50% corn planted
50-100% planted
OH-03, 2004
DailyPrecip (in)
Atrazine Residue (ppb) w/non detects @ LOD
Apr 25th %ile
May 75-90th %ile
Jun 50th %ile
Jul 10th %ile
Aug 50th %ile
Precipitation (in)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Atrazine Residues (ppb)
25
20
15
10
5
0
4/1/04
4/15/04
4/29/04
5/13/04
5/27/04
6/10/04
6/24/04
7/8/04
7/22/04
8/5/04
8/19/04
Date

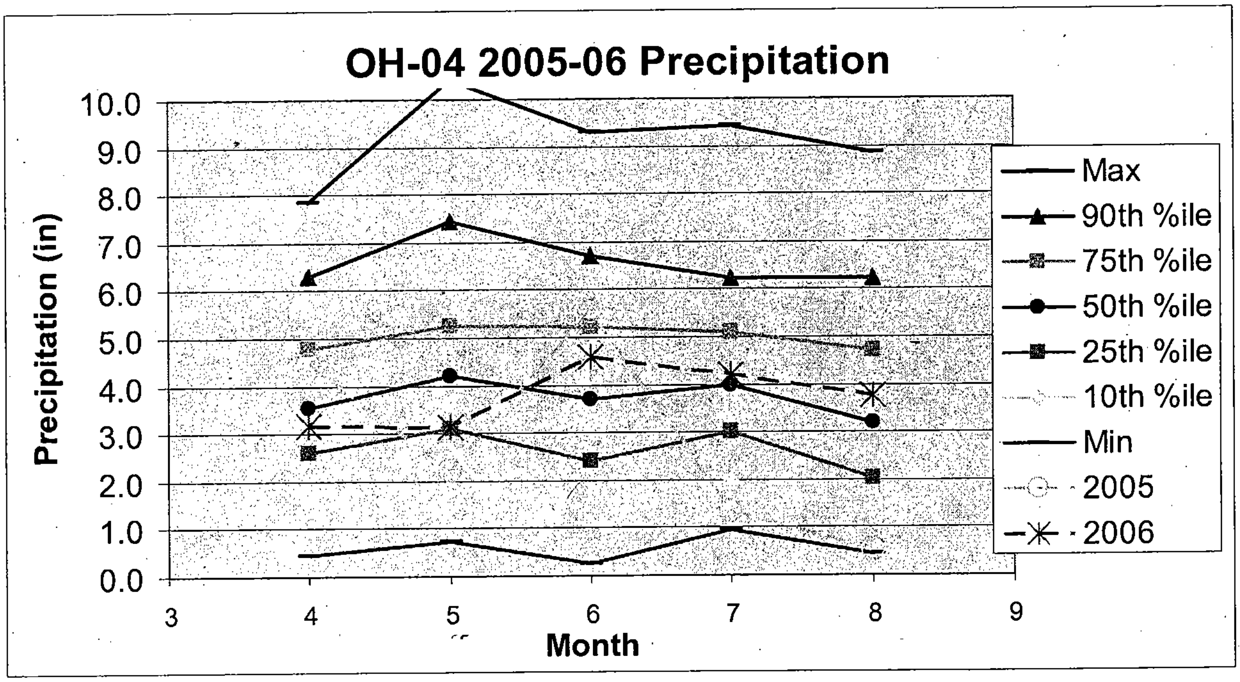

0-50% corn planted
50-100% planted
OH-03, 2005
DailyPrecip (in)
Atrazine Residue (ppb) w/non detects @ LOD
Apr 75th %ile
May 10th %ile
Jun 10th %ile
Jul <10th %ile
Aug 10th %ile
Precipitation (in)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Atrazine Residues (ppb)
25
20
15
10
5
0
4/1/05
4/15/05
4/29/05
5/13/05
5/27/05
6/10/05
6/24/05
7/8/05
7/22/05
8/5/05
Date

39. OH-04 2005-06

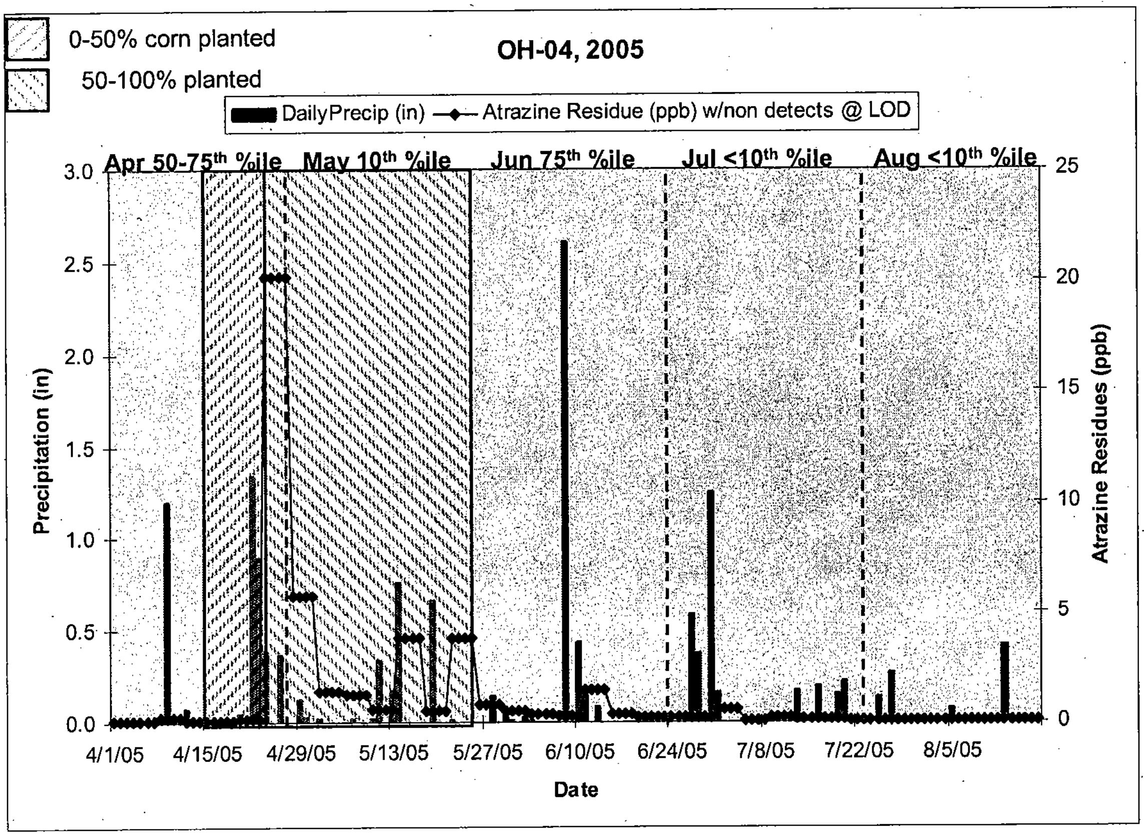
Watershed Location: Deer Creek Watershed, OH
NWS Weather Station:

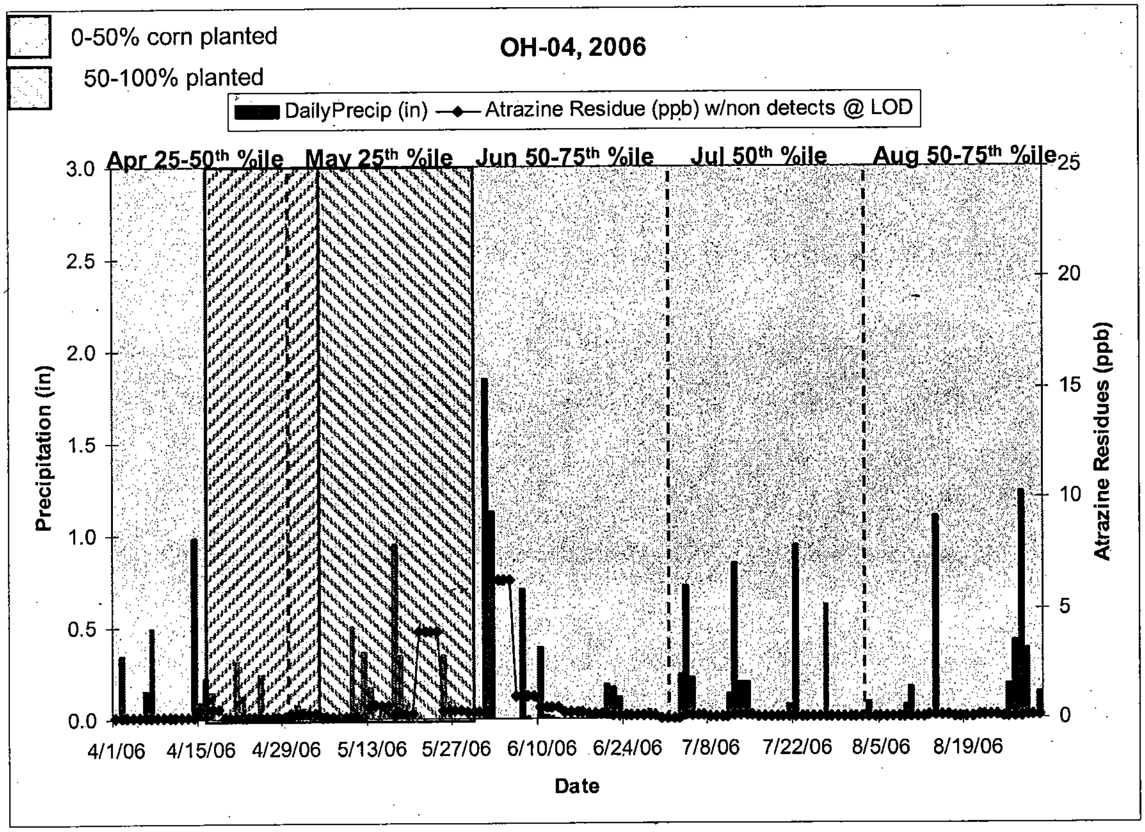
	April Total (in)	May Total (in)	June Total (in)	July Total (in)	August Total (in)	Apr-Aug Total (in)
Historical precipitation summaries, 1948-2001						
Max	7.84	10.41	9.30	9.43	8.85	32.91
90th %ile	6.30	7.44	6.71	6.23	6.22	24.69
75th %ile	4.77	5.24	5.21	5.10	4.72	22.82
50th %ile	3.53	4.20	3.71	3.98	3.19	19.00
25th %ile	2.61	3.10	2.39	2.99	2.04	16.02
10th %ile	1.72	1.86	1.46	1.95	1.36	14.41
Min	0.43	0.72	0.25	0.94	0.44	11.10
Monthly totals during the monitoring study						
2005	4.47	2.21	5.53	1.32	0.55	14.08
2006	3.18	3.12	4.59	4.2	3.78	18.87

Monthly precipitation totals for 2005 were below the 25th percentile in May, July, and August, and above the median in April and June. Monthly rainfall totals in 2006 were below the median in April and May and above the median in June through August.



The following figures show the daily precipitation and atrazine residues in water for 2005 and 2006. The planting season is shaded to provide a point of reference for the likely timing of applications in the watershed.


0-50% corn planted
50-100% planted
OH-04, 2005
DailyPrecip (in)
Atrazine Residue (ppb) w/non detects @ LOD
Apr 50-75th %ile
May 10th %ile
Jun 75th %ile
Jul <10th %ile
Aug <10th %ile
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Precipitation (in)
25
20
15
10
5
0
Atrazine Residues (ppb)
4/1/05
4/15/05
4/29/05
5/13/05
5/27/05
6/10/05
6/24/05
7/8/05
7/22/05
8/5/05
Date

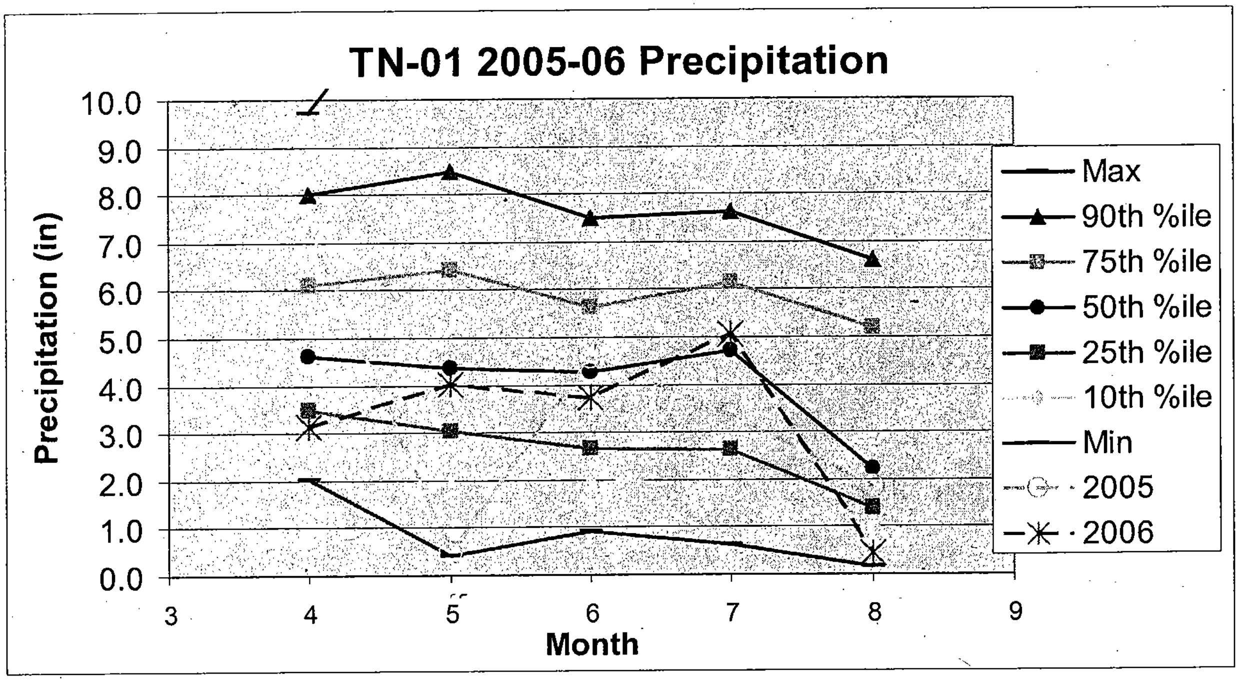

0-50% corn planted
50-100% planted
OH-04, 2006
DailyPrecip (in)
Atrazine Residue (ppb) w/non detects @ LOD
Apr 25-50th %ile
May 25th %ile
Jun 50-75th %ile
Jul 50th %ile
Aug 50-75th %ile
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Precipitation (in)
25
20
15
10
5
0
Atrazine Residues (ppb)
4/1/06
4/15/06
4/29/06
5/13/06
5/27/06
6/10/06
6/24/06
7/8/06
7/22/06
8/5/06
8/19/06
Date

40. TN-01 2005-06

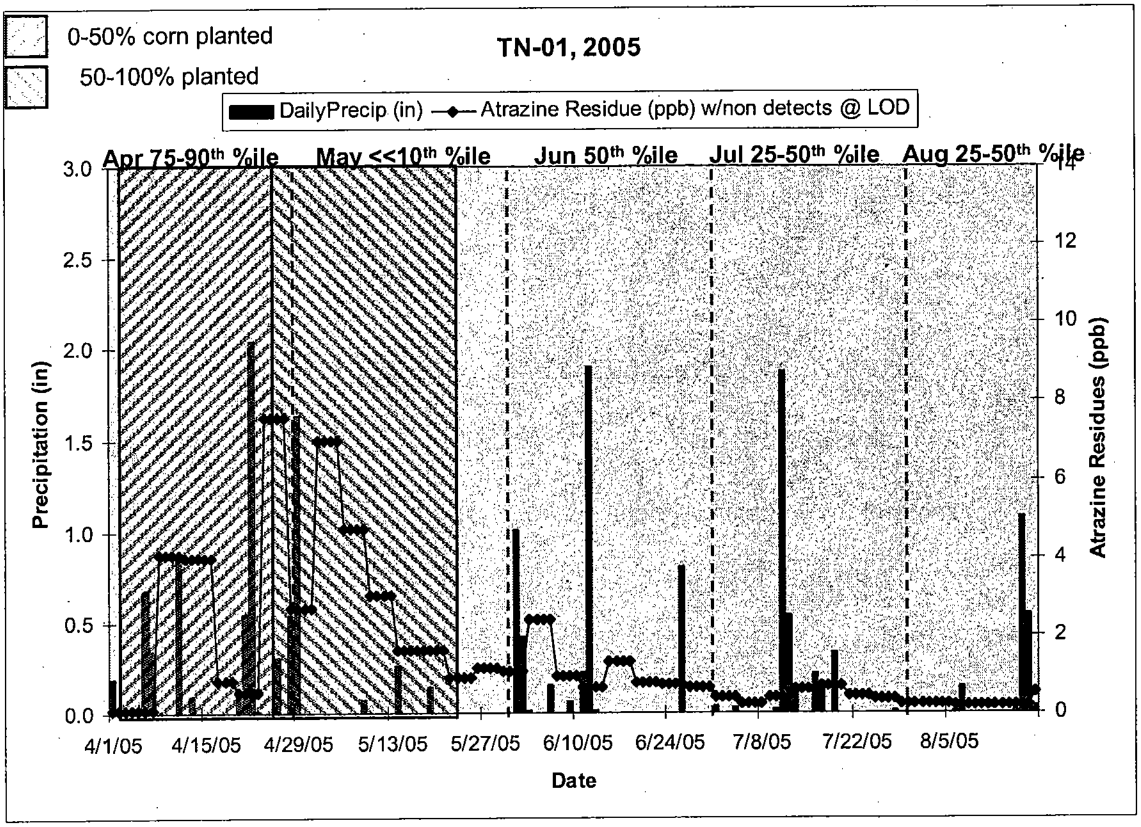
Watershed Location: Obion Middle Fork Watershed, TN
NWS Weather Station:

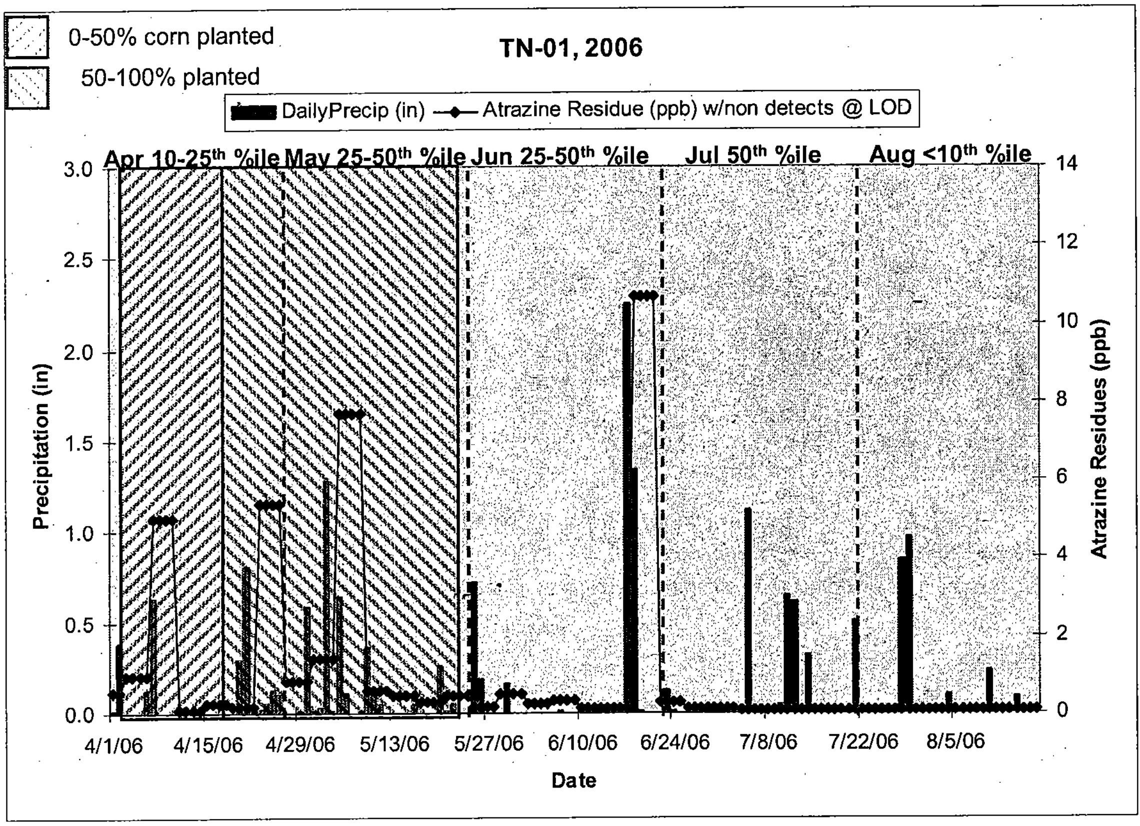
	April Total (in)	May Total (in)	June Total (in)	July Total (in)	August Total (in)	Apr-Aug Total (in)
Historical precipitation summaries, 1948-2001						
Max	8.01	8.47	7.51	7.63	6.61	30.26
90th %ile	6.12	6.41	5.63	6.14	5.19	26.34
75th %ile	4.61	4.38	4.29	4.71	2.21	22.08
50th %ile	3.48	3.04	2.66	2.62	1.40	18.84
25th %ile	2.74	2.13	2.10	1.75	0.99	16.74
10th %ile	2.02	0.41	0.93	0.64	0.15	12.15
Min	0.43	0.72	0.25	0.94	0.44	11.10
Monthly totals during the monitoring study						
2005	7.33	0.47	4.58	3.35	1.82	17.55
2006	3.14	4.03	3.75	5.07	0.44	16.43

Monthly precipitation totals for 2005 went from near the 90th percentile in April to near the minimum level in May, with June, July, and August between the median and the 25th percentile. Monthly rainfall totals in 2006 were near the 25th percentile in April and between the median and 25th percentile for the rest of the sampling period.



The following figures show the daily precipitation and atrazine residues in water for 2005 and 2006. The planting season is shaded to provide a point of reference for the likely timing of applications in the watershed.


▨ 0-50% corn planted
▨ 50-100% planted
TN-01, 2005
DailyPrecip (in)
Atrazine Residue (ppb) w/non detects @ LOD
Apr 75-90th %ile
May <<10th %ile
Jun 50th %ile
Jul 25-50th %ile
Aug 25-50th %ile
Precipitation (in)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Atrazine Residues (ppb)
14
12
10
8
6
4
2
0
4/1/05
4/15/05
4/29/05
5/13/05
5/27/05
6/10/05
6/24/05
7/8/05
7/22/05
8/5/05
Date


▨ 0-50% corn planted
▨ 50-100% planted
TN-01, 2006
DailyPrecip (in)
Atrazine Residue (ppb) w/non detects @ LOD
Apr 10-25th %ile
May 25-50th %ile
Jun 25-50th %ile
Jul 50th %ile
Aug <10th %ile
Precipitation (in)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Atrazine Residues (ppb)
14
12
10
8
6
4
2
0
4/1/06
4/15/06
4/29/06
5/13/06
5/27/06
6/10/06
6/24/06
7/8/06
7/22/06
8/5/06
Date