ENVIRONMENTAL PROTECTION AGENCY
[OPP-xxxx; FRL-xxxx]

DRAFT

Carbofuran: Intent to Cancel All Registrations for Pesticide Products Containing Carbofuran

AGENCY: Environmental Protection Agency (EPA, the Agency).

ACTION: Notice of Intent to Cancel.

SUMMARY: Pursuant to section 6(b) of the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), this Notice announces that the Agency intends to cancel the registrations for all products containing the active ingredient carbofuran.

DATES: Requests for a hearing by an affected registrant must be received by the Office of Hearing Clerk at the address given below on or before **[insert date 30 days after date of publication in the FEDERAL REGISTER]**, or within 30 days of receipt of this Notice by the registrant or applicant, whichever occurs later. Requests for a hearing by any other adversely affected party must be received by the Office of the Hearing Clerk on or before **[insert date 30 days after date of publication in the FEDERAL REGISTER]**.

ADDRESSES: Requests for a hearing must be submitted to: Hearing Clerk (1900), Environmental Protection Agency, 1200 Pennsylvania Ave., N.W., Washington, DC 20460.

Additional information supporting this action is available for public inspection at www.regulations.gov and from 8 a.m. to 4 p.m., Monday through Friday, except legal holidays in:

FOR FURTHER INFORMATION, CONTACT: By mail: [Jude Andreason] Special Review and Reregistration Division (7508P), Office of Pesticide Programs, Environmental Protection Agency.

SUPPLEMENTARY INFORMATION:

I. Introduction

For the reasons set forth below, EPA has determined that all registered carbofuran products, when used in accordance with widespread and commonly recognized practice, generally cause unreasonable adverse effects on humans and the environment. Accordingly, EPA is today issuing this Notice of Intent to Cancel the registrations of all pesticide products containing carbofuran. A complete list of the affected products, identified by registration number, appears in Unit ////.

II. Carbofuran Regulatory History

Carbofuran is a broad spectrum *N*-methyl carbamate insecticide and nematicide registered for control of soil and foliar pests on a variety of field, fruit, and vegetable crops. It was first registered in the United States in 1969. Through an agreement between EPA and the technical registrant in 1991, granular carbofuran has been limited to the sale of 2,500 lbs of active ingredient per year in the U.S. since 1994, for use only on certain crops. Today granular carbofuran is limited to use only on spinach grown for seed, pine seedlings, bananas (in Hawaii only), and cucurbits. Carbofuran is classified as a restricted use pesticide.

In the late 1990s, the technical registrant made a number of changes to flowable carbofuran labels to reduce drinking water and ecological risks of concern. These included reducing application rates and numbers of applications for alfalfa, cotton, corn, potatoes, soybeans, sugarcane, and sunflowers. Numbers of applications were also restricted per season on some soils to reduce groundwater concentrations.

There are currently one technical, two manufacturing-use, and six end-use products registered under section 3 of the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA). There are also 77 active Special Local Need registrations under section 24(c) of FIFRA. This Notice of Intent to Cancel covers all currently registered products and uses.

III. Legal Authority

Before a pesticide product may be lawfully sold or distributed in either intrastate or interstate commerce, the product must be registered by EPA under FIFRA section 3(a). 7 U.S.C. §136a (a). A registration is a license allowing a pesticide product to be sold and distributed for specified uses in accordance with specified use instructions, precautions, and other terms and conditions. A pesticide product may be registered or remain registered only if it performs its intended pesticidal function without causing "unreasonable adverse effects on the environment." 7 U.S.C. §136a (c)(5). "Unreasonable adverse effects on the environment" is defined as "(1) any unreasonable risk to man or the environment, taking into account the economic, social, and environmental costs and benefits of the use of [the] pesticide, or (2) a human dietary risk from residues of that result from use of [the] pesticide in or on any food inconsistent with the standard under section 408 of the Federal Food, Drug and Cosmetic Act." 7 U.S.C. §136 (bb). The standard established under section 408 of the FFDCA is that "there is a reasonable certainty that no harm will result from aggregate exposure to the pesticide chemical residue, including all anticipated dietary exposures and all other exposures for which there is reliable information." 21 U.S.C. §346a(b)(2)(A)(ii). Section 408 directs EPA, in making this determination, to "consider, among other relevant factors– . . . .available information concerning the aggregate exposure levels of consumers (and major identifiable subgroups of consumers) to the pesticide chemical residue . . . [and] available information concerning the cumulative effects of such residues and other substances that have a common mechanism of toxicity." 21 U.S.C. §346a(b)(2)(D)(v) and (vi). Other provisions address in greater detail exposure considerations involving "anticipated and actual residue levels" and "percent of crop actually treated." See 21 U.S.C. §346a(b)(2)(E) and (F). Section 408(b)(2)(C) requires EPA to give special consideration to risks posed to infants and children. EPA must apply an additional tenfold margin of safety for the protection of infants and children unless EPA concludes, based on reliable data, that a different margin would be safe.

The burden to demonstrate that a pesticide product satisfies the criteria for registration is at all times on the proponents of initial or continued registration. 40 C.F.R. §164.80(b). *See also, Industrial Union Dept. v. American Petroleum Institute*, 448 U.S. 607, 653 n. 61 (1980); *Stearns Electric Paste v. EPA* 461 F.2d 293, (7th Cir. 1972); *Environmental Defense Fund v. Ruckelshaus*, 439 F.2d 584, 593 (D.C. Cir. 1971).

Under FIFRA section 6(b), the Agency may issue a Notice of Intent to Cancel the registration of a pesticide product whenever it appears either that: (1) A pesticide or its labeling or other material required to be submitted does not comply with FIFRA, or (2) when used in accordance with widespread and commonly recognized practice, the pesticide generally causes unreasonable adverse effects on the environment. 7 U.S.C. §136d (b). The Agency may specify particular modifications in the terms and conditions of registration, such as deletion of particular uses or revisions of labeling, as an alternative to cancellation. If a hearing is requested by an adversely affected person, the final order concerning cancellation of the product is not issued until after a formal administrative hearing.

In the cancellation hearing, the Agency has the burden of going forward to present an affirmative case for cancellation. 40 C.F.R. § 164.80(a). However, the ultimate burden of proof is on the proponent of the registration. 40 CFR §164.80. *Industrial Union Dept*., 448 U.S. at 653 n. 61; *Stearns Electric Paste v. EPA* 461 F.2d 293, (7th Cir. 1972). Once the Agency makes its prima facie case that the risks of the product's continued use fails to meet the FIFRA standard for registration, the responsibility to demonstrate that the product meets the FIFRA standard is upon the proponents of continued registration. *Dow v Ruckelshaus*, 477 F.2d 1317, 1324 (8th Cir. 1973).

IV. Findings Concerning Unreasonable Adverse Effects

EPA has today determined that pesticide products containing carbofuran, when used in accordance with widespread and commonly recognized practice, generally cause unreasonable adverse effects on humans and the environment. In making this determination, EPA has relied upon the evidence and analyses demonstrating that carbofuran's use presents human dietary risk inconsistent with the safety standard under section 408 of the FFDCA; *i.e*., EPA has concluded that the carbofuran tolerances are not "safe." In addition, this determination relies upon the significant risks carbofuran use poses to human health from worker exposure, as well as the substantial and well documented risks to wildlife. EPA also considered evidence and analyses relating to the benefits of continued use of carbofuran products, and has determined that for the majority of uses, the benefits are, at best minimal. Although a few uses have higher benefits, no use of carbofuran provides sufficient benefits either to individual growers, or at the national level, to outweigh the substantial combined occupational and ecological risks. EPA has further determined that none of the available alternatives to cancellation of all registered uses could reduce the potential risks to acceptable levels. Accordingly, EPA is issuing this Notice of Intent to Cancel all carbofuran products.

V. Risk Assessment

A. Effects on Humans. EPA has reviewed data indicating that carbofuran poses a significant risk to exposed persons resulting from its toxicity following acute exposure. Because it is extremely toxic, exposure to even small amounts of carbofuran creates a substantial risk to human health. Residues of carbofuran measured on food and modeled concentrations in drinking water pose potential risks of concern, especially to children. EPA's concerns about the risks from exposure to carbofuran are corroborated by data from human poisoning incidents associated with occupational exposure from carbofuran use. This section of the Notice describes the Agency's rationale for the human health risk concerns associated with carbofuran.

1. EPA's Approach for Human Health Risk Asessment. EPA uses two different approaches to estimate human risk to carbofuran: a reference dose (RfD) approach and a margin of exposure (MOE) approach. Although the risk metric is somewhat different, each method of calculation involves similar considerations including:

● a 'point of departure'(PoD) — the value from a dose-response curve that is at the low end of the observable data and is used for risk extrapolation;
● the potential for a difference in toxic response between humans and animals used in toxicity tests (i.e., interspecies extrapolation);
● the potential for differences in sensitivity in the toxic response across the human population (for intraspecies extrapolation);
● the need for an additional safety factor (SF) to protect infants and children, as specified in FFDCA section 408(b)(2)(C); and
● estimated human exposure levels to carbofuran.

For dietary risks, EPA uses the chosen PoD to calculate a safe dose or reference dose (RfD). The RfD is calculated by dividing the chosen PoD by all applicable safety or uncertainty factors. Typically, a combination of safety or uncertainty factors providing a hundredfold (100X) margin of safety is used: 10X to account for interspecies extrapolation and 10X to account for intraspecies extrapolation. Further, in evaluating the dietary risks, an additional safety factor of 10X is presumptively applied to protect infants and children, unless reliable data support selection of a different factor. In implementing FFDCA section 408, EPA's Office of Pesticide Programs (OPP), also calculates a variant of the RfD referred to as a Population Adjusted Dose ("PAD"). A PAD is the RfD divided by any portion of the FFDCA safety factor that does not correspond to one of the traditional additional uncertainty/safety factors used in general Agency risk assessment. The reason for calculating PADs is so that other parts of the Agency, which are not governed by FFDCA section 408, can, when evaluating the same or similar substances, easily identify which aspects of a pesticide risk assessment are a function of the particular statutory commands in FFDCA section 408. For acute assessments, the risk is expressed as a percentage of a maximum acceptable dose (i.e., the dose which EPA has concluded will be "safe"). Throughout this document general references to EPA's calculated safe dose are denoted as an acute PAD or aPAD, because the relevant point of departure for carbofuran is based on an acute risk endpoint.

To quantitatively describe risk using the aPAD approach, estimated exposure is expressed as a percentage of the aPAD. Dietary exposures greater than 100 percent of the aPAD are generally cause for concern.

For non-dietary risk assessments, such as the assessment of risk from occupational exposure to carbofuran, the toxicological level of concern is not expressed as a safe dose or RfD/PAD but rather as the MOE that is necessary to be sure that exposure to a pesticide is safe. To calculate the MOE for a pesticide, human exposure to the pesticide is divided into the PoD from the available studies. A safe MOE is generally considered to be a margin at least as high as the product of all applicable safety factors for a pesticide. For example, if a pesticide needs a 10X factor to account for interspecies differences and a 10X factor for intraspecies differences, the safe or target MOE would be a MOE of at least 100. In contrast to the RfD/PAD approach, the higher the MOE, the lower the pesticide's risk. Accordingly, if the product of the safety factors considered appropriate for a particular pesticide risk assessment (referred to as the "target MOE") is 100, MOEs exceeding 100 would generally not be of concern.

The RfD/PAD and MOE approaches are fundamentally equivalent. For a given risk and given exposure of a pesticide, if the pesticide was found to be safe under an RfD/PAD analysis it would also pass under the MOE approach, and vice-versa.

a. Estimating Human Dietary Exposure Levels. Pursuant to section 408(b) of the FFDCA, in evaluating carbofuran's dietary risks EPA evaluates the "aggregate exposure"to carbofuran, which is the analysis of exposure to carbofuran alone by multiple pathways and routes of exposure. EPA uses available data, together with assumptions designed to be protective of public health, and standard analytical methods to produce separate estimates of exposure for a highly exposed subgroup of the general population, for each potential pathway and route of exposure. EPA then calculates potential aggregate exposure and risk by using probabalistic[1] techniques to combine distributions of potential exposures in the population for each route or pathway. For dietary analyses, the relevant sources of potential exposure to carbofuran are from the ingestion of residues in food and drinking water. The Agency uses a combination of monitoring data and predictive models to evaluate environmental exposure of humans to carbofuran.

i. Exposure from Food. Data on the residues of carbofuran in foods are available from a variety of sources. One of the primary sources of the data come from federally-conducted surveys, including the Pesticide Data Program (PDP) conducted by the U.S. Department of

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[1]Probabilistic analysis is used to predict the frequency with which variations of a given event will occur. By taking into account the actual distribution of possible consumption and pesticide residue values, probabilistic analysis for pesticide exposure assessments "provides more accurate information on the range and probability of possible exposure and their associated risk values." U.S. EPA, Choosing a Percentile of Acute Dietary Exposure as a Threshold of Regulatory Concern 15 (March 22, 2000). In capsule, a probabilistic pesticide exposure analysis constructs a distribution of potential exposures based on data on consumption patterns and residue levels and provides a ranking of the probability that each potential exposure will occur. People consume differing amounts of the same foods, including none at all, and a food will contain differing amounts of a pesticide residue, including none at all.

Agriculture (USDA), and the Food and Drug Administration (FDA) Surveillance Monitoring data. In addition, market basket studies, which are typically performed by registrants, can provide residue data. These data generally provide a characterization of pesticide residues in or on foods consumed by the U.S. population that closely approximates real world exposures because they are sampled closer to the point of consumption in the chain of commerce than field trial data, which are generated to establish the maximum level of legal residues that could result from maximum permissible use of the pesticide.

EPA uses a computer program known as the Dietary Exposure Evaluation Model – Food Commodity Intake Database ("DEEM-FCID") to estimate exposure by combining data on human consumption amounts with residue values in food commodities. DEEM-FCID also compares exposure estimates to appropriate RfD /PAD values to estimate risk. EPA uses DEEM-FCID to estimate exposure for the general U.S. population as well as 32 subgroups based on age, sex, ethnicity, and region. DEEM-FCID allows EPA to process great volumes of data on human consumption amounts and residue levels in making risk estimates. Matching consumption and residue data, as well as managing the thousands of repeated analyses of the consumption database conducted under probabilistic risk assessment techniques, essentially requires the use of a computer.

DEEM-FCID contains consumption and demographic information on the individuals who participated in the USDA's Continuing Surveys of Food Intake by Individuals ("CSFII") in 1994-1996 and 1998. The 1998 survey was a special survey required by the FQPA to supplement the number of children survey participants. DEEM-FCID also contains "recipes" that convert foods as consumed (*e.g.,* pizza) back into their component raw agricultural commodities (*e.g.,* wheat from flour, or tomatoes from sauce). This is necessary because residue data are generally gathered on raw agricultural commodities rather than on finished ready-to-eat food. Data on residue values for a particular pesticide and the RfD/PADs for that pesticide have to be input into the DEEM-FCID program to estimate exposure and risk.

For carbofuran's assessment, EPA used DEEM-FCID to calculate risk estimates based on a probabilistic distribution. DEEM-FCID combines a single residue value for each food with the full range of data on individual consumption amounts to create a distribution of exposure and risk levels. More specifically, DEEM-FCID creates this distribution by calculating an exposure value for each reported day of consumption per person ("person/day") in CSFII assuming that all foods potentially bearing the pesticide residue contain such residue at the chosen value. The exposure amounts for the thousands of person/days in the CSFII are then collected in a frequency distribution. EPA also uses DEEM-FCID to compute a distribution taking into account both the full range of data on consumption levels and the full range of data on potential residue levels in food. Combining consumption and residue levels into a distribution of potential exposures and risk requires use of probabilistic techniques.

The probabilistic technique that DEEM-FCID uses to combine differing levels of consumption and residues involves the following steps:

(1) identification of any food(s) that could possibly bear the residue in question for each person/day in the CSFII;

(2) calculation of an exposure level for each person/day based on the foods identified in Step #1 by randomly selecting residue values for the foods from the residue database;
(3) repetition of Step #2 one thousand times for each person/day; and
(4) collection of all of the hundreds of thousands of potential exposures estimated in Steps ## 2 and 3 in a frequency distribution.

The resulting probabilistic assessment presents a range of exposure/risk estimates.

ii Exposure from water EPA may use either or both field monitoring data and simulation water exposure models to generate pesticide exposure estimates in drinking water. Monitoring and modeling are both important tools for estimating pesticide concentrations in water and can provide different types of information. Monitoring data can provide estimates of pesticide concentrations in water that are representative of the specific agricultural or residential pesticide practices in specific locations, under the environmental conditions associated with a sampling design (*i.e*., the locations of sampling, the times of the year samples were taken, and the frequency by which samples were collected). Although monitoring data can provide a direct measure of the concentration of a pesticide in water, it does not always provide a reliable basis for estimating spatial and temporal variability in exposures because sampling may not occur in areas with the highest pesticide use, and/or when the pesticides are being used.

Because of the limitations in most monitoring studies, EPA uses simulation water exposure models as the primary means to estimate pesticide exposure levels in drinking water. EPA's models are based on extensive monitoring data and detailed information on soil properties, crop characteristics, and weather patterns. (69 FR 30042, 30058-30065 (May 26, 2004)). These models calculate estimated environmental concentrations of pesticides using laboratory data that describe how fast the pesticide breaks down to other chemicals and how it moves in the environment. Computer modeling provides an estimate of pesticide concentrations in ground and surface water. These concentrations can be estimated continuously over long periods of time, and for places that are of most interest for any particular pesticide. Modeling is a useful tool for characterizing vulnerable sites, and can be used to estimate peak concentrations from infrequent, large rain events.

As discussed below in greater detail, EPA relied on models it has developed for estimating exposure in both surface water and ground water. EPA uses a two-tiered approach to modeling pesticide exposure in surface water. In the initial tier, EPA uses the FQPA Index Reservoir Screening Tool (FIRST) model. FIRST replaces the GENeric Estimated Environmental Concentrations (GENEEC) model that was used as the first tier screen by EPA from 1995 to 1999. If the first tier model suggests that pesticide levels in water may be unacceptably high, a more refined model is used as a second tier assessment. The second tier model is actually a combination of two models: Pesticide Root Zone Model (PRZM) and the Exposure Analysis Model System (EXAMS). For estimating pesticide residues in groundwater, EPA uses the Screening Concentration In Ground Water (SCI-GROW) model.

EPA also uses DEEM-FCID to generate a distribution of exposures from consumption of drinking water contaminated with pesticides. These results are then used to calculate a probabilistic assessment of the aggregate human exposure and risk from residues in food and drinking water. Because probabilistic assessments generally use more realistic residue levels, EPA's starting point for estimating exposure and risk for such assessments is the 99.9th percentile

2. Toxicity of Carbofuran.

The most serious hazard associated with the use of carbofuran is its toxicity following acute exposure. Acute exposure is defined as an exposure of short duration, usually characterized as lasting no longer than a day. EPA classifies carbofuran as Toxicity Category I, the most toxic category, based on its potency by the oral and inhalation exposure routes. The lethal potencies of chemicals are usually described in terms of the "dose" given or the "concentration" in air that is estimated to cause the death of 50 percent of the animals exposed (abbreviated as LD_{50} or LC_{50}). Carbofuran has an oral LD_{50} of 7.8-6.0 mg/kg, and an inhalation LC_{50} of 0.08 mg/l. (Refs. 13, 50, 68). The lethal dose and lethal concentration levels for the oral and inhalation routes fall well below the limits for the Toxicity Category I. Carbofuran is significantly more toxic than almost all of the likely alternatives to carbofuran.

Carbofuran is an N-methyl carbamate pesticide. Like other pesticides in this class, the primary toxic effect seen following carbofuran exposure is neurotoxicity resulting from inhibition of the enzyme acetylcholinesterase (AChE). AChE breaks down acetylcholine (ACh), a compound that assists in transmitting signals through the nervous system. Carbofuran inhibits the AChE activity in the body. When AChE is inhibited at nerve endings, the inhibition prevents the ACh from being degraded and results in prolonged stimulation of nerves and muscles. Physical signs and symptoms of carbofuran poisoning include headache, nausea, dizziness, blurred vision, excessive perspiration, salivation, lacrimation (tearing), vomiting, diarrhea, aching muscles, and a general feeling of severe malaise. Uncontrollable muscle twitching and bradycardia (abnormally slow heart rate) can occur. Severe poisoning can lead to convulsions, coma, pulmonary edema, muscle paralysis, and death by asphyxiation. Carbofuran poisoning also may cause various psychological, neurological and cognitive effects, including confusion, anxiety, depression, irritability, mood swings, difficulty concentrating, short-term memory loss, persistent fatigue, and blurred vision (Ref. 13 at 65-68).

Carbofuran has a steep dose-response curve. For example, carbofuran data in juvenile rats (PND11 and PND17) demonstrates that small differences in carbofuran doses (0.1 mg/kg to 0.3 mg/kg) is the difference between significant brain and RBC AChE inhibition without clinical signs (0.1 ,mg/kg) and a dose causing significant AChE inhibition, tremors, and decreased motor activity (0.3 mg/kg). In other words there is a slight difference in exposure levels that produces no noticeable outward effects and the level that causes adverse effects. This means that small differences in exposures can have significant consequences for large numbers of individuals. For example, as discussed in greater detail in Unit V.A.6.a.ii below, the difference between the amount of food with carbofuran residues that can be safely consumed without adverse effect, and the amount that provides a dose that exceeds the estimated level at which outward effects are expected to occur is minimal. Children who consume typical amounts of cucumber (i.e., 0.2 ounces) containing carbofuran residues of 0.5 ppm–a residue level detected in PDP data--are receiving 200 percent of the safe daily dose. For children who consume larger amounts of cucumbers, i.e., 1.5-2 ounces, or roughly ½ cup, the risks increase approximately ten-fold; *i.e.*, assuming a carbofuran residue of 0.5 ppm, the risks are equal to or greater than 2000 percent of the safe daily dose. When one also accounts for the ingestion of normal amounts of drinking water from sources within watersheds vulnerable to carbofuran runoff and/or leaching from agricultural fields, exposures exceed the safe levels dramatically (Refs 12, 13). Similarly, workers' exposure to low levels of carbofuran during agricultural activities such as scouting, weeding, and harvesting can also produce serious effects (Ref 13). For example, thirty-four workers who spent four hours weeding a carbofuran-treated cotton field two hours after application were exposed to residues of carbofuran on the foliage. These workers were hospitalized with a variety of clinical signs of cholinesterase poisoning, such as nausea, eye irritation, and respiratory problems (Ref.13 at 65-68)

2.1 Deriving points of departure

EPA has relied on a benchmark dose approach for deriving the PoD from the available rat toxicity studies. A benchmark dose, or BMD, is a point estimate along a dose-response curve that corresponds to a specific response level. For example, a BMD_{10} represents a 10% change from the background or typical value for the response of concern. Generically, the direction of change from background can be an increase or a decrease depending on the biological parameter and the chemical of interest. In the case of carbofuran, inhibition of AChE is the toxic effect of concern. Following exposure to carbofuran, the biological activity of the AChE enzyme is decreased (i.e., inhibited). Thus, when evaluating BMDs for carbofuran, the Agency is interested in a decrease in activity from background. "Background" estimates are usually provided by untreated animals used in experimental studies (*i.e*., negative control animals not treated with carbofuran).

In addition to the BMD, a "confidence limit" was also calculated. Confidence limits express the uncertainty in a BMD that may be due to sampling and/or experimental error. The lower confidence limit on the dose used as the BMD is termed the BMDL, which the Agency uses as the PoD. Use of the BMDL for deriving the PoD rewards better experimental design and procedures that provide more precise estimates of the BMD, resulting in tighter confidence intervals. Use of the BMDL also helps ensure with high confidence (*e.g*., 95%) that the 10% inhibition of AChE is not exceeded. And from the PoD, EPA calculates the RfD and aPAD, or calculates MOEs.

Numerous scientific peer review panels over the last decade have supported the Agency's application of the BMD approach as an improvement over the historically applied approach of using no-observed-adverse-effect levels (NOAELs) or lowest-observed-adverse-effect-levels (LOAELs) and as a scientifically supportable method for deriving PoDs in human health risk assessment. The NOAEL/LOAEL approach does not account for the variability and uncertainty in the experimental results, which are due to characteristics of the study design, such as dose selection, dose spacing, and sample size. With the BMD approach, all the dose response data are used to derive a PoD. Moreover, the response level used for setting regulatory limits can vary based on the chemical and/or type of toxic effect (Ref. 33, 34, 35). Specific to carbofuran and other *N*-methyl carbamates, the FIFRA Scientific Advisory Panel (SAP) has reviewed and supported the statistical methods used by the Agency to derive BMDs and BMDLs on two occasions, February 2005 and August 2005 (Refs. 34, 35)

As mentioned above, carbofuran exerts neurotoxicity through inhibition of AChE. This can occur in both the central (brain) and peripheral nervous systems. AChE inhibition is the initial adverse biological event which results from exposure to carbofuran and which may lead to other effects such as tremors, dizziness, as well as gastrointestinal and cardiovascular effects, including bradycardia. (Ref. 13 at 65-68). Thus, AChE inhibition provides the most appropriate effect to use in risk extrapolation for derivation of RfDs, PADs, and MOEs.

There are laboratory data on carbofuran for cholinesterase activity in plasma, red blood cell (RBC), and brain. Due to technical difficulties regarding dissection of peripheral nerves and the rapid nature of carbofuran toxicity, measures of ChE inhibition in the peripheral nervous system (PNS) are very rare for *N*-methyl carbamate pesticides. As a matter of science policy, blood cholinesterase data (plasma and RBC) are considered appropriate surrogate measures of potential effects on PNS acetylcholinesterase activity, and of potential effects on the central nervous system (CNS) when brain ChE data are lacking (Ref. 34). Other state and national agencies such as California, Washington, Canada, the European Union, and World Health Organization (WHO), all use blood measures in human health risk assessment and/or worker safety monitoring programs. It is further noted that when RBC ChE data are of adequate quality, RBC ChE data are preferred over plasma ChE data since RBCs contain a higher proportion of AChE, the enzyme, compared with plasma which contains predominately butyrlcholinesterase, an enzyme with limited toxicological significance (Ref. 34).

In the BMD dose analysis used by EPA to derive PoDs for adult workers and for people consuming food and/or water containing carbofuran residues, the Agency has used a response level of 10% AChE inhibition and has thus calculated BMD_{10}s and $BMDL_{10}$s. These values (the central estimate and lower confidence bound, respectively) represent the estimate dose where AChE is inhibited by 10% compared to untreated animals. In the last few years, this 10% value has been used by EPA to regulate AChE inhibiting pesticides including organophosphate pesticides and NMCs including carbofuran. For a variety of toxicological and statistical reasons, EPA chose 10% brain AChE inhibition as the response level for use in calculating BMD and BMDL calculations. EPA analyses have demonstrated that 10% is a level that can be reliably measured in the majority of rat toxicity studies, and is generally at or near the limit of sensitivity for discerning a statistically significant decrease in AChE activity across the brain compartment and is a response level close to the background AChE level (Refs. 34, 35)

The Agency has used a meta-analysis to calculate the BMD_{10} and $BMDL_{10}$ for pups and adults; this analysis includes data from studies where either adult or juvenile rats or both were exposed to a single oral dose of carbofuran. The Agency has used a dose-time-response exponential model where benchmark dose and half life to recovery can be estimated together. This model and the statistical approach to deriving the BMD_{10}s, $BMDL_{10}$s, and half-life to recovery have been reviewed and supported by the FIFRA SAP (Refs. 34, 35). The meta-analysis approach offers the advantage over using single studies by combining information across multiple studies and thus provides a robust PoD.

There are three studies available which compare the effects of carbofuran on postnatal day 11 (PND11) rats with those in young adult rats (herein called ‘comparative AChE studies’). Two of these studies were submitted by FMC, the registrant, and one was performed by EPA’s

Office of Research and Development (ORD). An additional study conducted by EPA-ORD involved postnatal day 17 (PND17) rats. Although it is not possible to directly correlate ages of juvenile rats to humans, PND11 rats are believed to be close in development to newborn humans. PND17 rats are believed to be closer developmentally to human toddlers (Ref. 9). Other studies in adult rats used in the Agency's analysis included data from Padilla et al (2007), and McDaniel et al (2007).

Data used by the Agency in the analysis are derived from two basic study designs: 1) time course studies to evaluate time to peak effect and time to recovery and 2) dose-response studies to evaluate changes in response from different doses of carbofuran. Generally, in the time course studies, one or two different carbofuran treatment groups were observed and/or sacrificed over time. Earliest observations were approximately at 15 minutes post-dosing. Latest observations varied from 4 hours up to 24 hours for different studies. In the dose-response studies, 3-4 different doses of carbofuran were used. Brain and RBC AChE and, in some cases, behavioral observations (*e.g.*, clinical signs, motor activity) were measured at the approximate peak time of effect.

Qualitatively, the available studies with juvenile rats show a consistent pattern—namely, that juvenile rats are more sensitive to carbofuran than adult rats. This pattern has also been observed for other N-methyl carbamate pesticides, which exhibit the same mechanism of toxicity as carbofuran (Ref. 88). Because juvenile rats, called 'pups' herein, are more sensitive than adult rats, data from pups provide the most relevant endpoint for evaluating risk to infants and young children and are thus used to derive the PoD.

OPP evaluated the quality of the AChE data in all the available studies. In this review, particular attention was paid to the methods used to assay AChE inhibition in the laboratory conducting the study. Because of the nature of carbofuran inhibition of AChE, care must be taken in the laboratory such that experimental conditions do not promote enzyme reactivation (i.e., recovery) while samples of blood and brain are being processed and analyzed. If this reactivation occurs during the assay, the results of the experiment will underestimate the toxic potential of carbofuran (Ref. 91). Through the Agency's review of available studies, the Agency identified problems and irregularities with the RBC AChE data from both FMC supported comparative AChE studies. These problems are described in detail in the Agency's study review (Ref. 24). As such, the Agency determined that the RBC AChE inhibition data from both FMC studies were unreliable and not useable in extrapolating human health risk. The brain AChE data from the two FMC studies are acceptable and have been used in the Agency's BMD analysis

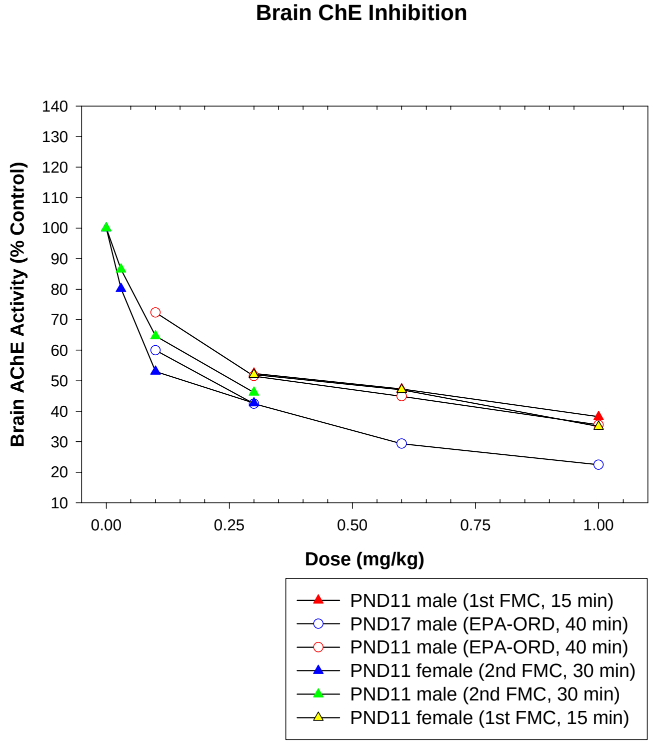
3. Toxicity Estimates Relating to Dietary Risks.

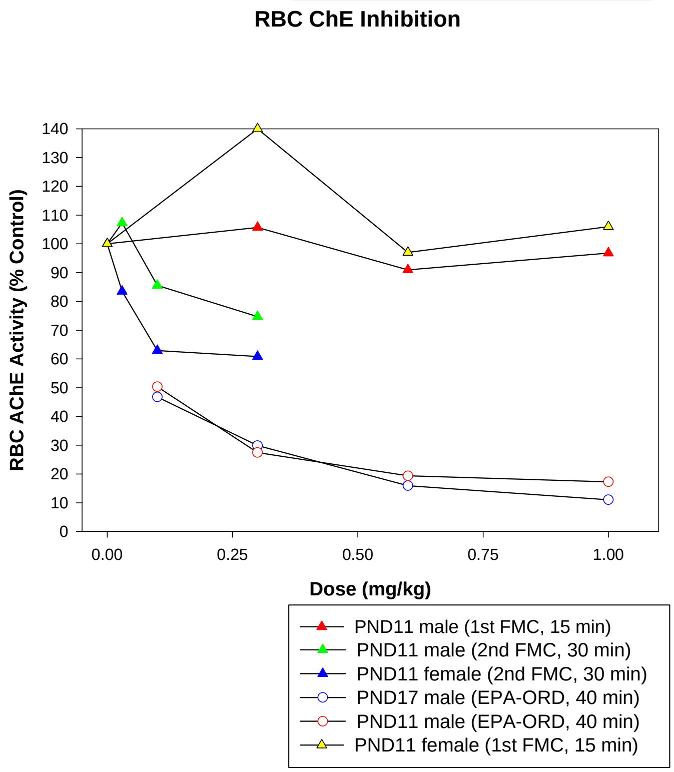
EPA estimates risk from the diet (food and water) to all age groups. Typically (and is the case for carbofuran), young children (ages 0-5) tend to be the most exposed age groups because they tend to eat larger amounts of food per their body weight than do teenagers or adults. Moreover, it is not unusual for infants or young children to be more sensitive to chemical exposures as metabolism processes in young children are still developing. Specific to carbofuran, there are several studies in juvenile rats that show they are more sensitive than adult rats to the effects of carbofuran. These effects include inhibition in AChE in addition to incidence of clinical signs of neurotoxicity such as tremors. As such, the focus of EPA's analysis of dietary risk from food and water to carbofuran is on young children (ages 0-5). Since these age groups experience the highest levels of dietary risk, protecting these groups against the effects of carbofuran will, in turn, also protect other age groups.

Although four studies with juvenile rats are available, there remains uncertainty surrounding the dose-response relationship for RBC AChE inhibition in pups. RBC AChE data from both FMC supported studies are not reliable and thus are not appropriate for use in PoD derivation. EPA-ORD studies with PND 11 and PND 17 pups show clearly (Figures 1 and 2) that RBC AChE is more sensitive (*i.e*., inhibited at lower levels of carbofuran) than brain AChE at each tested dose. However, the EPA studies did not include data at the low end of the dose-response curve--the area on the dose-response curve most relevant for risk assessment. Because of this, there is significant uncertainty in estimating the BMD_{10} and $BMDL_{10}$ for the EPA-ORD RBC AChE data in pups.

In contrast to the RBC AChE inhibition data, quality brain AChE data from three studies (2 FMC, 1 EPA-ORD) with PND11 pups are available, which in combination provide data to describe both low and high doses. By combining the three studies in PND11 animals together in a meta-analysis, the entire dose-response range is covered (Figure 1 below). The Agency believes the BMD analysis for the PND11 brain AChE data is the most robust analysis for purposes of PoD selection. Using data from PND11 rat brain AChE levels, the estimated oral dose that will result in 10% brain AChE inhibition (BMD_{10}) is 0.04 mg/kg. The lower 95 % confidence limit on the BMD_{10} ($BMDL_{10}$) is 0.03 mg/kg—this $BMDL_{10}$ of 0.03 mg/kg provides the PoD.

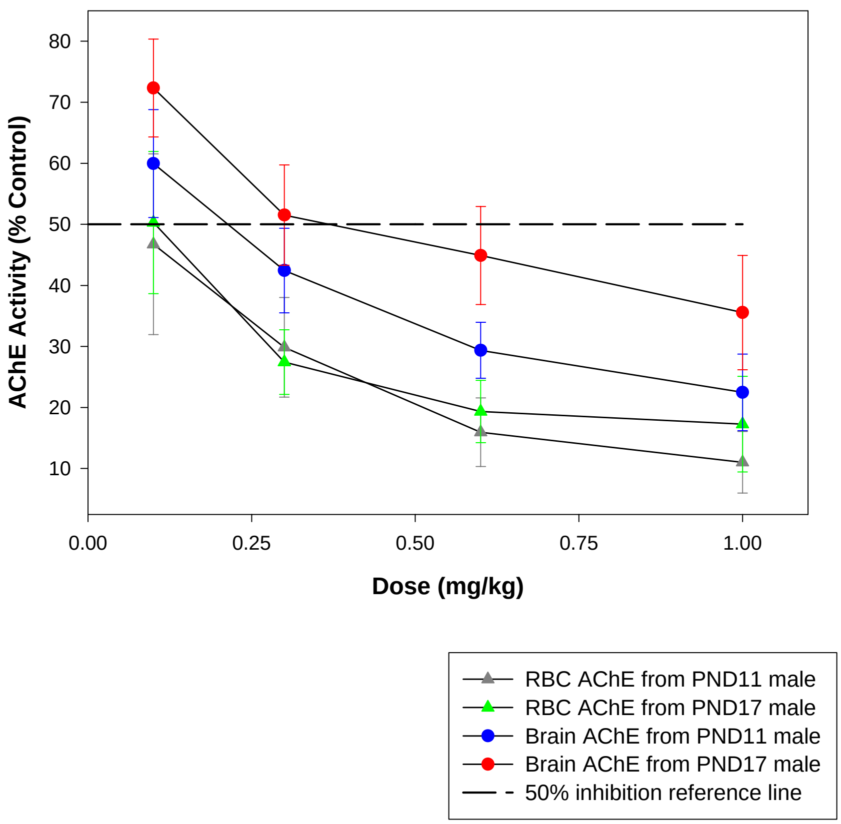
Figure 1. Brain and RBC AChE inhibition in pups following exposure to carbofuran





However, as shown in Figure 2, RBC AChE in pups is expected to be more sensitive compared to brain AChE inhibition. To account for the lack of RBC data in pups at the low end of the response curve, and for the fact that RBC AChE inhibition appears to be a more sensitive point of departure compared to brain AChE inhibition (and may be considered an appropriate surrogate for the peripheral nervous system), EPA is retaining a portion (5X) of the FFDCA section 408(b)(2)(C) Safety Factor (See below in Unit V.A.5.3).

Figure 2. Comparison of brain and RBC AChE inhibition in PND11 and PND17 pups.



4. Toxicity Estimates Relating to Worker Risks.

The limited dermal absorption data for carbofuran indicate that carbofuran can be absorbed through the skin. However, there are no suitable dermal or inhalation toxicity studies for use in the carbofuran risk assessment. Although 21-day day dermal studies in the rat and rabbit were available, neither study was suitable for use in the carbofuran risk assessment. No AChE inhibition was noted in the dermal rabbit study at doses as high as 1000 mg/kg/day. Based on available data, the rat is the more appropriate model for assessing human risks to carbofuran because the rabbit, in contrast to the rat, appears to be significantly insensitive to carbofuran, based on clinical signs and cholinesterase inhbition noted in oral toxicity studies. Although AChE inhibition was observed in the recently submitted rat dermal study (unlike the rabbit 1991 study), the rat dermal study did not provide the necessary information (i.e., time-of-onset, time-of-peak inhibition, time until recovery) critical to adequately assess cholinesterase inhibition for carbofuran, a rapid reversible cholinesterase inhibitor. In addition, other limitations of the rat dermal study included: (1) considerable variability in the RBC measurements; (2) lack of dose-response relationships within the 7-day (range finding study) and 21-day studies; and (3) disparity in brain and RBC dose-response relationships between the 7-day (range finding study) and 21-day studies. Also, there were reported difficulties with sample analyses "meeting acceptability and reproducibility criteria" in both the 7-day and 21 day studies, which likely led to the underestimation of the toxic effect.

The $BMDL_{10}$ value of 0.024 mg/kg/day calculated for the adult RBC AchE inhibition data was derived based on a meta-analysis of data from Padilla et al (2007), McDaniel et al (2007), and the adult data from the EPA-ORD PND11 comparative AChE study. This $BMDL_{10}$ is appropriate for assessing dermal and inhalation exposure risks (all durations) for occupational workers (the most sensitive effect in the population of concern, adults).

Since an oral dose was selected for all dermal scenarios, a dermal absorption factor of 6%, from a rat dermal penetration study published in the literature, is used in this risk assessment for route-to-route extrapolation (Ref. 73). A default 100% absorption factor for inhalation exposure is applied for all inhalation scenarios. This assumes that all of the inhaled carbofuran is absorbed into the body.

5. Deriving the Safe Regulatory Level for Carbofuran.

5.1. Differences between animals and humans—Interspecies Extrapolation. In the case of carbofuran, the mode of action causing toxicity is well understood in both animals and humans. The AChE enzyme in humans and rats has similar function and structure (Ref. 13). Both animals and humans exhibit signs of neurotoxicity following acute poisonings. For example, workers entering a carbofuran treated field earlier than allowed were treated at a medical clinic for the following symptoms: headeache, nausea, dizziness, abdominal pain, eye irritation, and bradycardia, among others (Refs. 13, 40). In rats, the major clinical sign is tremors.

There are toxicity studies with human subjects available for carbofuran. However, the Agency has not used these studies in its quantitative risk assessment based on a review by the Human Studies Review Board (HSRB), which found the studies to be scientifically (oral and dermal studies) and/or ethically deficient (dermal studies) (Ref. 42). Thus, the Agency has relied only on data from animal studies in its quantitative risk assessment of carbofuran. There are, however, human studies available for three NMC pesticides other than carbofuran (oxamyl, methomyl, and aldicarb), which have also been reviewed by the HSRB and found to be both scientifically and ethically conducted. Each of these studies show that humans are more sensitive than rats. Consistent with Agency practice and peer-review guidance documents, the Agency has applied an uncertainty factor of 10-fold to extrapolate from animals to humans. There are sometimes instances where the standard 10-fold factor can be refined or reduced based on chemical-specific data, which informs quantitative differences between animals and humans. Such data do not exist for carbofuran—thus the 10-fold factor has been applied.

5.2. Differences among humans and extrapolation to sensitive humans—Intraspecies Extrapolation. Not all humans respond to chemical agents in the same manner. Some people will be more sensitive to chemical agents and will respond to lower exposure levels than others. The Agency accounts for this human variation by using a 10-fold uncertainty factor for variation among humans. This 10-fold factor is standard practice at EPA and consistent with peer-reviewed Agency guidance. It is rare to have data that inform the magnitude of variation among humans, and none are available for carbofuran.

5.3. *10X Safety Factor for Infants and Children*. Section 408(b)(2)(C) of the FFDCA requires EPA to "apply an additional tenfold margin of safety for the pesticide chemical residue and other sources of exposure…for infants and children to take into account potential pre- and postnatal toxicity and completeness of data with respect to exposure and toxicity to infants and children." 21 U.S.C. §346a(b)(2)(C). Section 408 (b)(2)(C) further states that, "the Administrator may use a different margin of safety for the pesticide chemical residue only if, on the basis of reliable data, such margin will be safe for infants and children."

In determining whether a different factor is safe for children, EPA focuses on the three factors listed in section 408(b)(2)(C) - the completeness of the toxicity database, the completeness of the exposure database, and potential pre- and post-natal toxicity. In examining these factors, EPA strives to make sure that its choice of a safety factor, based on a weight-of-the-evidence evaluation, does not understate the risk to children.

Overall, the Agency believes that there are quality data and scientifically supportable methods to account for specific exposure and behavioral patterns of children. There is a high degree of confidence in the exposure data and methodologies used when assessing aggregate risk to children from food and drinking water exposure. Because characteristics of children are directly accounted for in the exposure assessment and the Agency's methods are not expected to underestimate exposure to carbofuran, evaluating the potential for increased toxicity to juveniles is the key component in determining the magnitude of the FFDCA safety factor for carbofuran.

As noted in Section 4, none of the available studies in juvenile rats include data that characterize RBC AChE inhibition at the low end of the dose response curve. Moreover, based on data in PND11 and PND17 pups, at higher doses, RBC AChE was more sensitive than brain AChE at every tested dose. The brain AChE data in PND11 pups provide a robust and scientifically supportable basis for deriving the PoD for risk extrapolation. As such, the Agency is not using the most sensitive endpoint for derivation of the PoD for children. Thus, the Agency has determined that at least a portion of the FFDCA 10X safety factor must be retained to account for this uncertainty.

Because of the shape of the carbofuran dose-response curve, it is scientifically more reliable to compare relative sensitivity of brain and RBC AChE at response levels similar to that used for PoD determination (ie., 10% AChE inhibition). For brain AChE, the BMD_{10}s are 0.23 and 0.20 mg/kg for PND11 and PND17, respectively. For RBC AChE, the BMD_{10}s are 0.05 and 0.07 mg/kg for PND11 and PND17, respectively. However, in the case of the carbofuran, the RBC estimates of 10% inhibition from the EPA pup studies are not of high confidence due to lack of tested doses at the lower end of the dose response curve. Consequently, the Agency also calculated the RBC BMD_{50} for the EPA PND11 and PND17 studies. Because there are data at or near the 50% response level, the BMD_{50} estimates are more reliable than those of the BMD_{10} for these studies. The BMD_{50} for RBC AChE in pups ranges from 3-5X lower than that for brain AChE inhibition. This range is similar to the database uncertainty factor of 5X used in the 2006 risk assessment. The Agency has concluded that uncertainty remains in the shape of the dose response relationship for RBC AChE inhibition in pups and that this uncertainty warrants the application of a database uncertainty factor. However, this uncertainty does not require the application of the default 10X but that a safety factor of 5X will be health protective.

5.4. *Calculation of the Acute Population Adjusted Dose (aPAD)*: Considering all of these factors (inter-species extrapolation, intra-species extrapolation, FFDCA SF) and the PoD of 0.03 mg/kg, EPA calculated the aPAD for infants and children to be 0.00006 mg/kg. This calculation relies on application of the default 10X safety factors to account for inter and intra-species variability, and on the 5X FFDCA SF described above. For the general population, and all other population subgroups, the Agency calculated the aPAD to be 0.0002 mg/kg (a $BMDL_{10}$ of 0.02 mg/kg with a 10X safety factor for interspecies variability and another 10X safety factor for intraspecies variability).

5.5. *Calculation of Margin of Exposure(MOE):* An MOE of 100 is applicable, based on EPA's determination, explained previously, that application of the default 10X factors to account for inter and intra-species variability is appropriate for assessing carbofuran's toxicity. EPA determined that application of a 5X uncertainty factor, as was done in calculating the aPAD for infants and children, as described above, was not necessary to protect workers handling or otherwise exposed to carbofuran, as the available RBC data in adults is sufficiently robust.

6. Circumstances of Human Exposure

a. Dietary Exposure to Carbofuran (Food)

i. *EPA methodology and background*. EPA conducted a refined (Tier 3) acute probabilistic dietary risk assessment for carbofuran residues on the following crops: alfalfa, artichokes, banana (domestic use only), barley, corn, cranberry, cucumber, grapes, melons, milk, oats, peppers, potatoes, pumpkin, rice, sorghum, soybean, spinach, squash, strawberry, sugar beets, sugar cane, sunflower seed, and wheat. To conduct the assessment, EPA relied on DEEM-FCID, Version 2.00-2.02, which uses food consumption data from the USDA's Continuing Surveys of Food Intakes by Individuals (CSFII) from 1994-1996 and 1998.

Using data on the percent of the crop actually treated with carbofuran and data on the level of residues that may be present on the treated crop, EPA developed estimates of combined anticipated residues of carbofuran and 3-hydroxycarbofuran on food. 3-hydroxycarbofuran is a degradate of carbofuran and is assumed to have toxic potency equivalent to carbofuran (Refs. 13, 68). Anticipated residues of carbofuran for most foods were derived using USDA PDP monitoring data from recent years (through 2003 for all commodities, except milk, for which recently available 2004 and 2005 data were used). In some cases, where PDP data were not available to cover a particular crop, EPA translated PDP monitoring data from surrogate crops based on the characteristics of the crops and the use patterns; for example, PDP data for cantaloupes were translated to casaba and honeydew and used to derive anticipated residues.

USDA PDP provides the most comprehensive sampling design, and the most extensive and intensive sampling procedures for pesticide residues of the various data sources available to EPA. Additionally, the intent of PDP's sampling design is to provide statistically representative samples of food commodities eaten by the U.S. population specifically for the purpose of performing dietary risk assessments for pesticides. The program focuses on high-consumption foods for children and reflects foods typically available throughout the year. A complete description of the PDP program (including all data through 2005) is available online.

The PDP analyzed for parent carbofuran and its metabolite of concern, 3-hydroxycarbofuran. Most of the samples analyzed by the PDP contained no detectable residues of carbofuran or 3-hydroxycarbofuran. Consequently, the acute assessment for food assumed a concentration equal to ½ of the level of detection (LOD) for PDP monitoring samples with no detectable residues, with zeros incorporated to account for the percent of the crop not treated with carbofuran.

An additional source of data on carbofuran residues was provided by a market basket survey of *N*-methyl carbamate pesticides in single-serving samples of fresh fruits and vegetables collected in 1999-2000 (Carringer, 2000), which was sponsored by the Carbamate Market Basket Survey Task Force. EPA relied on these data to construct the residue distribution files for 2 crops (bananas and grapes) because the use of these data resulted in more refined exposure estimates. The combined Limits of Quantitation (LOQs) for carbofuran and its metabolite in the Market Basket Survey (MBS) were between 10 and 20 fold lower than the combined LODs in the PDP monitoring data.

For certain crops where PDP data were not available (sugar beets, sugarcane, and sunflower seed), anticipated residues were based on field trial data. EPA also relied on field trial data for particular food commodities that are blended during marketing (barley, field corn, popcorn, oats, rice, soybeans and wheat), as use of PDP data can result in significant overestimates of exposure. Field trial data are typically considered to overestimate the residues that are likely to occur in food as actually consumed because they reflect the maximum application rate and shortest preharvest interval allowed by the label. However, for crops that are blended during marketing, such as corn or wheat, use of field trial data can provide a more refined estimate than PDP data, by allowing EPA to better account for the percent of the crop actually treated with carbofuran.

EPA used average and maximum percent crop treated (PCT) estimates for most crops, following the guidance provided in HED SOP 99.6 (*Classification of Food Forms with Respect to level of Blending*; 8/20/99), and available processing and/or cooking factors. The maximum PCT estimates were used to refine the acute dietary exposure estimates. Maximum PCT ranged from <1 to 35%. The estimated percent of the crop imported was applied to crops with tolerances currently maintained solely for import purposes (cranberry, rice, strawberry).

ii. Acute Dietary Exposure (Food Alone) Results and Conclusions. The estimated acute dietary (food only) exposure from the uses listed above exceeds EPA's level of concern for the all children's population subgroups at the 99.9th percentile of exposure. Carbofuran dietary exposure at the 99.9th percentile was estimated at 0.000188 mg/kg/day (310% of the aPAD) for children 3-5 years old, the population subgroup with the highest estimated dietary exposure. Estimated dietary exposure to carbofuran also exceeds EPA's level of concern for children 1-2 years old and 3-5 years at the 99th percentile of exposure. (See results Table 1 below).

Table 1. Results of Acute Dietary Exposure Analysis for Food Alone

Population Subgroup	aPAD (mg/kg/day)	99th Percentile		99.9th Percentile	
		Exposure (mg/kg/day)	% aPAD	Exposure (mg/kg/day)	% aPAD

Table 1. Results of Acute Dietary Exposure Analysis for Food Alone					
Population Subgroup	**aPAD (mg/kg/day)**	**99th Percentile**		**99.9th Percentile**	
		Exposure (mg/kg/day)	**% aPAD**	**Exposure (mg/kg/day)**	**% aPAD**
All Infants (< 1 year old)	0.00006	0.000042	70	0.000151	250
Children 1-2 years old	0.00006	0.000076	130	0.000180	300
Children 3-5 years old	0.00006	0.000065	110	**0.000188**	**310**
Children 6-12 years old	0.00006	0.000045	74	0.000135	230
Youths 13-19 years old	0.0002	0.000030	15	0.000104	52

The foods contributing most heavily to acute exposure at the 99.9th percentile of exposure are listed below for the overall U.S. population and the children's subgroups having the highest estimated exposures (children, 1-2 yrs. old and 3-5 yrs. old).

Table 2. Major Food Contributors to Carbofuran Acute Exposure at the 99.9th Percentile (Expressed as an Approximate Percent of Total Exposure)	
Children, 1-2 Years Old	Children, 3-5 Years Old[1]
Potato (60%)	Potato (43%)
Cucumber (9%)	Cucumber (17%)
Grape (4%)	Watermelon (12%)
Squash (2%)	Grape (4%)
	Cranberry (1%)

[1]The population subgroup with the highest estimated acute exposure from food alone.

Exposure estimates for all of the major food contributors were based on PDP monitoring data adjusted to account for the percent of the crop treated with carbofuran and, therefore, may be considered highly refined.

As noted previously, because most of the PDP samples contained no detectable residues of carbofuran or its 3-hydroxy metabolite, the acute assessment for food assumed a concentration equal to ½ of the LOD for PDP monitoring samples with no detectable residues, with zeros incorporated to account for the percent of the crop not treated with carbofuran. In accordance with OPP policy for analyzing commodities with non-detectable residues,[1] EPA performed additional analyses to determine the impact of using ½ the LOD to estimate exposure.

In the first analysis (Sensitivity Analysis #1), those commodities that had no detectable residues *at all* in the monitoring data or field trials were eliminated from the assessment. The commodities that were eliminated included barley, coffee, corn, cranberry, oats, potato, raisin, rice, soybean, spinach, strawberry, sugar beet, sunflower, winter squash, and wheat. For the remaining commodities, EPA continued to substitute the ½ LOD values for the percent of the crop treated with carbofuran, with zeros incorporated to account for the remaining untreated percent of the crop. This analysis resulted in estimated exposures that were still above EPA's level of concern for all population subgroups but two at the 99.9th percentile.

To further understand the extent to which the ½LODs from the PDP monitoring data were affecting the risk assessment, EPA conducted an additional sensitivity analysis, (Sensitivity Analysis #2) which excluded the crops for which PDP and MBS data were not available and assigned zeros for all non-detected residues in commodities sampled in the PDP or MBS. In this analysis, estimated dietary exposures at the 99.9th percentile of exposure remained above EPA's level of concern for children 1-2 yrs. old (140% of the aPAD) and children 3-5 yrs. old (110% of the aPAD). The results of these sensitivity analyses at the 99.9th percentile of exposure are compared to the results using ½LOD for non-detectable residues in Table 3 below.

Table 3. Impact of Using ½LOD for Non-Detectable Residues on Estimated Exposure from Food[1]

Population Subgroup	aPAD (mg/kg/day)	Analysis Assuming ½LOD for Non-Detectable Residues		Sensitivity Analysis #1[2]		Sensitivity Analysis #2[3]	
		Exposure (mg/kg/day)	% aPAD	Exposure (mg/kg/day)	% aPAD	Exposure (mg/kg/day)	% aPAD
All Infants (< 1 year old)	0.00006	0.000151	250	0.000044	73	0.000043	71
Children 1-2 years old	**0.00006**	**0.000180**	**300**	**0.000086**	**140**	**0.000085**	**140**
Children 3-5 years old	0.00006	0.000188	310	0.000064	110	0.000063	110
Children 6-12 years old	0.00006	0.000135	220	0.000040	67	0.000040	66

[1]At the 99.9th Percentile of Exposure

[1] USEPA "Assigning Values to Nondetected/Nonquantified Pesticide Residues in Human Health Dietary Exposure Assessments", 3/00.

[2]Non-detectable PDP residues assumed to be zero *only* for commodities having no detectable residues at all in the PDP monitoring data and field trials (i.e., these commodities were eliminated from the analysis). Crops without PDP data and detectable residues in field trials were *included*, based on the distribution of residues from field trial studies.
[3]Non-detectable residues assumed to be zero for *all* commodities. Commodities without PDP or Market Basket data were *excluded* from the analysis.

The major contributors in sensitivity analysis # 2, to the estimated dietary exposure of children are listed in Table 4 below.

Table 4. Major Contributors to Carbofuran Acute Exposure at the 99.9th Percentile in Sensitivity Analysis #2 (Expressed as an Approximate Percent of Total Exposure)

Food	Infants, <1 year old	Children, 1-2 Years Old	Children, 3-5 Years Old
Cucumber	<1	6	10
Squash	2	2	<1
Grape	6	12	16
Banana	11	2	2
Milk[1]	79	73	63
Watermelon	<1	2	2

[1]Milk is a major contributor to infant dietary exposure to carbofuran, accounting for more than 20% of total exposure for this subgroup.

The results of the sensitivity analyses indicate that the dietary risk assessment for carbofuran is sensitive to the assumed concentrations (i.e., ½LOD) for non-detectable residues in the PDP monitoring data and suggest that the assessment may overestimate dietary exposures to carbofuran at the upper percentiles of exposure, particularly for crops where there were no detectable residues in the PDP data and the percent crop treated is low. In these cases, assuming ½ LOD for "treated" nondetects may be conservative as the assumed finite residues in these samples may, in fact, be closer to zero than to half the LOD. However, it is not possible to precisely determine the value of these assumed residues and, therefore, to what extent exposures may be overestimated. Further, the available information demonstrates that carbofuran residues are present; when a lower level of detection was utilized, both in the most recent PDP milk analyses, and in the Carbamate MBS data, residues of 3-hydroxycarbofuran were detected. Therefore, EPA considers that these results represent a reasonably conservative estimate, in light of the available information. Most importantly, as discussed in more detail below, in both sensitivity analyses, dietary exposures at the 99.9th percentile of exposure exceed EPA's level of concern for a number of population subgroups, which suggests that EPA's estimates do not significantly overestimate carbofuran exposures.

The results of the second sensitivity analysis represent the lower bound of potential dietary exposures to carbofuran, since this analysis is based solely on detected residues in the PDP monitoring data. PDP samples with non-detectable residues were assumed to contain no carbofuran or 3-hydroxycarbofuran, and residues in crops for which PDP data were not available were also assumed to be zero. Since both of these assumptions are highly unlikely to be true, Sensitivity Analysis #2 represents an underestimate of dietary exposures to carbofuran. Actual dietary exposures to carbofuran likely fall somewhere between those shown for sensitivity analysis #2 and those in the full assessment (i.e., with all crops and assuming ½LOD for non-detectable residues in the "treated" portion of the crop).

Although sensitivity analysis #2 likely underestimates actual dietary exposure to carbofuran, this analysis highlights an important point regarding the carbofuran risk assessment. That is, at the upper percentiles of exposure, relatively low residues in a small percentage of food samples result in estimated exposures that are above EPA's level of concern for children's subgroups. As a result of this finding, EPA performed additional calculations to determine the risk to children consuming typical (50th percentile) or high-end (90th percentile) amounts of a single commodity (either cucumbers or summer squash) containing residues of carbofuran at levels detected by the PDP. The results are summarized in Table 5 below.

Table 5. Risk to Children Consuming Typical or High-end Amounts of Cucumbers or Squash Containing Carbofuran Residues

Food	Population Subgroup	Typical: 50th Percentile of Consumption				High-End: 90th Percentile of Consumption			
		Consumption (g/kg bw)	PDP Residue[1] (ppm)	Exposure (mg/kg bw)	% aPAD	Consumption (g/kg bw)	PDP Residue[1] (ppm)	Exposure (mg/kg bw)	% aPAD
Cucumber	Children 1-2	0.305009 (less than 5g of cucumbers for a 15 kg child)	0.005	0.000002	3	2.485074 (less than 40g for a 15 kg child)	0.005	0.000012	21
			0.029	0.000009	15		0.029	0.000072	120
			0.063	0.000019	32		0.063	0.000160	260
			0.117	0.000036	59		0.117	0.000291	480
			0.137	0.000042	70		0.137	0.000340	570
			0.147	0.000045	75		0.147	0.000365	610
			0.437	0.000133	220		0.437	0.001086	1800
			0.537	0.000164	270		0.537	0.001334	2200
	Children 3-5	0.293744 (approx. 6g of cucumbers for a 20 kg	0.005	0.000015	2	2.517696 (approx. 50 g or ½ cup for a 20 kg	0.005	0.000013	21
			0.029	0.000009	14		0.029	0.000073	120
			0.063	0.000019	31		0.063	0.000160	260
			0.117	0.000034	57		0.117	0.000296	490

Table 5. Risk to Children Consuming Typical or High-end Amounts of Cucumbers or Squash Containing Carbofuran Residues

Food	Population Subgroup	Typical: 50th Percentile of Consumption				High-End: 90th Percentile of Consumption			
		Consumption (g/kg bw)	PDP Residue[1] (ppm)	Exposure (mg/kg bw)	% aPAD	Consumption (g/kg bw)	PDP Residue[1] (ppm)	Exposure (mg/kg bw)	% aPAD
			0.137	0.000040	67		0.137	0.000345	570
			0.147	0.000043	72		0.147	0.000370	620
			0.437	0.000128	210		0.437	0.001100	1800
			0.537	0.000158	260		0.537	0.001352	2300

[1] The PDP detected residues of carbofuran in 11 of 1479 cucumber samples at levels ranging from 0.005 ppm to 0.537 ppm. No adjustment was made to account for reductions of residues during cooking of squash. Application of the 0.75x reduction factor for cooked squash would result in slightly lower exposure and risk estimates.

Detectable residues of carbofuran and/or 3-hydroxycarbofuran were found in only a few samples of cucumbers in monitoring data (11 out of 1479 or less than one percent). However, if young children aged 1 to 5 consume moderate amounts of cucumbers (*i.e*., the median or 50th percentile of consumption, corresponding to approximately 0.2 ounces of cucumber) that contain observed levels of carbofuran, the percent of the aPAD that would be utilized ranges from about 3 percent of the safe daily dose for the lower observed residue values to over 200 percent of the safe daily dose for the higher observed values. For children who consume larger amounts of cucumbers (*i.e*., the 90th percentile of consumption, corresponding to 1.5 to 2 ounces of cucumbers or roughly ½ cup), exposure increases approximately 10-fold (21 percent to over 2000 percent of the aPAD). Many of these values significantly exceed the Agency's level of concern based on the consumption of a single daily serving of one commodity.

The results from consumption of summer squash are equally dramatic. Monitoring data are now available for summer squash, which showed one residue (0.055 ppm) in 186 total samples of summer squash. Since children's squash consumption at the 50th (median) percentile is about three times higher than median cucumber consumption, aPAD exceedance is even more dramatic for this commodity. At the higher end (90th percentile) of consumption, the Agency's level of concern is exceeded any time a child consumes squash with PDP detected levels of carbofuran (460 percent of the aPAD). At these exposure levels, this equates to approximately 1 million children per year that are at risk from consuming unsafe doses of carbofuran.

EPA focused on children in making these calculations, because children have the highest estimated dietary exposure to carbofuran; however, it is reasonable to assume that adult exposures from a single treated food item could also exceed EPA's level of concern, particularly at the high end of consumption.

b. Drinking Water Exposures

EPA's drinking water assessment uses both monitoring data for carbofuran and modeling methods, and takes into account contributions from both surface water and groundwater sources (Ref. 50).[2] Concentrations of carbofuran in drinking water, as with any pesticide, are in large part determined by the amount, method, timing and location of pesticide application, the physical characteristics of the watersheds and/or aquifers in which the community water supplies (CWS) or wells are located, and other environmental factors, such as rainfall, which can cause the pesticide to move from the location where it was applied. While there is a considerable body of monitoring data that has measured carbofuran residues in drinking water sources, these data generally are not designed to capture peak concentrations of pesticides moving through a watershed. Capturing these peak concentrations is particularly important for assessing risks from carbofuran because the toxicity end-point of concern results from short-term exposure (acute effects). Because pesticide loads in surface water tend to move in relatively quick

[2] EPA's assessment of drinking water exposures is also discussed in detail in the March 7, 2006 Carbofuran Environmental Risk Assessment and Drinking Water Exposure Assessment that EPA conducted in support of its interim reregistration eligibility decision (RED) for carbofuran.

pulses in flowing water, frequent targeted sampling is necessary to reliably capture peak concentrations for surface water sources of drinking water. Pesticide concentrations in ground water, however, are generally the result of longer-term processes and less frequent sampling can better characterize peak ground water concentrations. However, such data must be targeted at the most vulnerable watersheds to capture peak concentrations. As a consequence, monitoring data tends to underestimate exposure for acute endpoints. Simulation modeling complements monitoring by making estimations at vulnerable sites and can be used to represent daily concentration profiles, based on a distribution of weather conditions. Thus, modeling can account for the cases when a pesticide is used in drinking water watersheds at the label rate and is applied to a substantial proportion of the crop, and stochastic processes, such as rainfall represented by 30 years of existing weather data maintained by the National Oceanic and Atmospheric Administration.

i. Exposure to Carbofuran From Drinking Water Derived from Ground Water Sources. Drinking water taken from shallow wells is particularly vulnerable to contamination in areas where carbofuran is used around sandy, highly acidic soil. Some areas with these characteristics include Long Island, parts of Florida, and the Atlantic coastal plain. Exposure estimates for this assessment are drawn primarily from (1) the results of a prospective groundwater (PGW) study developed by the registrant in the early 1980s; and (2) additional groundwater modeling conducted as part of the N-methyl carbamate cumulative assessment in 2007. All available monitoring of water resources, including monitoring of drinking water supplies, is described to characterize exposure. The results of the PGW study are consistent with a number of other targeted groundwater studies conducted in the 1980s showing that high concentrations of carbofuran can occur in vulnerable areas; the results of these studies as well as the PGW study are summarized in Ref 14. While there have been additional groundwater monitoring studies that included carbofuran as an analyte since that time, there has been no additional monitoring targeted to vulnerable aquifers. Accordingly, EPA believes the PGW study continues to be the most relevant monitoring data for assessing drinking water exposures from groundwater from vulnerable sites. Because this study was conducted over only one growing season, however, and was conducted at use rates that now exceed current label maximum rates for the use being studied (3 lb ai/acre vs. the current 2 lb ai/acre for corn), EPA has scaled the results to represent impacts from carbofuran use over a long-term period (25 years) at current label rates. Temporal scaling was necessary because the PGW study represents water quality impacts from a single application rather than repeated years of use. Based on EPA's assessment, the maximum 90-day average carbofuran concentrations in vulnerable groundwater for various application rates were estimated to range from a low of 1.4 parts per billion (ppb) based on the rate used on alfalfa at low application rates to a high of 110 ppb, based on the rate used on grapes. To further characterize exposure, the assessment includes an extensive summary of historical monitoring that included carbofuran as an analyte, including a compilation of drinking water monitoring at large public water supply wells developed by EPA's Office of Water.

EPA conducted additional groundwater modeling for the *N*-methyl carbamate cumulate risk assessment, and developed a time series of exposure at locations selected based on potential exposure to a combination of carbamate insecticides relevant for cumulative exposure assessment for use in probabilistic dietary assessments using DEEM. EPA estimated groundwater concentrations associated with two possible use scenarios: potatoes in northeastern Florida and cucurbits on the Delmarva Peninsula in the Mid-Atlantic region. While the modeled potato use scenario in Florida did not show high concentrations of carbofuran, estimated carbofuran concentrations associated with the cucurbit use in the Delmarva Peninsula – a region with shallow, acidic groundwater and acidic, sandy soils – are in line with EPA's assessment of the PGW study discussed above. Specifically, the assessment indicated that at high application rates, maximum concentrations were 38.5 ppb at a recurrence frequency of one in one hundred days. EPA does not believe the results of this assessment are particularly conservative, since the application rate used in this assessment was a typical "high" rate of 1.25 lb./acre on melons rather than the maximum application rate that growers could use.

Based on these estimates, EPA compiled a distribution of estimated carbofuran concentrations in water that could be used to generate probabilistic assessments of the potential exposures from drinking water derived from vulnerable ground water sources. The results of EPA's probabilistic assessments are represented below in Table 6.

Table 6. Results of Acute Dietary (Water Only) Exposure Analysis Using DEEM FCID and Incorporating the Delmarva Groundwater Scenario.

Population Subgroup	aPAD (mg/kg/day)	95th Percentile		99th Percentile		99.9th Percentile	
		Exposure (mg/kg/day)	% aPAD	Exposure (mg/kg/day)	% aPAD	Exposure (mg/kg/day)	% aPAD
All Infants (< 1 year old)	0.00006	0.003800	6300	0.006006	>10000	**0.010030**	**>10000**
Children 1-2 years old	0.00006	0.001612	2700	0.002732	4600	0.004628	7700
Children 3-5 years old	0.00006	0.001459	2400	0.002405	4000	0.004613	7000
Children 6-12 years old	0.00006	0.001018	1700	0.001710	2800	0.002792	4700
Youth 13-19 years old	0.0002	0.000809	400	0.001441	720	0.002919	1500
Adults 20-49 years old	0.0002	0.000955	480	0.001632	820	0.003073	1500
Adults 50+ years old	0.0002	0.000884	440	0.001345	670	0.002271	1100

**The values for the highest exposed population for each type of risk assessment are bolded*

While the registrant has attempted to address drinking water exposure from ground water sources by including on carbofuran product labeling an advisory statement warning growers against application in vulnerable areas, this language does not preclude use in such areas. Accordingly, EPA continues to believe that its assessment of drinking water from groundwater sources based on current labels is a realistic assessment of potential exposures to those portions of the population consuming drinking water from shallow wells in highly vulnerable areas.

ii. Exposure from Drinking Water Derived from Surface Water Sources. EPA's evaluation of environmental drinking water concentrations of carbofuran from surface water, as with its evaluation of groundwater, takes into account the results of both surface water monitoring and modeling. As is the case with ground water, the most extensive source of national water monitoring data for pesticides is the United States Geological Survey National Water Quality Assessment (USGS NAWQA) program. The NAWQA program focuses on ambient water rather than on drinking water sources, is not specifically targeted to high pesticide use areas, and is sampled at a frequency (generally weekly or bi-weekly during the use season) not sufficient to provide reliable estimates of peak pesticide concentrations in surface water. The program, rather, provides a good understanding on a national level of the occurrence of pesticides in flowing water bodies that can be useful for screening assessments of potential drinking water sources. A detailed description of the pesticide monitoring component of the NAWQA program is available on the NAWQA Pesticide National Synthesis Project (PNSP) web site (http://ca.water.usgs.gov/pnsp/).

A summary of the first cycle of NAWQA monitoring from 1991 to 2001 indicates that carbofuran was the most frequently detected carbamate in streams and ground water in agricultural areas. Overall, where carbofuran was detected, these non-targeted monitoring results generally found carbofuran at levels below 0.5 ppb. The highest concentrations of carbofuran are reported from at a sampling station on Zollner Creek, in Oregon. USGS monitoring at that location from 1993 to 2006 detected carbofuran annually in 40-100 % of samples. Although the majority of concentrations detected there are also in the sub-part per billion range, concentrations have exceeded 1 ppb in 8 of the 14 years of sampling. The maximum measured concentration was 32.2 ppb, observed in the spring of 2002. The frequency of detections generally over a 14-year period suggests that standard use practices rather than aberrational misuse incidents in the region are responsible for high concentration levels at this location. This creek, located in the Molalla-Pudding sub-basin of the Willamette River, is not directly used as a drinking water source. While available monitoring from other portions of the country suggest that the circumstances giving rise to high concentrations of carbofuran may be rare, EPA has no basis to conclude that the conditions are necessarily unique and that such concentrations cannot occur in other watersheds that have similar conditions. Zollner Creek is a steep-gradient low-order stream and its watershed is small (approximately 40 km^2) and intensively farmed, with a diversity of crops grown, including plant nurseries.

EPA modeled estimated daily drinking water exposures to carbofuran using PRZM to simulate field runoff processes and EXAMS to simulate receiving water body processes. A detailed description of the models is available from the EPA OPP Water Models web site:http://www.epa.gov/oppefed1/models/water/index.htm. These models provide a means for EPA to estimate daily pesticide concentrations in surface water sources of drinking water (a reservoir) using local soil, site, hydrology, and weather characteristics along with pesticide application and agricultural management practices, and pesticide environmental fate and transport properties. Consistent with the recommendations of the FIFRA SAP, EPA also considers regional percent cropped area factors (PCA) which takes into account the potential extent of cropped areas that could be treated with pesticides in a particular area. The PRZM and EXAMS models used by EPA were developed by EPA ORD, and are used by many international pesticide regulatory agencies to estimate pesticide exposure in surface water. EPA's use of the percent cropped area factors and the Index Reservoir scenario was reviewed by the FIFRA SAP in 1999 and 1998, respectively.[3]

In modeling potential surface water concentrations, EPA attempts to capture areas of the country that are highly vulnerable to surface water contamination rather than simply model "typical" concentrations occurring across the nation. As such, EPA models exposures occurring in small highly agricultural watersheds over a 30-year period in different growing areas nationally. The scenarios are designed to capture residue levels in drinking water from reservoirs with small watersheds with a large percentage of land use in agricultural production that has been treated with the pesticide. EPA believes these assessments are likely reflective of a small subset of the watersheds across the country that maintain drinking water reservoirs, representing a drinking water source generally considered to be most vulnerable to frequent high concentrations of pesticides. For carbofuran, EPA's modeling estimated 1-in-10-year peak concentrations ranging from 0.11 ppb to 168 ppb, varying in accordance with application rates, crop and location. For example for corn, the environmental fate and effects science chapter for the IRED describes variability in exposure estimates for corn based on different application patterns (26 ppb assuming the maximum rate; 19 ppb assuming a typical rate) and variability using regional percent cropped area factors reflective of corn intensity nationally (19 – 49 ppb). The monitoring data from Zollner Creek in the Willamette Valley would suggest that EPA's assessment reasonably reflects carbofuran concentrations that can occur in small streams in within vulnerable watersheds. EPA compiled distributions of estimated carbofuran concentrations in surface water in order to conduct probabilistic assessments of the potential exposures from drinking water from such sources. EPA modeled a range of crops at locations that would be considered more vulnerable than most places where the crops are grown, based on the maximum labeled use rates (Refs. 50, 67). These results were then adjusted to reflect different regional levels for agricultural intensity.

Available environmental fate studies do not show formation of 3-hydroxycarbofuran through most environmental processes except soil photolysis, where

[3] 1999 SAP rep. http:/www.epa.gov/scipoly/sap/meetings/1999/index.html#052599; Ref. 1998 SAP rep. http:/www.epa.gov/scipoly/sap/meetings/1998/july/10art4.pdf).

in one study it was detected in very low amounts. Even though 3-hydroxycarbofuran was not explicitly considered as a separate entity in the EFED exposure assessment, it would not be expected to significantly add to exposure estimates. There are additional sources of uncertainty associated with estimating exposure of carbofuran in surface water source drinking water. Several of the most significant of these are the effect of treatment in removing carbofuran, the impact of percent crop treated assumptions, and the variation in pH across the landscape. The effect of the percent crop treated assumption in the case of carbofuran is discussed in detail in EPA's assessment of additional data submitted by the registrant (Refs. 50, 67). Available data on the degree to which carbofuran may be removed are summarized in Appendix E-3 of the Revised *N*-Methyl Carbamate Cumulative Assessment (Ref. 88). The impact of pH on estimated concentrations is described in the IRED. These three sources of uncertainty for carbofuran are detailed below.

Unlike drinking water derived from private groundwater wells, public water supplies (surface water or ground water source) will generally be treated before it is distributed to consumers. An evaluation of laboratory and field monitoring data indicate that *N*-methyl carbamates may be effectively removed (60 – 100%) from drinking water by lime softening and activated carbon. Data compiled by EPA's Office of Water show that carbofuran was detected in treated drinking water at a few locations. Based on samples collected from 1394 surface water source drinking water supplies in 16 states in 2002, carbofuran was found at two public ground water systems and one surface water public water supply at concentrations greater than 4 ppb (measurements below this limit were not reported). Although EPA is aware of the mitigating effects of specific treatment processes, treatment processes employed at public water supply utilities across the country vary significantly both from location to location and throughout the year, and therefore are difficult to incorporate quantitatively in drinking water exposure estimates. The assumption that there is no reduction in carbofuran concentrations in surface water source drinking water is conservative and introduces uncertainty into surface water exposure estimates used for human health risk assessment.

Uncertainty associated with percent crop treated assumptions can be a major factor in EPA's drinking water exposure assessment for surface-water sources. Estimates of the percent of major crops (for example, corn) that are treated with pesticides are available at the state level, but are generally not available on a smaller scale suitable for estimating drinking water exposure in a watershed. If state-scale estimates are used to account for PCT it will underestimate the risk for some of the drinking water facilities in the state as the state-wide estimate represents an average: values for individual facilities will be both lower and higher than the state-wide estimate. In some cases, the underestimate can be substantial if the application pattern tends to form cluster or pockets of high usage. Insecticides like carbofuran are particularly prone to this use pattern, as insect outbreaks often tend to be locally intense, rather than widespread. Without data collected at a finer spatial scale, it is not possible to know whether pesticide usage is evenly dispersed through the state or is locally clustered. This results in large uncertainty in the drinking water exposure assessments when percent crop treated is moderate or low.

Consequently, EPA does not typically include such information in its surface-water exposure assessments.

Surface water modeling did not take into account the variation in pH across the landscape; a pH of 7 was assumed. Thus for water bodies with pH higher than 7, degradation rates increase and the subsequently estimated carbofuran concentrations would be lower; whereas in water bodies that are acidic, degradation rates would be lower and estimated concentrations would be higher. Also, model estimates for acute exposure are relatively insensitive to degradation rates—even in cases where degradation is quite rapid. The effect of this is that the hydrolysis rate, which can be rapid for carbofuran in some environments, has little impact on estimated acute exposure values. Resolving this uncertainty would decrease the magnitude of estimated concentrations, however, the decrease cannot be quantified.

Notwithstanding the degree of uncertainty in the data, EPA compiled a distribution of estimated carbofuran concentrations in surface water in order to conduct probabilistic assessments of the potential exposures from drinking water, as required by statute. EPA modeled a range of crops at locations that would be considered more vulnerable than most places where the crops are grown, resulting in estimated peak concentrations of 1.4-168 ppb (Ref. 67). These results were then adjusted to reflect different regional levels for agricultural intensity.

The table below presents the results of EPA's exposure analysis based on an Illinois corn scenario assuming two applications at the maximum label rate of 1 pound a.i./A. The Illinois corn scenario used a crop specific PCA of 0.44 which is the maximum proportion of corn acreage in a Hydrologic Unit Code 8-sized basin in the United States. (The US Geological Survey has classified all watersheds in the US into basins of various sizes, according to hydrologic unit codes, in which the number of digits indicates the size of the basin). Although other crop scenarios resulted in higher exposure, estimates for corn are presented here, as it is a major crop. The populations described in the table are those people who consume untreated water from a reservoir located in a small watershed predominated by corn production with all of the corn treated with carbofuran at the maximum labeled rate. This assessment is intended to be representative of highly vulnerable sites on which corn could be grown on a national basis, and is used as a screen for corn on a national basis. More details on these assessments, as well as the assessments EPA conducted for other crop scenarios, can be found in (Refs. 12, 67).

Table 7. Results of Acute Dietary (Water Only) Exposure Analysis Incorporating the Illinois Corn Scenario

Population Subgroup	aPAD (mg/kg/day)	95th Percentile		99th Percentile		99.9th Percentile	
		Exposure (mg/kg/day)	% aPAD	Exposure (mg/kg/day)	% aPAD	Exposure (mg/kg/day)	% aPAD

Table 7. Results of Acute Dietary (Water Only) Exposure Analysis Incorporating the Illinois Corn Scenario							
Population Subgroup	**aPAD (mg/kg/day)**	**95th Percentile**		**99th Percentile**		**99.9th Percentile**	
		Exposure (mg/kg/day)	**% aPAD**	**Exposure (mg/kg/day)**	**% aPAD**	**Exposure (mg/kg/day)**	**% aPAD**
All Infants (< 1 year old)	0.00006	0.001131	1900	0.003148	5200	**0.007671**	**>10000**
Children 1-2 years old	0.00006	0.000482	800	0.001318	2200	0.003364	5600
Children 3-5 years old	0.00006	0.000451	750	0.001201	2000	0.002971	5000
Children 6-12 years old	0.00006	0.000309	520	0.000831	1400	0.002092	3500
Youth 13-19 years old	0.0002	0.000231	120	0.000649	320	0.001723	860
Adults 20-49 years old	0.0002	0.000299	150	0.000795	400	0.002005	1000
Adults 50+ years old	0.0002	0.000318	160	0.000779	390	0.001757	880

**The values for the highest exposed population for each type of risk assessment are bolded*

Given that we would expect current surface water simulation modeling methods to likely be an overestimate for carbofuran, it would be reasonable to consider monitoring data as an alternative line of evidence in estimating exposure. The large difference between concentrations seen in the monitoring data on the low side, and the simulation modeling on the high side is an indication of the uncertainty in the assessment for surface-water source drinking water exposure. In reality, drinking water concentrations resulting from use of carbofuran are likely to be occurring at higher concentrations than those measured in most monitoring studies, but below those estimated with simulation modeling. If the overall use of carbofuran was to continue at the current level, we would expect that representative drinking water concentrations are more likely to be closer to values observed in the monitoring data than the simulation modeling estimates; however the exact values are highly uncertain. The concentrations reported in available non-targeted monitoring from ambient surface water are of concern to the Agency.

FMC has criticized EPA's assessment for failing to account more fully for the percent of the crop treated (PCT) in its modeling. As previously discussed, given the lack of reliable data on PCT at the watershed level, EPA does not typically include such information in its surface-water exposure assessments. However, in response to FMC's concerns, EPA performed an exposure assessment based on the percent of the crop treated in the watershed suggested by the registrant (10%), to determine the extent to which some consideration of PCT could meaningfully affect the outcome of the risk assessment. The results suggest that, even at the percentage suggested by the registrant, exposures from drinking water derived from surface waters can contribute significantly to the aggregate dietary risks, particularly for infants and children. Details on the assessments EPA conducted for other crop scenarios, which showed higher contributions from drinking water, can be found in (Ref. 12, 13, 67). Accordingly, these assessments suggest that EPA's use of PCA, rather than PCT, will not meaningfully affect the risk assessment.

c. Aggregate Dietary Exposures (Food and Drinking Water)

EPA conducted a number of probabilistic analyses to combine the national food exposures with the exposures from the individual region and crop-specific drinking water scenarios. Although food is distributed nationally, and residue values are therefore not expected to vary substantially throughout the country, drinking water is locally derived and concentrations of pesticides in source water fluctuate over time and location for a variety of reasons. Pesticide residues in water fluctuate daily, seasonally, and yearly as a result of the timing of the pesticide application, the vulnerability of the water supply to pesticide loading through runoff, spray drift and/or leaching, and changes in the weather. Concentrations are also affected by the method of application, the location and characteristics of the sites where a pesticide is used, the climate, and the type and degree of pest pressure. Consequently, EPA conducted several estimates of aggregate dietary risks by combining exposures from food and drinking water. More details on the individual aggregate assessments presented below, as well as the assessments EPA conducted for other regional and crop scenarios, can be found in (Refs. 12, 13).

The first table reflects the results of aggregate exposures from food and from drinking water derived from ground water in vulnerable areas (i.e., from shallow wells associated with sandy soils and acidic aquifers, such as are found in the Delmarva peninsula). The estimates range between 1100% aPAD for adults over 50 years, to over 10,000% aPAD for infants.

Table 8. Results of Acute Dietary (Food and Water) Exposure Analysis incorporating the Delmarva Groundwater Scenario.

Population Subgroup	APAD (mg/kg/day)	95th Percentile		99th Percentile		99.9th Percentile	
		Exposure (mg/kg/day)	% aPAD	Exposure (mg/kg/day)	% aPAD	Exposure (mg/kg/day)	% aPAD
All Infants (< 1 year old)	0.00006	0.003800	6300	0.006027	>10000	**0.010010**	**>10000**
Children 1-2 years old	0.00006	0.001625	2700	0.002744	4600	0.004646	7700
Children 3-5 years old	0.00006	0.001467	2400	0.002416	4000	0.004275	7100
Children 6-12 years old	0.00006	0.001027	1700	0.001717	2900	0.002829	4700
Youth 13-19 years old	0.0002	0.000814	410	0.001443	720	0.002921	1500
Adults 20-49 years old	0.0002	0.000959	480	0.001639	820	0.003094	1500

Table 8. Results of Acute Dietary (Food and Water) Exposure Analysis incorporating the Delmarva Groundwater Scenario.							
Population Subgroup	APAD (mg/kg/day)	95th Percentile		99th Percentile		99.9th Percentile	
		Exposure (mg/kg/day)	% aPAD	Exposure (mg/kg/day)	% aPAD	Exposure (mg/kg/day)	% aPAD
Adults 50+ years old	0.0002	0.000889	440	0.001351	680	0.002279	1100

**The values for the highest exposed population for each type of risk assessment are bolded*

The peak values for the Delmarva groundwater scenario time series are consistent with monitoring data from wells in vulnerable areas where carbofuran was used. For example, the maximum value from the time series is 38.5 ppb while maximum values from targeted ground water monitoring studies ranged from 1.4 ppb for a study in Maryland, to 151 ppb for a study in Manitoba (Refs. 50, 67). For studies with multiple measurements at each well, central tendency estimates were also in the same range as the time series. The median for the Manitoba site was 16 ppb, and the mean from wells under no-till agriculture in Queenstown, MD was 7.0 ppb, while the median for the modeling was 15.5 ppb. The 90-day average concentration, based on the registrant's prospective ground waster study conducted on corn in the Delmarva (adjusted for current application rates) is 22 ppb.

The next table presents the results of aggregate exposure using the Illinois corn surface water scenario.

Table 9. Results of Acute Dietary (Food and Water) Exposure Analysis Using the Illinois Corn Scenario							
Population Subgroup	**aPAD (mg/kg/day)**	**95th Percentile**		**99th Percentile**		**99.9th Percentile**	
		Exposure (mg/kg/day)	**% aPAD**	**Exposure (mg/kg/day)**	**% aPAD**	**Exposure (mg/kg/day)**	**% aPAD**
All Infants (< 1 year old)	0.00006	0.001132	1900	0.003150	5300	**0.007680**	**>10000**
Children 1-2 years old	0.00006	0.000494	820	0.001334	2200	0.003322	5500
Children 3-5 years old	0.00006	0.000461	770	0.001221	2000	0.003048	5100
Children 6-12 years old	0.00006	0.000316	530	0.000841	1400	0.002092	3500
Youth 13-19 years old	0.0002	0.000235	120	0.000661	330	0.001764	880

Table 9. Results of Acute Dietary (Food and Water) Exposure Analysis Using the Illinois Corn Scenario							
Population Subgroup	**aPAD (mg/kg/day)**	**95th Percentile**		**99th Percentile**		**99.9th Percentile**	
		Exposure (mg/kg/day)	**% aPAD**	**Exposure (mg/kg/day)**	**% aPAD**	**Exposure (mg/kg/day)**	**% aPAD**
Adults 20-49 years old	0.0002	0.000304	150	0.000804	400	0.002011	1000
Adults 50+ years old	0.0002	0.000323	160	0.000786	390	0.001774	890

**The values for the highest exposed population for each type of risk assessment are bolded*

Typically, EPA's food and water exposure assessments sum exposures over a 24-hour period, and EPA used this 24-hour total in developing its acute dietary risk assessment for carbofuran. Because of the rapid nature of carbofuran toxicity and recovery, EPA considered that it might be appropriate to consider durations of exposure less than 24 hours. EPA has developed an analysis using information about external exposure, timing of exposure within a day, and half-life of AChE inhibition from rats to estimate risk to carbofuran at durations less than 24 hours. Specifically, EPA has evaluated individual eating and drinking occasions and used the AChE half-life information to estimate the residual effects from carbofuran from previous exposures within the day. The carbofuran analyses are described in the 2007 aggregate (dietary) memo (Refs. 12, 13).

EPA has used two approaches for considering the impact of rapid reversibility on exposure estimates in the food and drinking water risk assessments. These approaches have been used previously by EPA in the cumulative risk assessment of the *N*-methyl carbamate pesticides and/or risk assessments for other *N*-methyl carbamate pesticides (e.g., methomyl and aldicarb)(Ref. 88).

Incorporating eating occasion analysis and either the 150 minute or 300 minute recovery half life for carbofuran into the Food Only analysis does not significantly change the risk estimates when compared to baseline levels (for which a total daily consumption basis – and not eating occasion - was used). From this, it is apparent that modifying the analysis such that information on eating (i.e. food) occasions and carbofuran half life is incorporated results in only minor reductions in estimated risk.

The food analysis showed that over 70% of exposures at the top 0.2%-ile for children ages 1-2 and 3-5 are from a single eating event of carbofuran indicating that OPP's food risk is not substantively overstated. Moreover, when incorporating half-life to recovery information, risks from summing exposures over 24 hours are similar to those when incorporating half-life to recovery of 150 or 300 minutes. Regarding drinking water exposure, accounting for drinking water consumption throughout the day and using the half-life to recovery information, MOEs are increased (ie, risk is reduced) by approximately 2-3X.

Consequently, risk estimates for which food and drinking water are jointly considered and incorporated (i.e, Food + Drinking Water) are reduced considerably--by a factor of two or more in some cases--compared to baseline. This is not unexpected, as infants receive much of their exposures from indirect drinking water in the form of water used to prepare infant formula. But even though the risk estimates from aggregate exposure are reduced, they nonetheless still substantially exceed EPA's level of concern for infants and children. Using drinking water derived from the surface water from the Upper Colorado Cucurbit scenario, which estimated the lowest exposures, aggregate exposures ranged from a low of 270% aPAD for infants, based on a 150 minute half-life, to a high of 320% aPAD for infants, based on a 300 minute half-life.

The two approaches discussed above are used to evaluate the extent to which the Agency's 24-hour approach to dietary risk assessment overestimates risk from carbofuran exposure. The results of both approaches indicate that the risk to carbofuran is indeed not substantively overestimated using the current exposure models and the 24-hour approach. This is due to the fact that exposure to carbofuran occurs predominantly through single eating events and not from multiple events that occur throughout the day. Based on these analyses, the Agency concludes that the current exposure assessment methods used in the carbofuran dietary assessment provide realistic and high confidence estimates of risk to carbofuran exposure through food.

The result of all of these analyses clearly demonstrate that aggregate exposure from all registered uses of carbofuran fail to meet the FFDCA section 408 safety standard, and that cancellation of all registrations and revocation of the associated tolerances is warranted. Based on the contribution from food alone, dietary exposures to carbofuran exceed EPA's level of concern for all of the more sensitive subpopulations of infants and children. In addition, EPA's analyses show that those individuals–both adults as well as the more sensitive subpopulations--who receive their drinking water from vulnerable sources are also exposed to levels that exceed EPA's level of concern—in some cases by orders of magnitude. This primarily includes those populations consuming drinking water from groundwater from shallow wells in acidic aquifers overlaid with sandy soils that have had crops treated with carbofuran. It could also include those populations that obtain their drinking water from reservoirs located in small agricultural watersheds, prone to runoff, and predominated by crops that are treated with carbofuran, although there is substantially more uncertainty associated with these exposure estimates. Every sensitivity analysis EPA has performed has shown that estimated exposures significantly exceed EPA's level of concern for infants and children. Although the magnitude of the exceedence varies depending the level of conservatism in the assessment, the fact that in each case, aggregate exposures from registered uses of carbofuran fail to meet the FFDCA section 408 safety standard strongly corroborates EPA's conclusion that registered uses of carbofuran are not safe.

d. Occupational Exposures

This discussion summarizes the worker risk concerns that form the basis of EPA's decision to cancel and deny registrations for products containing flowable and granular carbofuran for all remaining uses. EPA's assessment of these risks is discussed in detail in (Ref. 40). Those documents, along with EPA's responses to comments on that assessment and on the IRED itself are available at www.regulations.gov (Docket number: EPA-HQ-OPP-2005-0162).

As previously discussed in Unit V.A.2 above, carbofuran inhibits AChE, with its technical active ingredient and liquid formulations being acutely toxic by the oral and inhalation routes (acute toxicity category I for both TGAI and liquid formulations). Pesticide products in acute toxicity category I have the signal word "Danger" on the label in accordance with 40 CFR 156.64(a)(1). Carbofuran is also a restricted use pesticide due to its acute inhalation toxicity. 40 CFR 152.175. Most uses of the granular formulation uses of carbofuran were phased out in the 1990s with a limited amount (2500 lbs active ingredient/annum) allowed for use on cucumbers, spinach grown for seed, bananas (in Hawaii only) and pine seedlings. The flowable formulation makes up the bulk of current carbofuran use and can be applied to a number of food, feed and ornamental crops including: alfalfa, barley, corn (field, pop, and sweet), cotton, oats, potato, soybean, sugarcane, sunflower, wheat and tobacco.

Carbofuran can be applied with aerial equipment, in chemigation systems (including drip irrigation) and with tractor-drawn ground boom sprayers and tractor-drawn granular spreaders. Small-scale treatments can be made on ornamental plants with handheld equipment. Mixtures of clays and carbofuran (slurries), used for root coatings, are prepared by handlers to treat pine seedlings prior to transplanting for protection against soil-borne insects. Application rates vary from 0.25 to 10 pounds active ingredient (ai) per acre depending upon the application scenario. Many of the registered uses of carbofuran involve applications 'to the soil' only and do not result in treatment of plant foliage. However, the application of sprays to foliage may occur for alfalfa, small grains (wheat, barely, oats), corn (field, pop, sweet), ornamentals, potatoes, soybeans, sugarcane, sunflowers, sorghum, and sugar beets resulting in substantial contact with treated foliage by post- application reentry workers. Post-application exposures following soil incorporation of carbofuran were not assessed since they are deemed "no contact" by the Worker Protection Standard (WPS), found at 40 CFR Part 170, and do not involve any activities where workers may come in contact with the pesticide.

Handlers (*i.e.,* people who mix, load, or apply pesticides) have the potential to be exposed to carbofuran by the dermal and inhalation routes during routine handling activities. Mixer/loaders of the flowable formulation may be exposed to the concentrated formula while pouring or transferring carbofuran into spray tanks. Mixer/loaders may also be exposed to dilute mixtures and aerosolized droplets containing carbofuran during the loading, or pouring operations. Applicators and flaggers are exposed primarily to dilute spray mists via the dermal and inhalation routes during normal field operations.

Under the WPS, interim personal protective equipment (PPE) requirements and Restricted Entry Intervals (REI) are issued for pesticides based on their acute toxicities. Carbofuran was issued an interim restricted entry interval of 48 hours for field reentry workers. For handlers (mixing/loading, applying and flagging), current labeling requires that long-sleeved shirt, long pants, shoes, and socks be worn. Personal protective equipment (PPE) includes chemical resistant gloves, protective eyewear and a respirator. For outdoor areas, the respirator must be a Mine Safety and Health Administration/National Institute of Occupational Safety (MSHA/NIOSH) approved dust/mist filtering respirator.

EPA routinely evaluates interim WPS REIs and PPE based on chemical-specific toxicity databases in addition to the acute toxicity data delineated in the WPS. In EPA's Revised Risk Assessment (Ref. 13) exposure estimates based on current label PPE and REIs were evaluated against the bench mark dose ($BMDL_{10}$) value of 0.024 mg/kg/day. This $BMDL_{10}$ was calculated for adult RBC AChE inhibition based on two comparative cholinesterase assay (cca) studies submitted by FMC and an EPA-conducted cca study. Additionally, a 6% dermal absorption factor and a 100% inhalation factor were applied. In the revised risk assessment for carbofuran, handler and worker scenarios for current uses were identified and evaluated. For handlers and workers, estimates of daily exposure were expressed in terms of mg/kg/day. Estimates of exposure are used to calculate MOEs, which is the quotient obtained when the $BMDL_{10}$ (mg/kg/day) is divided by estimates of handler/worker exposure (mg/kg/day). For carbofuran, MOEs must be greater than 100, to not exceed EPA's level of concern. The MOE requirement of 100 includes a 10X uncertainty factor for inter-species extrapolation and a 10X factor for intra-species variability.

Estimated total MOEs (dermal plus inhalation) for mixer/loaders and applicators involved in mechanized applications of liquid formulations are less than 100, and therefore of concern, even when the mixer/loaders and applicators comply with current WPS PPE requirements. Workers who are exposed to levels of concern include those applying carbofuran by aerial and ground equipment as well as the mixer/loaders supporting the spray operations. In addition, for most uses the MOEs remain below 100 at the maximum exposure mitigation level – in other words, the use of engineering controls such as enclosed cabs and closed mixing/loading systems, which provide the greatest degree of exposure mitigation, are insufficient to bring occupational risks to below the Agency's level of concern. The majority of estimated MOEs for mixers/loaders for flowable carbofuran are 20 or lower. Scenario-specific handler MOEs are delineated in Table 10 presented below.

Table 10. Summary of Handler Scenarios Total (Dermal and Inhalation) MOEs with Engineering Controls (Maximum MOEs)

Exposure Scenario	Crop	Application Rate	Daily Area Treated	Total MOEs
MIXER/LOADER				

Table 10. Summary of Handler Scenarios Total (Dermal and Inhalation) MOEs with Engineering Controls (Maximum MOEs)				
Exposure Scenario	Crop	Application Rate	Daily Area Treated	Total MOEs
Mixing/Loading Liquids for Aerial application	Alfalfa, Corn (field and pop), Cotton	1 lb ai per acre	1200 Acres per day	2.4
	Potatoes	2 lb ai per acre	350 Acres per day	4.0
	Sorghum	0.50 lb ai per acre	1200 Acres per day	4.7
	Small grains (wheat, barley, oat), Soybeans	0.25 lb ai per acre	1200 Acres per day	9.3
	Ag Fallow/Idle land	0.19 lb ai per acre	350 Acres per day	43
	Corn (sweet), Sunflowers	0.50 lb ai per acre	350 Acres per day	16
	Sugarcane	0.75 lb ai per acre	350 Acres per day	11
Mixing/Loading Liquids for Chemigation application	Grapes	6 lb ai per acre	350 Acres per day	1.4
Mixing/Loading Liquids for Groundboom application	Grapes	10 lb ai per acre	80 Acres per day	3.5
	Ornamentals	10 lb ai per acre	40 Acres per day	7.1
	Coffee (seedbeds)	6.90 lb ai per acre	80 Acres per day	5.0
	Tobacco	6 lb ai per acre	80 Acres per day	6.0
	Peppers	3 lb ai per acre	80 Acres per day	12
	Sugar Beets	2 lb ai per acre	200 Acres per day	7.1
	Sunflowers	1.40 lb ai per acre	80 Acres per day	25
	Alfalfa, Corn (field and pop), Cotton	1 lb ai per acre	200 Acres per day	14
	Potatoes	3 lb ai per acre	80 Acres per day	12
	Sugarcane	0.75 lb ai per acre	80 Acres per day	47

Table 10. Summary of Handler Scenarios Total (Dermal and Inhalation) MOEs with Engineering Controls (Maximum MOEs)				
Exposure Scenario	Crop	Application Rate	Daily Area Treated	Total MOEs
	Sorghum	0.50 lb ai per acre	200 Acres per day	28
	Corn (sweet)	1 lb ai per acre	80 Acres per day	35
	Artichoke			35
	Small grains (wheat, barley, oat), Soybeans	0.25 lb ai per acre	200 Acres per day	56
Mixing/Loading Granulars for Tractor-drawn Spreaders application	Rice, cucurbits, spinach	0.50 lb ai per acre	80 Acres per day	970
APPLICATOR				
Aerial application	Alfalfa, Corn (field and pop), Cotton	1 lb ai per acre	1200 Acres per day	3.8
	Potatoes	2 lb ai per acre	350 Acres per day	26.5
	Sorghum	0.50 lb ai per acre	1200 Acres per day	7.5
	Small grains (wheat, barley, oat), Soybeans	0.25 lb ai per acre	1200 Acres per day	15
	Corn (sweet), Sunflowers	0.50 lb ai per acre	350 Acres per day	28
	Ag Fallow/Idle land	0.19 lb ai per acre	350 Acres per day	70
	Sugarcane	0.75 lb ai per acre	350 Acres per day	18
Groundboom application	Grapes	10 lb ai per acre	80 Acres per day	6.2
	Ornamentals	10 lb ai per acre	40 Acres per day	12
	Coffee (seed beds)	6.90 lb ai per acre	80 Acres per day	8.8
	Tobacco	6 lb ai per acre	80 Acres per day	10
	Peppers	3 lb ai per acre	80 Acres per day	21

Table 10. Summary of Handler Scenarios Total (Dermal and Inhalation) MOEs with Engineering Controls (Maximum MOEs)				
Exposure Scenario	Crop	Application Rate	Daily Area Treated	Total MOEs
	Sugar Beets	2 lb ai per acre	200 Acres per day	12
	Sunflowers	1.40 lb ai per acre	80 Acres per day	44
	Alfalfa, Corn (field and pop), Cotton	1 lb ai per acre	200 Acres per day	24
	Potatoes	3 lb ai per acre	80 Acres per day	21
	Sugarcane	0.75 lb ai per acre	80 Acres per day	81
	Sorghum	0.50 lb ai per acre	200 Acres per day	49
	Corn (sweet)	1 lb ai per acre	80 Acres per day	62
	Small grains (wheat, barley, oat), Soybeans	0.25 lb ai per acre	200 Acres per day	100
	Artichoke	1 lb ai per acre	80 Acres per day	62
Applying Granulars for Tractor-drawn Spreaders application	Rice, cucurbits, spinach	0.50 lb ai per acre	80 Acres per day	120
FLAGGER				
Flagging for Spray application	Potatoes	2 lb ai per acre	350 Acres per day	120
	Sorghum	2 lb ai per acre	1200 Acres per day	35
	Small grains (wheat, barley, oat), Soybeans	2 lb ai per acre	1200 Acres per day	35
	Corn	0.50 lb ai per acre	350 Acres per day	470
	Sugarcane	0.75 lb ai per acre	350 Acres per day	320

Estimated MOEs for reentry workers performing the majority of activities involving contact with carbofuran-treated foliage are below 100, and therefore of concern, even when workers comply with the interim WPS REI of 48 hours. The activities in which reentry workers engage, involve scouting: soybeans, barley, oats and wheat (MOEs did not reach 100 until 9 days after treatment); scouting and irrigating alfalfa, sugar beets, and potatoes (MOEs reached within 14 days after treatment). In a previous carbofuran risk assessment, EPA set an REI of 14 days for scouting sunflowers, sorghum and scouting and harvesting and other crop maintenance activities associated with corn (sweet, field and pop). This 14-day REI is acceptable for sunflowers and sorghum only. For individuals harvesting sweet corn and detasseling seed corn (field, sweet and pop) an REI could not be established with MOEs equal to or greater than 100 until 32 days after application for harvesting and 14 days after application for detasseling. Scenario-specific worker post application MOEs are delineated in Table 11 presented below.

Table 11. Post-application reentry exposure estimates.

Transfer Coefficient Group	Crop	Max Foliar Rate (lb ai/acre)	DFR Data Used	Transfer Coefficient (cm2/hr)			# of days until MOE reaches 100			REI (days) on current product label
				Low	Med	High	Low	Med	High	
Field/row crops, low/medium	Soybeans	0.25	Cotton	100	1500		3	9		2
	Small Grains	0.25	Cotton	100	1500		3	9		2
	Alfalfa	1	Potatoes	100	1500		0	14		2
	Sugar Beets	2	Potatoes	100	1500		3	>14 *		2
Field/row crops, Tall	Corn (field and pop)	1	Corn (MN site)	100	1000		0	10		14 days for foliar applications
			Corn (CA site)	100	1000		14	32		14 days for foliar applications
	Corn (sweet)	0.5	Corn (MN site)	100	1000	17000	0	9	>11*	14 days for foliar applications
			Corn (CA site)	100	1000	17000	0	30	>32*	14 days for foliar applications
	Sunflowers	0.5	Potatoes	100	1000		0	8		14 days for foliar applications
	Sorghum	0.5	Potatoes	100	1000		0	8		14 days for foliar applications
Sugarcane	Sugarcane	0.75	Potatoes	100	1000	2000	0	10		2
Vegetable, root	Potatoes	1	Potatoes	300	1500		0	14		2

Crop groupings and transfer coefficients from Science Advisory Council for Exposure: Policy Memo #003.1 'Agricultural Transfer Coefficients', August 17, 2000.
* Those values reported as greater than (>) a number of days until MOE reaches 100 require extrapolation outside the parameters of the days tested for each respective study used to determine DFR data.

In addition to estimating occupational exposures for use-specific scenarios, EPA considered evidence of real-world incidents involving carbofuran. EPA uses a wide variety of pesticide incident databases when conducting occupational and non-occupational risk assessments. These databases include the: Incident Data System (IDS) (1992- 2003), Poison Control Center (PCC)(1993-2001), California Department of Pesticide Regulation's Pesticide Illness Surveillance Program (PISP) (1982-2002), National Pesticide Telecommunications Network (NPTN)(1984-1991), National Institute of Occupational Safety and Health's Sentinel Event Notification System for Occupational Risks (NIOSH SENSOR)(1998 - 2002). Many of the illnesses reported for carbofuran were systemic with symptoms such as nausea, vomiting, abdominal cramps, headaches and dizziness. These symptoms are consistent with cholinergic acute poisoning from other AChE inhibiting pesticides (Bushnell and Moser, 2006). Most of the occupational risk from this product is due to use by pesticide handlers, especially mixer/loaders who handle the concentrated liquid material and are either accidentally exposed or exposed when preparing spray mixture. This is true even in the state of California which requires mixer/loaders handling pesticides labeled "Danger" to use closed mixing/loading systems. In addition, a review of available incident information shows groups of people have been poisoned from spray drift or from exposure to field residue. A 1998 case in California illustrates the effects from field residues when workers reentered treated cotton fields two hours after application, instead of the required 48 hours. In that incident, workers were exposed for approximately 3.5 hours. These workers also developed symptoms such as headache, nausea, vomiting and diarrhea suggesting such residues are capable of causing moderate to relatively serious effects that require medical treatment.

It appears that the number of incidents involving carbofuran has decreased over the past decade. This is most likely due to a decrease in pounds of carbofuran used and/or the increase in state or local restrictions imposed on handlers. In addition, pesticide incidents are likely underreported because farmworkers may not seek medical care for mild symptoms due to the cost or reluctance to take time off work. Incidents may also be underreported because when medical attention is sought, symptoms of carbofuran poisoning may not be recognized as such because they are common to many illnesses. Even considering these factors, carbofuran incidents continue to occur and, when they occur, can result in relatively serious consequences.

B. Ecological Effects

This discussion summarizes the ecological risk concerns that form part of the basis of EPA's decision to cancel and deny registrations for products containing flowable and granular carbofuran for all remaining uses. EPA's assessment of these risks is discussed in detail in the March 7, 2006 Carbofuran Environmental Risk Assessment and Drinking Water Exposure Assessment (hereinafter referred to as the Environmental Risk Chapter) that EPA conducted in support of its interim reregistration eligibility decision (RED) for carbofuran. Since the development of EPA reregistration assessment, EPA has received additional data from FMC addressing the avian impacts of carbofuran and EPA has conducted additional analyses taking these data into account. EPA's original assessment, its evaluations of FMC's submissions as well as other supporting documentation are available at www.regulations.gov (Docket number: EPA-HQ-OPP-2005-0162) The majority of the discussion below addresses the ecological risks to birds, fish, aquatic invertebrates and mammals from exposure to liquid (flowable) formulations. These formulations make up the overwhelming majority (99%) of carbofuran's current uses.

1. Ecological Risk Assessment for Flowable Formulations of Carbofuran

a. Summary of EPA's Ecological Risk Assessment. EPA has concluded that the flowable formulations of carbofuran present risks of concern to both terrestrial and aquatic non-target animal species. The risks to birds are particularly significant and exist for all registered uses of carbofuran. Three lines of evidence were examined to evaluate the ecological risks of the use of flowable carbofuran products. They include (1) a screening level risk assessment (deterministic), (2) a refined assessment (probabilistic) for acute risks to birds and aquatic life, and (3) the consideration of field data (including incidents, monitoring studies and controlled field studies) for carbofuran.

In conducting its deterministic assessment, EPA utilized its standard screening level risk quotient method to estimate both acute and chronic risk to non-target aquatic and terrestrial organisms associated with the major uses of flowable carbofuran. This approach allows EPA to determine whether residues of carbofuran in cropped areas may exceed levels that can cause adverse effects to non-target species. EPA conducts this assessment by comparing toxicity endpoints (such as mortality, growth or reproductive effects) from ecological toxicity studies to the estimated environmental concentrations (EECs) of the pesticide that EPA derives from review of data regarding the environmental fate characteristics of a pesticide as well as from pesticide-specific usage data and exposure models. This comparison allows EPA to create a risk estimate for given wildlife taxa that is termed a "risk quotient" (RQ). The RQ is the ratio of the EEC to the most sensitive non-target species toxicity endpoint values identified in the ecological toxicity studies. An RQ of 1 means that the EEC is equal to the selected toxicity value. For example, in the context of acute avian risk estimates (e.g., mortality), an RQ of 1 would mean that non-target bird species may be exposed in the environment to an amount of the pesticide that results in mortality (specifically, the dose at which 50% of the test species died). EPA then compares these RQ values to the Agency's "levels of concern" (LOCs) for non-target species. The LOC represents the exposure levels at which, in EPA's judgment, a pesticide has the potential to cause risks of concern to non-target organisms. Thus, when the RQ for a pesticide exceeds the LOC for a particular category of non-target species, the Agency believes there is a risk of concern for species in that category. The LOC for terrestrial and aquatic animals are provided in Table 12.

Table 12. EPA's Levels of Concern and Associated Risk Presumptions

Risk Presumption	LOC terrestrial animals	LOC aquatic animals
Acute Risk – there is potential for acute risk	RQ > 0.5	RQ > 0.5
Acute Endangered and Threatened Species - species listed as threatened or endangered under the Endangered Species Act may potentially be adversely affected	RQ > 0.1	RQ > 0.05
Chronic Risk - there is potential for chronic risk	RQ > 1	RQ > 1

Because the deterministic assessment is intended to serve as a screening tool for identifying a potential for adverse effects, it is somewhat limited and conservative by design. As a result, EPA does not believe that the RQs derived in the deterministic assessment can be used as a precise measure of risk. However, when, as with carbofuran, the deterministic assessment indicates that the RQs significantly and consistently exceed LOCs across taxa and across uses, application rates and application methods, EPA believes the assessment serves as a good indicator that adverse effects, including mortality in this instance, are occurring regularly.

While the deterministic assessment makes clear that carbofuran poses a risk of serious adverse effects, including mortality, to certain exposed non-target species, it does not provide a means for EPA to estimate the probability that a member of a particular exposed species will suffer such effects. However, in assessing the ecological risks of carbofuran to birds and aquatic species, EPA also conducted a refined assessment to evaluate the probability of effects to a range of potentially exposed species (under a range of exposure scenarios) likely to be associated with carbofuran use. The refined probabilistic assessment models the magnitude and probability of adverse effects to non-target species in and around carbofuran treated fields by integrating distributions of toxicity with distributions of various factors contributing to carbofuran exposure, such as carbofuran residue concentrations and bird feeding behaviors. The refined risk assessments address bird mortality from acute exposures, as well as survival and reproductive effects to fish and aquatic invertebrates following acute and longer term exposures to carbofuran. The probabilistic models and methods developed and used by EPA were subjected to external peer review by the FIFRA SAP in 2000, 2001 and 2004. The SAP supported EPA's modeling approach, while suggesting the EPA explore the development of refinements to better reflect avian behavior and routes of exposure. EPA has refined the models in light of the SAP's comments. Among the important updates to the terrestrial probabilistic risk assessment (PRA) are the inclusion of an hourly exposure time-step to more appropriately capture avian feeding behaviors, more realistic modeling of pesticide puddle concentrations to which birds may be exposed when drinking water from treated areas, and the inclusion of inhalation and dermal exposure routes in addition to dietary exposure.

Lastly, available field data, including field studies, monitoring programs, and documented wildlife mortality incident reports attributed to the agricultural use of flowable carbofuran were examined in the Agency's risk assessment. As explained in more detail in the discussion below, all three lines of evidence support the conclusion that there are risk concerns to both aquatic and terrestrial species from acute and chronic exposure following the use of flowable carbofuran. As noted, these risk concerns are particularly high for avian species.

b. Risks to Birds

i Deterministic Assessment. Various sources of information support the conclusion that numerous terrestrial wildlife species utilize cropped areas throughout the country both where and when carbofuran is used. These sources include census data, controlled field studies and incident data. The available data indicate that numerous bird species are found in agricultural environments and that birds can utilize treated areas for feeding, as water sources, and, for some species, as sites for nesting. In its deterministic assessment, EPA estimated carbofuran exposures to wildlife species by predicting the amount of carbofuran residues found on animal food items in areas treated with carbofuran and then used estimated food consumption rates of several size classes of birds and mammals to determine the amount of pesticide consumed. EPA's estimate of carbofuran residues on animal feed items is based on (1) the Fletcher nomogram,[2] a model which relates pesticide application rate and pesticide residues on food items; (2) current label maximum and minimum labeled application rates for each use site; (3) maximum labeled application frequency; and (4) the potential for residue dissipation between applications.

Numerous avian acute toxicity studies for carbofuran covering a range of species indicate that carbofuran is very highly toxic to avian species. The acute toxicity endpoint of concern for birds is mortality resulting from AChE inhibition. For purposes of this assessment, EPA used the acute LD_{50} value for the most sensitive test species--the fulvous whistling duck--of 0.238 mg/kg of body weight.

In general, for the various crop and application methods examined, the higher the labeled use rates, the higher the risk. The exceptions to this are the soil applications that involve incorporation (*i.e.*, in-furrow method). Banded methods yielded higher RQs than in-furrow methods at similar use rates. Foliar broadcast applications yielded higher RQs than broadcast soil incorporated applications.

Direct comparisons of RQs calculated for the various application methods (*i.e.*, foliar broadcast, in-furrow, banded, soil incorporated, and drip irrigation) can be problematic and can lead to erroneous risk conclusions if the RQs are used to differentiate risk between different application methods. Different assumptions are applied to each application method introducing a range of uncertainty levels for the derived RQs. RQs for the in-furrow and banded application methods are based on the treated acre accounting for incorporation but not accounting for the untreated area between the rows. The broadcast soil application is also based on the treated acre, accounting for incorporation. However, the entire field is presumed to be treated. The foliar quotients also are based on treating the entire field and may be more comparable to the broadcast soil treatment, assuming the incorporation factor correctly accounts for difference in residue levels on the wildlife food sources. Therefore, RQs for in-furrow and banded applications -- in comparison to foliar application methods--are based on different assumptions and are not directly comparable. However, some comparisons of calculated RQs are possible within similar application methods. It should also be noted that the range in both acute and chronic RQs in part reflects differences attributed to bird size and dietary preferences.

EPA's comparison of estimated avian exposure to available wildlife toxicity data shows that EPA's LOC for acute effects to avian species is exceeded for all registered uses of flowable carbofuran. The minimum registered foliar application rate for carbofuran is a single application at 0.125 lbs a.i./A, yielding RQs ranging from 0.6 to 144. This minimum registered application rate includes uses on alfalfa, small grains, sunflowers, and soybeans. The maximum registered single foliar application rate for carbofuran is 1 lb a.i./A for use on alfalfa, corn, and potatoes yielding RQs that range

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[2] see Fletcher,J., Nelessen, and T. Pfleeger 1994. Environmental Toxicology and Chemistry 13(9):1381-1391.

from 5 to 1150. The maximum registered foliar application rate for carbofuran is 2 applications at 1 lb a.i./A on potatoes and corn, yielding RQs of 9 to 2150, which are approximately twice as high as the single foliar rate. The other foliar uses examined, sorghum, and sugarcane, as well as other foliar use rates registered for the above mentioned crops, (small grains, sunflowers, soybeans, corn and potatoes) have intermediate use rates, yielding lower RQs in comparison to the high foliar use rates, as would be expected. The tobacco broadcast over the soil application (4 to 6 lbs a.i./A), while at higher use rates than the foliar applications, yielded RQ's similar to the higher use rates for foliar treatments because exposure was reduced from incorporation. The RQs for the tobacco soil application ranged from 3 to 1035.

For soil treatments that concentrate the pesticide in or between the rows, the in-furrow application method yielded the lowest avian acute RQs. The in-furrow soil applications of carbofuran, at 0.08 lbs a.i./1000ft of row to corn, cotton and sorghum yielded RQs of 1 to 241. The in-furrow soil applications to potato fields yielded higher RQs because of the higher labeled use rates (0.45 lbs a.i./1000 ft of row). RQs ranged from 5 to 1345. The grape broadcast soil incorporated treatment, at 10 lbs ai/A, yielded RQs of 7 to 1724, and the grape drip irrigation for one application gave RQs somewhat higher, ranging from 9 to 2299. The banded applications to corn and sorghum at 0.08 lbs a.i./1000 ft. of row yielded higher RQs by approximately a factor of three. These RQs ranged from 26 to 6898.

EPA also evaluated the potential for secondary poisoning of certain avian species that feed on both dead and living animals exposed to carbofuran. Based on the incident reports (see *iii*. below) and a limited quantitative assessment, secondary poisoning to raptor species may occur in carbofuran use areas. Although evidence indicates that raptor species are at risk, given their mobility, it is difficult to accurately quantify the magnitude of secondary poisonings because other causes of direct mortality, such as collisions, may in fact be associated with carbofuran poisoning.

For assessing chronic effects to birds for the broadcast uses of flowable carbofuran, the Agency uses a standard chronic quotient model, the "No Observable Adverse Effect Concentration" (NOAEC) divided by EECs. A true NOAEC could not be established from available chronic toxicity studies because the death of the test animals from carbofuran exposure obscured any reproductive physiology or developmental impairment that may have occurred in the tests. The Lowest Observable Adverse Effect Level (LOAEC) for the most sensitive tested species, the mallard, was 2.0 ppm. EPA therefore used <2.0ppm as the NOAEC for the purposes if its chronic assessment. Although the studies showed parental toxicity from chronic exposure, the tests did not reveal information about effects on reproductive physiology or developmental effects and did not establish a concentration where adverse effects were not occurring. Parental toxicity, developmental effects, or effects on the reproductive physiology may lead to the same outcome: lower reproductive output. However, the absence of a true NOAEC introduces a great deal of uncertainty into the assessment concerning what chronic exposure levels will not cause adverse effects.

Notwithstanding the use of the less conservative LOAEC concentration, EPA's chronic avian risk LOC is also exceeded for all use patterns. Foliar applications to alfalfa, soybeans, and sunflowers give similar avian chronic RQs at their lower use rates (RQs range from >1 to >15). The avian RQs for the maximum use rate for small grains, and soybeans, range from 4 to 56. Corn, potatoes, and sugarcane avian chronic RQs for one foliar application at their lowest labeled rates are slightly higher (RQs range from >4 to >60). The avian chronic RQs for the grape broadcast soil application range from >11 to >180 which is approximately three times higher than the RQs for the maximum labeled rates for soybeans and sunflowers.

At their maximum labeled rates, corn and potatoes have the highest avian chronic RQs (from >14 to >224) for a single foliar application. Corn, potatoes, sugarcane, and alfalfa (broadcast soil incorporated application single application) yield similar avian chronic RQs at maximum labeled rates following multiple applications. The tobacco soil-incorporated RQs range from >5 to >108. All flowable carbofuran registered foliar and broadcast soil application rates for all crops exceed established chronic risk LOCs for birds.

For soil applications that concentrate pesticide in the row, the in-furrow applications yield lower avian chronic RQs than banded applications. The in-furrow soil applications of carbofuran to corn, cotton, and sorghum give the lowest avian chronic RQs (RQs range from >2 to >25). The in-furrow soil applications to potatoes yield avian chronic RQs somewhat higher because of higher labeled use rates (RQs range from >4 to >71). The lowest labeled rate for drip irrigation of grapes yields intermediate avian chronic RQs (RQs range from >15 to >135). The banded soil applications to corn and sorghum yields higher avian chronic RQs by approximately a factor of three (RQs range from >45 to > 720). The RQs for the grape drip irrigation at maximum labeled rates fall in the same range (>53 to > 473). All the registered carbofuran soil applications exceed established chronic risk LOC for birds.

As noted in the deterministic assessment document, EPA does not believe the RQ values generated in both its avian and mammalian (see below) screening level assessments provide a precise measurement of risk. As explained in detail in that assessment, there are a number of points that must also be considered in evaluating the significance of the results of the screening-level assessment for both acute and chronic risks. These include: residue level assumptions, foliar half-life assumptions, the occurrence of wildlife species in and around treated fields, the effect of soil incorporation, the need to consider additional routes of exposure, species sensitivity assumptions, quotient model use of the LD_{50} value and the failure to identify true chronic end-points. These considerations suggest that certain assumptions used in the screening level assessment may tend to overestimate risks in some cases and underestimate risk in other cases. As detailed in the Environmental Risk Chapter (Appendix 1 at 59-61), EPA conducted certain limited sensitivity analyses to determine the extent to which certain factors such as EPA's 100% food contamination assumption or its use of "default" half-life values may tend to result in the over-estimation risk. While modifying these factors to include less conservative values would tend to reduce risks estimates, many RQs would continue to significantly exceed EPA's levels of concern. This analysis provides EPA with a measure of confidence that the conclusion of the deterministic assessment – that birds are at high risk of mortality from carbofuran – is sound.

ii. Probabilistic Risk Assessment. While results of the deterministic ecological risk assessment indicate that a risk of adverse effects to avian species, including mortality, exists across all uses of carbofuran, EPA also conducted a probabilistic assessment to better estimate the likelihood and magnitude of adverse effects to birds associated with the use of carbofuran. The probabilistic approach generates estimates of risk and explicitly considers variability and uncertainty in a wide variety of biological and physical parameters. The resulting output is a probability that certain outcomes, such as avian mortality, will occur. EPA's probabilistic assessment, which assessed acute avian risk associated with use on corn and alfalfa only, predicted high mortality in at least some species, regardless of the application rate and method. EPA believes this assessment is also relevant to other carbofuran use sites with similar application rates and avian utilization characteristics. Incident reports support this contention with dead birds found in a variety of crops such as potatoes, sunflowers, grain, squash and soybeans after carbofuran was used legally (see *iii.* below). Also, results from the deterministic assessment show a potential for adverse effects to birds for all crop uses indicating that risks are in large part driven by carbofuran application rates and its inherent toxicity to birds. The probabilistic analysis takes into consideration both foliar and soil applications at use rates that span the majority of application rates for which carbofuran is registered (0.125 to 1.0 lbs a.i./A). Based on the sensitivity distribution, the more sensitive the species is to carbofuran, the higher the mortality predicted from exposure.

Results of the refined assessment presented in the carbofuran RED chapter were based on EPA's Terrestrial Investigation Model v1.0 (TIM v1.0) and show that from 55% to 95% of the bird species modeled – all of which are species that are found in agricultural areas where carbofuran is applied -- will experience at least some mortality in and around a treated field as a result of the application of flowable carbofuran. For example, at the highest application rate for corn, 95% of all bird species found in and around carbofuran-treated areas will experience 10 % mortality on average, and 15% of bird species will have 70% mortality or greater, with a predicted maximum mortality rate of 99%.

Since the release of the Environmental Risk Chapter, EPA has further developed its probabilistic modeling approach based on recommendations from previous FIFRA Scientific Advisory Panel meetings (2001, 2004). Among other improvements, the new model incorporates added features designed to more accurately capture the feeding behavior of birds and to account for other routes of pesticide exposure. Specifically, TIM v2.1 includes an hourly time step and bimodal feeding pattern that more accurately captures avian behaviors and a varying volume puddle model that generates pesticide puddle concentrations more representative of expected concentrations. Also, since the release of the carbofuran RED chapter, EPA has received additional data from the registrant regarding brain acetylcholinesterase inhibition and recovery in birds, the effect of food-matrix on carbofuran toxicity in birds, and the effects of carbofuran on feeding behavior in birds.

EPA also notes that its probabilistic modeling approaches for birds have assumed that all fields exhibit a residue variability comparable to a mixed data estimate of variance (i.e., within fields and among fields data to contributing to the variance estimate) which may represent a somewhat conservative approach. An alternative assumption, adopted by the registrant, is that all variance associated with the underlying avian food item residue data is only attributable to among field variance and that there is no residue variance within a field. The Agency has reviewed a number of pesticide residue datasets and carbofuran-specific field data and has concluded that at best, variance within a field is lower than variance among fields, but under some circumstances variance within a field could approach estimates among fields.

An important component of any avian probabilistic model is the estimation of carry-over effects between model time-steps. The time-steps in the avian probabilistic model are the units of time where birds are feeding and/or drinking and after every time-step the accumulated carbofuran is compared to the tolerance (sensitivity) of a given bird, which is randomly assigned based on known dose-response relationships. If the accumulated carbofuran exceeds the bird's tolerance, a bird is considered dead. Hence, carry-over effects or accumulation of carbofuran between time-steps will impact estimates of mortality. In the original RED chapter for carbofuran, carry-over effects were modeled using data based on elimination of carbofuran by birds through metabolism and excretion, which was estimated to be approximately 83% over a 24-hour period. Because carbofuran's mode of action is AChE inhibition, an alternative approach for estimating carry-over effects is to use the AChE recovery half-life. A study of AChE inhibition and recovery was submitted to EPA by FMC in April 2007. Review of this study showed AChE inhibition and recovery varying as a function of carbofuran exposure. Recovery half-lives ranged from about 1.1 hour at the lowest dose and 4.4 hours at the highest dose. Importantly, some birds died at the highest dose and those that lived did not reach baseline AChE activity levels by study termination. To explore the potential impact on avian PRA outcomes of using the AChE recovery half-life rather than the elimination rate, EPA used a recovery half-life of 4.4 hours adjusted to the model time-steps. EPA's assessment indicates that conclusion based on model results using AChE recovery half-life instead of the elimination rate were not different (Ref. 44).

FMC submitted a second study in May 2007 designed to evaluate the extent to which Mallard ducks avoid carbofuran-treated feed. After review of the study, EPA concluded that the study is suitable as a screen for potential avoidance behaviors only and cannot be used as a definitive study on avian avoidance of carbofuran-treated food items. Because birds were cage housed, provided a concentrated source of food (cups) and were not under hunger stress, the data are of limited utility for probabilistic modeling purposes. That said, an arguable relationship between carbofuran exposure and feed reduction was observed. To explore the potential impact of a reduction in food consumption associated with carbofuran exposure, this relationship was incorporated into the TIM model. Because feed reduction can also result in energy deficits, EPA modified the model to allow birds to partially reduce a feeding deficit from exposure to carbofuran by consuming more food at a later time. Overall, results showed that these changes had little effect on risk outcomes (Ref. 44).

Currently, EPA's avian probabilistic models do not assume any effects of the food matrix on carbofuran toxicity. Toxicity estimates used in the PRA are based on administration of carbofuran to birds via gavage. However, exposure in the field will occur as a result of carbofuran on or in food items and this combination may result in a difference in toxicity compared to when the chemical is administered as an aqueous bolus dose. In May and June of 2007, FMC submitted two studies on the potential effects of a food matrix on carbofuran acute toxicity to birds. The design employed exposing Mallard ducks and Bobwhite quail to carbofuran as an aqueous dose and as a bolus dose mixed in feed. For Bobwhite quail, a comparison of the LD_{50} showed that the toxicity of the aqueous bolus dose was 3.9 times greater than the toxicity of the bolus dose mixed in feed. The Mallard study was partially confounded by the regurgitation of test material by many of the study animals, however a coarse comparison of LD_{50} values showed a 2-fold difference in toxicity between the aqueous bolus dose and the bolus dose mixed in feed. Although both studies suffered from low sample sizes and inherent uncertainties regarding the applicability of these data to birds in the wild, EPA evaluated the impact of food matrix effects on acute carbofuran toxicity by multiplying the toxicity values used in the PRA by 2.0 and 3.9 to assess the potential impacts on the risk outcomes of the PRA. These outcomes were compared to baseline model outcomes using the original (gavage) LD_{50} studies. These adjustments to the LD_{50} had the greatest impact on risk outcomes from any of the four submitted studies and the effects were the most significant for less sensitive species (Ref 44).

Overall, EPA concludes that the four avian studies submitted by FMC in 2007 provide limited insight into the potential risks of carbofuran to avian species. Table 13 provides a summary of EPA's model outputs that include inputs described above based on the four submitted studies. Importantly, there still remain significant areas of uncertainty regarding some elements of FMC's study design and how results from each of these laboratory toxicity studies apply to birds under field conditions. Birds in the field are coping with a number of environmental conditions and variables that will impact the potential for adverse effects associated with pesticide exposure. Moreover, there can be considerable inter-species variability in sensitivity to toxicants and in behavioral patterns further complicating study interpretation and risk projections. Specifically, EPA does not believe that the four studies recently submitted by FMC thoroughly address uncertainties associated with the risks of carbofuran to avian species. Given the uncertainties and variability associated with assessing risks of carbofuran use to birds, the analysis presented here should be interpreted cautiously. The intent is to provide a sense of the range of possible risk outcomes associated with certain model assumptions that were informed by the four studies recently submitted by FMC. The results indicate that altering the model inputs based on information gleaned from the four studies broadens the range of possible risk outcomes but does not alter the conclusion that there is a high likelihood of mortality for avian species in and around carbofuran use areas. Indeed, for more sensitive species, the probability of mortality marginally changes when taking into account the modeled changes. For example, sensitive insectivorous species, such as killdeer at the 5^{th} percentile sensitivity, have average estimated mortality ranges from 99 to 84%. It should be noted that the results displayed in Table 13 are based solely on the dietary route of exposure. TIM v2.1 allows for estimates of exposure based on dietary exposure from food and drinking water, as well as dermal and inhalation exposure routes. While there are some additional uncertainties associated with these routes of exposure, consideration of these exposures only serves to increase EPA's estimate of the likelihood of avian mortality to some degree. EPA has conducted modeling efforts looking at the multiple routes of exposure. Results of this exercise are available in the public docket at regulations.gov (EPA-HQ-OPP-2005-0162).

In summary, results from EPA's model runs, as modified to reflect FMC's recently submitted data, corroborate those presented in the RED chapter and indicate that, overall, use of carbofuran is expected to result in bird mortality in excess of 90% for some species some of the time.

Table 13. Results of Avian Probabilistic Modeling for the Use of Carbofuran On Corn (at the maximum labeled rate of 1 lb a.i./A)

Species or Generic Species Type	Adjusted Inputs	Average Probability of Mortality		
		5^{th} percentile (most sensitive)	50^{th} percentile (medium sensitivity)	95^{th} percentile (least sensitive)
Model Results Based on EPA PRA Models[1]: Dietary Exposure Only				
Killdeer (Insectivore)	Baseline[2]	>90%	50-60%	<1-14%
Killdeer (Insectivore)	FMC data: AChE[3] Food matrix (2x)[4] Feed reduction[5]	≥90 %	25-30%	<1-11%
Killdeer (Insectivore)	FMC data: AChE, Food matrix (3.9x) Feed reduction	70-84%	1-9%	≤1%
Mourning Dove (Granivore)	Baseline	27-34%	1%	<1%
Mourning Dove (Granivore)	FMC data: AChE Food matrix (2x) Feed reduction	10-15%	<1%-11%	<1%
Mourning Dove (Granivore)	FMC data: AChE Food matrix (3.9x) Feed reduction	≤5%	<1%	<1%

[1] Range of results represents output from EPA PRA models TIM v1.0 and TIM v2.1
[2] Baseline conditions represent inputs presented in the carbofuran RED chapter
[3] AChE represents use of the brain cholinesterase recovery half life for estimating effects that carry-over between time steps

[4] The model LD_{50} was multiplied by 2 (2x) and 3.9 (3.9x) to account for potential food matrix effects
[5] Feed reduction based on relationship to carbofuran taking into account birds can compensate for reduced feeding in previous time-steps and conducted using TIM v1.0 only

iii. Field Studies, Monitoring and Incidents. Terrestrial field and monitoring data as well as incident data provide a third line of evidence that flowable carbofuran poses significant risks to birds. While the number of monitored mortalities found in available terrestrial field and monitoring studies do not reach levels predicted by the Agency's probabilistic assessment, it is important to note that these studies were not designed for the purpose of measuring the precise extent of adverse effects, but rather for the purpose of determining whether in fact mortality was occurring at all. And indeed, these studies demonstrated that bird mortality does occur at typical to low-end application rates. Of the nine flowable carbofuran field studies reviewed in the Environmental Risk Chapter, only one did not show adverse effects. Mortalities to birds, mammals, and amphibians were reported in several studies under different conditions and at minimum registered application rates. Of the five state monitoring studies submitted by FMC (four of which involved foliar use), adverse effects to non-target terrestrial species were not noted following the application of flowable carbofuran. However, the studies deviated from EPA guidance in significant respects, leading EPA to conclude that the studies provide limited insight into the effects of carbofuran. In most of the field and monitoring studies that located dead birds post-application, dead birds in and around treated fields were found to have significant carbofuran residues in their systems and the number of mortalities in these areas relative to untreated fields was high enough to reasonably conclude that carbofuran was the cause of death. In addition to direct avian mortality, these field studies and bird kill incident reports indicate that flowable carbofuran has the potential to cause secondary avian mortality in cases where raptors ingest prey species, such as small birds and mammals that have previously succumbed to carbofuran intoxication.

Throughout the registration history of carbofuran, EPA has received numerous reports of bird kill incident occurring following use of flowable carbofuran on five of the major crops where it is registered. Almost all of these are exclusively bird kills as a result of direct exposure. In total, EPA is aware of carbofuran poisonings affecting at least thirty-seven avian species, with a total of 7,300 carcasses reported in twelve different states.

In the late 1990s, the registrant made a number of label changes in order to attempt to address drinking water and ecological risk concerns. These included reducing application rates and numbers of applications for alfalfa, cotton, corn, potatoes, soybeans, sugarcane, and sunflowers. EPA has evaluated incidents that have occurred since the label amendments took effect. Since 1998, there have been 47 reported carbofuran-related adverse ecological effects incidents reported in EPA's Ecological Incident Information System (EIIS) which include both flowable and granular formulations. While relatively few of these reported incidents contain sufficient information to determine whether the applicator was using the pesticide properly, they demonstrate that carbofuran use continues to result in serious adverse incidents, notwithstanding these label amendments. For example, an incident in 2000 included the deaths of 800-1200 snow geese and ducks following exposure to alfalfa in fields treated with flowable carbofuran.

EPA also believes that reported incidents likely represent only a small fraction of the adverse incidents that are in fact occurring. In the absence of rigorous monitoring performed by highly trained observers immediately following pesticide applications, kills are not likely to be noticed in agricultural environments, which are generally away from human activity. Even when humans are present following a pesticide application, dead wildlife species, particularly small song birds and mammals, are easily overlooked by experienced and highly trained persons. Persons unfamiliar with the toxicity of pesticides to non-target species may fail to associate the finding with a pesticide application, especially if the two events are separated by several days and if only a few birds are observed dead. In addition, in cases where the association is made, the observer must be aware or have the motivation to find out where to report the incident. Finally, it should be noted that the decline in the number of reported incidents noted since the late 90s corresponds to a decline in state-sponsored wildlife incident monitoring programs. Given all the factors militating against reporting wildlife kill incidents, EPA believes that when, as with carbofuran, numerous mortality incidents have in fact been reported over the years, there is a strong indication that adverse incidents are likely to be occurring regularly.

c. Risks to Mammals

The results from a screening-level analysis indicate a potential for adverse effects to mammals associated with use of carbofuran. Review of available toxicity data indicates that carbofuran is very highly toxic to mammals on an acute exposure basis. Further, many mammal species, like birds, utilize areas where carbofuran is applied. EPA's comparison of mammalian carbofuran toxicity studies to EECs of carbofuran indicates that EPA's LOCs for both acute and chronic effects are exceeded for herbivorous, insectivorous, and granivorous mammals depending upon the species evaluated and the use scenario – particularly to herbivores and granivores. This assessment is discussed in detail in Appendix I of the Carbofuran Deterministic Environmental Risk Assessment. A probabilistic assessment was not conducted for mammalian species. While EPA does not discount the potential for adverse effects to mammalian species, there is considerably more information about the toxicity of carbofuran to wild birds, in part as a result of numerous incidents reports for birds. In addition, the database on toxicity of carbofuran to birds and the data on occurrence of birds in and around potential carbofuran use areas provided a suitable amount of information to generate a robust probabilistic assessment. Similar types of data for mammals, particularly regarding use of agricultural areas by mammalian wildlife, are much less available. However, the available incident information supports EPA's deterministic results regarding the potential for adverse effects to mammals associated with registered uses of carbofuran. Despite well-recognized difficulties in accurately accounting for all incidents, there are reported mortalities for labeled uses of flowable carbofuran for a wide range of species including squirrels, gophers, rats, deer mice, cottontail rabbits, and Eastern harvest mice.

d. Risks to Fish and Aquatic Invertebrates

To support its assessments of aquatic risks from carbofuran, EPA first assessed the potential for exposure of aquatic organisms to carbofuran by examining field monitoring data and utilizing mathematical water, sediment, biota, and soil exposure models. EPA initially reviewed carbofuran's physical, chemical and fate properties to determine the focus of its exposure estimates. Carbofuran has been demonstrated to be highly mobile in many soils and therefore has the potential to leach to ground water in many types of soils or reach surface water via runoff.

Monitoring data can provide estimates of pesticide concentrations in aquatic systems that are representative of the specific agricultural practices and environmental conditions associated with the use of a pesticide. Although monitoring data can provide a direct measure of the concentration of a pesticide in water, it does not always provide a reliable estimate of exposure because sampling may not occur in areas with the highest pesticide use, and/or the sampling may not occur when the pesticides are being used. EPA's review of available surface water monitoring data revealed an absence of studies that actually targeted carbofuran use near vulnerable water bodies and low order streams within agricultural landscapes where the pesticide is used. Nonetheless, the results of the USGS NAWQA program discussed below in section *d.v.* indicate that even in some untargeted monitoring studies, carbofuran has been measured over multiple years at levels that exceed lethal doses for certain aquatic species.

In the absence of properly targeted monitoring data, however, EPA relies more heavily on mathematical water exposure models to estimate exposures in the water compartment of aquatic ecosystems. EPA's models are based on extensive environmental data and detailed information on soil properties, crop characteristics, and weather patterns. See (69 FR 30042, 30058-30065 (May 26, 2004) and EPA's website at http://www.epa.gov/oppefed1/models/water/index.htm for a detailed description of EPA's surface water models. For the carbofuran assessment of aquatic exposure, EPA utilized its PRZM/EXAMS model. The surface water scenario used in the modeling was developed to reasonably represent peak short-term and long-term exposures for a variety of vulnerable aquatic systems that occur at the upper extremity of watersheds. These include: prairie potholes, playa lakes, vernal pools, ponds, as well as headwater and first-order streams, small swamps, and other wetlands that are important habitat for aquatic organisms. The model simulates water quality impacts resulting from application of a pesticide to a small field, which serves as the watershed for these small water bodies. The estuarine analogues of these small water bodies include small tidewater creeks and tributaries, low-order streams, and small estuarine inlets or ponds where relevant land-use abuts. These areas are dynamic and diverse with respect to biological diversity. The process used by EPA to estimate risk to estuarine/marine organisms has been reviewed by FIFRA Scientific Advisory Panels (1996 and 2001) and deemed appropriate for both screening-level assessments and more refined probabilistic assessments. EPA acknowledges that less vulnerable surface waters in both freshwater and estuarine and marine systems (e.g., lakes, reservoirs, mid-size and major rivers, estuarine mouths of rivers, the main stem of bays, and near- and off-shore marine environments) are not as well represented by the standard Tier II models. Exposure estimates from modeling using current PRZM/EXAMS scenarios are likely to be over-estimations of exposure in these larger settings with greater associated uncertainty.

Results of the PRZM/EXAMS modeling exercise were used to calculate the annual instantaneous 90th percentile peak and peak 21- and 60-day average concentration for use in a deterministic screening level risk assessment. The peak instantaneous results are used to assess risks of mortality to fish and aquatic invertebrates from acute or short-term exposure and the peak 21- and 60-day average concentrations are used to assess reproductive or long-term exposure risks to aquatic invertebrates and fish. All annual peak instantaneous concentrations and peak 21- and 60-day average concentrations were used to calculate a probabilistic assessment of aquatic organism exposure in a vulnerable surface water.

Not all carbofuran labeled uses and application rates were modeled directly; some labeled uses were grouped and a single representative label use from the group was selected and modeled. For the deterministic assessment seventeen crop use scenarios[3] were modeled that were chosen to ensure that: (1) the greatest acreage treated with flowable carbofuran was directly assessed; (2) all labeled application rates were either modeled directly or indirectly; and (3) EPA evaluated scenarios involving likely "high-end" exposures for the crop and carbofuran use combination. Only seven of the crop/location scenarios used in the deterministic assessment were modeled in the probabilistic assessment (e.g., alfalfa was not modeled) and additionally, only the highest labeled application rates were evaluated except for the cotton use where the lowest labeled rate was also assessed.

EPA evaluated acute and chronic toxicity values for a range of aquatic species based on registrant submitted data. The test species utilized in the screening assessment included freshwater fish (bluegill sunfish and rainbow trout), freshwater invertebrates (water flea), saltwater fish (Atlantic silverside, sheepshead minnow), saltwater invertebrates (pink shrimp, mysid) and saltwater mollusks (Eastern oyster). The specific toxicity values used for these species in EPA's assessment are set forth in Appendix 1 (Table 3.3.1) of the Environmental Risk Chapter.

i. Deterministic Assessment for Estuarine/Marine Fish and Invertebrate Species at Vulnerable Sites. EPA's deterministic assessment compares the exposure estimates derived from PRZM/EXAMS with the acute and chronic toxicity values for the saltwater fish and invertebrate species discussed above. In the case of several uses of carbofuran, the deterministic results indicate that both fish and invertebrates are adversely affected in

[3] The seventeen crops scenarios included the lowest and highest label application rates for six crop uses (alfalfa, corn, cotton, grapes, potatoes (for both the Section 3 and Special Local Need labels), and sorghum), and the label rate for tobacco. Additionally, the alfalfa use was modeled for vulnerable sites both in an arid climate, California, and a wetter climate, Pennsylvania.

vulnerable marine/estuarine locations. Specifically, the assessment indicates that estimated peak carbofuran concentrations at vulnerable estuarine/marine sites exceed EPA's acute or chronic LOCs for fish for all registered labeled uses except for the drip irrigation label for use on grapes and the lowest foliar rate on potatoes and on alfalfa (0.125 lbs ai/acre for the year) and by group association small grains, soybeans, and sunflower. Additionally the deterministic assessment indicates that all carbofuran uses, except for the drip irrigation label to grapes, exceed acute and chronic LOCs for invertebrates. Accordingly, this assessment indicates that estuarine and marine fish and aquatic invertebrates – both of which play vital ecological roles in estuarine and marine environments – will be adversely affected in vulnerable areas, resulting in the potential disruption of the function and quality of these estuarine/marine ecosystems. Specific RQ values derived in this assessment are discussed in Appendix 1 (Table 3.4.2) of the Environmental Risk Chapter.

ii.Probabilistic Assessment of Risk for Estuarine/Marine Fish and Invertebrate Species at Vulnerable Sites. EPA's probabilistic assessment allowed it to conduct a more refined analysis of the potential for risk to aquatic species at vulnerable sites using the exposure models and toxicity values for the species discussed above. By comparing the range of possible carbofuran residue values in the aquatic environment, as determined by EPA's exposure models, together with the concentration-response relationship for an organism, EPA can better assess both the range and probability of possible exposure. In addition, this assessment allows EPA to evaluate the possible magnitude of the response by the exposed population. Only acute mortality effects were modeled in this assessment because of the uncertainty in the representation of variability in long-term exposure estimates (i.e., 21- and 60-day averages) by the Tier II model in vulnerable estuarine/marine sites. Additionally, because acute mortality concentration-response relationships for estuarine/marine species were limited to one fish species, the Atlantic silverside (*Menidia menidia*), and one invertebrate species, the pink shrimp (*Penaeus duorarum)*, the probabilistic assessment was conducted for these species. However, these species are also residents of the type of vulnerable sites for which there is a concern or can be considered representative of similar species that would be found in the same ecological niche.[4] Aquatic invertebrates play vital ecological roles in the vulnerable systems of concern. In estuarine/marine systems, they form an important part of the food chain, serving as food items for other aquatic invertebrates, fish, aquatic mammals and reptiles, waterfowl, wading birds and sea birds that use these systems. Further, as part of the detrital and grazing food chain, they are particularly important in the break down and cycling of organic material and maintenance of water quality. Based on the best available toxicity information for estuarine/marine species, results for these species are

[4] The Atlantic silverside is found along the Atlantic coast from New Brunswick to Florida. It is an important forage fish for commercially important species of fish such as striped bass, Atlantic mackerel, and blue fish, and reaches high abundance in the shore-zone of salt marshes, estuaries, tidal creeks and tributaries throughout this region. This species is often the most abundant fish encountered in these areas. C.W. Fay, R.J. Neves, and G.B. Pardue. 1983. Species Profi1es: life histories and environmental requirements o f coastal fishes and invertebrates (Mid-At1antic) — Atlantic Silverside. U.S. Fish and Wildlife Service, Division of Biological Services. FWS/OBS-82/11.10. U.S. Army Corps of Engineers, TR EL-82-4. 15 pp.

assumed to represent a number of fish and crustacean species;[5] in vulnerable sites, although by no means does the assessment represent a "worst-case" scenario for such species.

For the highest label application rate on corn and sorghum, modeled exposure concentrations frequently resulted in close to 100% mortality[6] in exposed populations of estuarine/marine invertebrates, as represented by the pink shrimp. This supports the concern for adverse effects as indicated by deterministic findings with acute RQ values of 5.4 and 7.8, respectively, for these uses and rates.[7] However, the probabilistic assessment further reveals how frequently mortality events will occur and to what magnitude. For the highest foliar application rate on potatoes (Section 3 label), grown in non-arid coastal regions and broadcast applications on grapes, modeled exposure concentrations are frequently high enough to result in ≥67% mortality in exposed populations of invertebrates, as represented by pink shrimp. As with corn and sorghum, these results support the concern for adverse effects as indicated by deterministic findings, acute RQ values are 5.7 and 1.5, respectively, for these uses and rates. For in-furrow application on cotton at plant and soil incorporated applications for tobacco, at least half of modeled exposure concentrations were high enough to result in ≥53% and ≥23% mortality of exposed populations; the acute RQ values for these scenarios were 2.4 and 2.2, respectively. The probabilistic results for these uses and application rates indicate the potential for frequent disruptions in the function and quality of vulnerable estuarine/marine sites.

Except for the corn and sorghum uses, the probabilistic results indicate that mortality events for estuarine/marine fish are of low magnitude (e.g., <1 case of mortality in a million) for the minimum application rate on cotton to 9% mortality for the maximum application to potatoes. For use on corn and sorghum, the modeled surface water concentrations are estimated on average to result in greater than 18% mortality.

iii. <u>Deterministic Assessment of Risk to Freshwater Fish and Invertebrates at Vulnerable Sites</u>. The deterministic assessment indicated that, for freshwater invertebrates, modeled surface water concentrations exceed both the acute and chronic LOCs for freshwater invertebrates for all uses other than the drip irrigation label for use on grapes and the lowest foliar rate on potatoes and on alfalfa (0.125 lbs ai/acre for the year) and by group association small grains, soybeans, and sunflowers. As with estuarine/marine systems, aquatic invertebrates are a major food source for many species and therefore play vital ecological roles in the vulnerable systems of concern. They are part of the detrital and grazing food chain and are therefore particularly important in the

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[5] The Atlantic silverside was the most acutely sensitive species of three estuarine/marine species tested, a rough estimate is that 30% of fish species are as acutely sensitive or more sensitive than Atlantic silverside. Of the two crustacean species tested, early developmental stages of the opossum shrimp, *Neomysis mercedis*, were as sensitive or more sensitive than the pink shrimp.
[6] Fifty percent of modeled exposure concentrations are high enough to result in 99% mortality on average; 95% of modeled exposure concentrations are high enough to result in 88% to 100% mortality on average.
[7] The acute LOC is 0.5.

break down and cycling of organic material and maintenance of water quality. They are also important food resources for other aquatic invertebrates, fish, turtles, waterfowl, wading birds and other piscivorous birds and mammals that use these systems. Accordingly, EPA believes that adverse effects to such species from exposure to carbofuran disrupt the function and quality of these vulnerable freshwater ecosystems. Risks for freshwater fish are considerably less pronounced; however, some risk concerns exist. While acute or chronic risks to freshwater fish were not a concern for most uses, at both the lowest and highest label application rates, use on corn and sorghum exceeds the chronic LOC for fish. Chronic LOCs are exceeded at the highest Section 3 application rate on potatoes as well. Specific RQ values derived for freshwater species in this assessment are discussed in the Appendix 1 of the Environmental Risk Chapter (Table 3.4.2)

iv. <u>Probabilistic Assessment of Risk for Freshwater Fish and Invertebrate Species at Vulnerable Sites</u>. As with estuarine and marine species, to refine the understanding of risk to freshwater fish and invertebrate species in vulnerable freshwater ecosystems, EPA conducted a probabilistic risk assessment. For acute risks, the magnitude and frequency of acute mortality effects were calculated for a distribution of species. Chronic risk calculations for freshwater fish and invertebrates were limited to those species for which there were data; these species are considered surrogates for other freshwater fish and invertebrates. For chronic risks to freshwater fish, the frequency of exposures exceeding the chronic NOAEC was calculated for a coldwater species, the rainbow trout (*Oncorhynchus mykiss*), and a warmwater species, the bluegill sunfish (*Lepomis macrochirus*).[8] For chronic risks to freshwater invertebrates, the frequency of exceeding the chronic NOAEC was calculated for the water flea, *Ceriodaphnia dubia*.

The probabilistic assessment indicated that both acute and chronic adverse effects are likely to occur frequently for all labeled uses modeled. In EPA's refined probabilistic assessment, modeled surface water concentrations for all modeled uses resulted in at least 5% of exposed freshwater invertebrate species having greater than 80% mortality. Additionally for all modeled uses except the Idaho and Washington SLN labeled rate for potatoes, 25% of exposed freshwater species were estimated to have at least 28% mortality for all modeled uses. Reproductive effect levels for *C. dubia*, the most sensitive freshwater invertebrate tested, were exceeded for nearly all uses, except cotton and the Idaho and Washington SLN labeled rate for potatoes, in all application years. The frequency of exceedences of EPA's LOC for reproductive effects was in the range of 70% for cotton and 43% for the Idaho and Washington SLN labeled rates. Given the role aquatic invertebrate species play in vulnerable freshwater ecosystems, this assessment, as with the deterministic assessment, indicates the potential for frequent disruptions in the function and quality of vulnerable freshwater sites.

The probabilistic assessment indicated that acute risk is unlikely to be of concern for freshwater fish overall, with at least 95% of exposed fish species experiencing less

[8] A chronic NOAEC value was extrapolated for a warmwater species as there was only one fish early life stage test available, which was for the rainbow trout. The bluegill sunfish species, in addition to being a warmwater species was the most acutely sensitive species

than 0.5% mortality for any given use on average. This supports the deterministic assessment findings for most uses (e.g., acute RQ ≤0.1) but also indicated that adverse risk in this case is unlikely for those uses with acute RQ values of approximately 0.4. However, the results of EPA's probabilistic assessment supported chronic risk concerns identified in the deterministic assessment for the highest foliar application label rates to corn and sorghum, whereas it indicated that potentially the highest Section 3 label rate use on potatoes may infrequently result in adverse effects. The probabilistic assessment indicates that chronic risks (reproductive effects) to fish from carbofuran use on corn represent the highest risk to fish species. Specifically, reproductive effect levels for the warm water species, which is also the most sensitive tested freshwater species, are frequently exceeded by both modeled short-term and long-term exposure concentrations[9] for use on corn (up to 89% and 61%, respectively, of application years) and for use on sorghum (up to 78% and 59%, respectively, of application years).

v. Aquatic Field Studies, Monitoring and Incident Reports. No field data that documents or confirms expected concentrations in runoff from fields treated with carbofuran at the label rates or in adjacent surface waters were found in the literature. However, surface water monitoring data from USGS NAWQA from 1992-1997 confirms carbofuran detections in surface waters in Iowa, Ohio, Indiana, and other agricultural areas. Given that monitoring was not targeted to known high carbofuran use areas, and did not occur frequently enough to reliably capture peak concentrations, these detections likely under represent the occurrence and magnitude of carbofuran residues in surface waters. The upper 95th percent of detections in the 1992-1997 NAWQA data ranged from 0.68 to 9.7 ppb, which exceeds the *C. dubia* 96-hr LC_{50} (concentration expected to kill half of the exposed population) of 2.23 ppb, the estimated 5th percentile LC_{50} of 0.18 ppb, and the estimated chronic NOAECs for both the more sensitive freshwater fish (5.7 ppb) and aquatic invertebrate (0.75 ppb). NAWQA data collected from Zollner Creek in the Willamette Valley of Oregon from 1993-2006 indicate that maximum measured concentrations exceeded at least one of these aquatic toxicity values in 11 out of 14 years and all of these values in five years. These data serve to reinforce EPA's conclusion in its deterministic and probabilistic assessments that carbofuran can reach vulnerable aquatic sites at levels capable of causing mortality to important invertebrate species.

While there are considerably fewer reported incidents with fish and shellfish from lawful carbofuran use than for birds, EPA is aware of certain significant incidents that have been attributed to carbofuran use according to the label directions that involved significant fish, amphibian and aquatic invertebrate kills. Although the screening-level and probabilistic analyses indicate a low potential for adverse effects to most freshwater fish for most uses, the analyses do not exclude the potential for adverse effects to freshwater fish and indeed a limited number of species, like the bluegill sunfish, appear to be particularly vulnerable. Importantly for aquatic ecosystems, aquatic invertebrates are

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[9] As previously noted, carbofuran has a steep dose-response curve. In other words, the difference in exposure without noticeable outward effects and exposure with severe effects is minimal. Consequently, peak annual daily surface water modeled concentrations (i.e., short-term exposure) were assessed in addition to 60-day average surface water concentrations (i.e., long-term exposure).

most likely to be adversely affected by uses of carbofuran but least likely to be reported. Species from this taxa are very highly sensitive to carbofuran toxicosis. Both the screening-level analysis and the probabilistic assessments indicated a potential for adverse effects. Incidents associated with kills of aquatic invertebrates are highly unlikely to be reported since these species are typically small and any mortalities are likely to go completely unnoticed. The few fish kill incidents attributed to historical uses of carbofuran suggest that carbofuran can reach susceptible water bodies and exert toxic effects.

2. Granular Carbofuran Formulations

In 1991, the registrant agreed to phase out most of the granular carbofuran use because of high risks to birds. Currently, granular uses account for only a small fraction of the total amount of carbofuran use. The settlement agreement limited the annual use of the granular formulation to 2,500 lbs on cucurbits, spinach, and pine seedlings. Granular carbofuran is highly toxic to birds and continues to present a high risk of mortality to numerous avian species. Indeed, the LD_{50} for house sparrows is less than one small carbofuran granule. EPA's deterministic assessment for granular carbofuran confirms that many species have the potential to be exposed to such lethal doses. That assessment shows that acute risk LOCs for avian species are exceeded, in some instances by several orders of magnitude. This assessment is further confirmed by numerous avian mortalities in incident reports. While most of these reports are associated with major use sites prior to the 1991 phase out, the relevant circumstances of use associated with those incidents (application rates, methods, and bird usage) are comparable to the remaining use sites. Seven terrestrial field studies further document the risks associated with the use of granular carbofuran. Again, these studies were conducted in crops where carbofuran granular products are no longer used. However, application methods, use rates and avian use at the remaining sites would not be expected to differ significantly from use sites that were studied. These studies indicate that normal agricultural use of granular carbofuran results in mortality to birds and other wildlife from both direct and secondary exposure.

In addition, the modeled simulations of aquatic risk, discussed above in subsection *d.* of this section, are not affected by differences in carbofuran formulation. Accordingly, EPA believes the aquatic risks from granular formulations of carbofuran mirror those posed by equal label rates of the flowable formulations and therefore support EPA's decision to cancel all uses of granular carbofuran.

3. Endangered Species Considerations for both Flowable and Granular Carbofuran Formulations

The Agency's preliminary risk assessment for endangered species indicates that RQs exceed the endangered species LOC for terrestrial and aquatic animals, indicating the potential for direct effects to listed species. The Agency's screening analysis indicates that carbofuran is registered for use in areas of the country where listed species occur. Further, potential indirect effects to any species dependent upon a species that experiences effects from use of carbofuran cannot be precluded based on the screening level ecological risk assessment. These findings are based solely on EPA's screening level assessment and, because they do not take into account such factors as whether the species would be expected to be exposed to carbofuran, do not constitute "may affect" findings under the Endangered Species Act.

EPA is currently in consultation with the Fish and Wildlife Service and the National Marine Fisheries Service (collectively, "the Services") regarding the effects of carbofuran to listed threatened and endangered species and intends to complete these consultations unless and until the existing uses of carbofuran are cancelled. This process will ultimately result in a Service determination regarding whether carbofuran is likely to jeopardize listed species and/or adversely modify the designated critical habitat of any listed species. Should EPA determine, as a result of its own further assessment, or through consultation with the Services, that restrictions on use are also necessary to address adverse impacts to listed species or designated critical habitat, EPA may address those impacts through this cancellation action or it may initiate other appropriate action to address such impacts.

VI. Benefits

EPA reviewed use and usage data sources for crop sites registered for carbofuran use. These sources include EPA commercial proprietary pesticide use data bases, USDA statistics on crop production and pesticide use, USDA reports on specific crops (e.g., USDA Crop Profiles and Pest Management Strategic Plans), and articles from the published scientific literature. These sources were supplemented and validated by telephone and/or e-mail contact with crop extension agents, grower associations, and other knowledgeable experts in the field. EPA also considered all information provided by USDA, public comments, and by the registrant in response to the Agency's analyses.

Based on the analysis of these data, EPA has identified four groups of crop sites. The first group consists of crops for which EPA has concluded that carbofuran provides minimal benefits both to individual growers and at the national level. The second group consists of crops for which the Agency has concluded that carbofuran use may provide some benefits to growers, but provide minimal, if any benefits on a national scale. The third group consists of crops for which carbofuran appears to have some benefits, both to individual growers and on a national scale, based on available information. The fourth group consists of crops for which EPA conducted an extensive assessment based on benefits assessments submitted by the registrant.

Group 1 consists of coffee, flax, ornamentals, sugar beets and tobacco. It appears that a very small proportion of the U.S. area cultivated in these crops is treated with carbofuran, often less than 1%. For all of these crops, EPA is not aware of any available information that suggests that the use of carbofuran on these crops is more significant than is indicated by the low percentage of the crop treated. EPA has concluded that carbofuran presents minimal benefits for these crops.

Group 2 consists of crops for which the Agency received comments following publication of the IRED, but for which EPA concludes that carbofuran also has minimal benefits. The crops in this group are alfalfa, chili peppers, cotton, grapes, sorghum, soybeans, and small grains (barley, oats, and wheat). Conclusions were based on assessments of the uses and/or a review of information provided in the comments.

Group 3 consists of crops for which carbofuran appears to have some benefits. These crops are artichokes, bananas and plantains, pine seedlings (Southeastern United States only), spinach grown for seed, sugarcane and sweet corn. Conclusions were also based on assessments of the uses and/or a review of information provided in the comments.

Group 4 consists of crops for which the registrant submitted benefits information and/or an EPA analysis was conducted. These crops are corn, potato, sunflower, and cucurbits (cucumbers, pumpkins, squash, and melons). For cucurbits, the registrant focused solely on melons, but the EPA assessment also includes cucumber, pumpkin, and squash.

For crops where less than 1% of the national acreage is treated with carbofuran, EPA initially did not conduct an individualized economic analysis for the particular crops, but assumed that alternatives were cost-effective, based on the extremely low use of carbofuran. Exceptions are alfalfa and corn, because a large amount of carbofuran is used, although a small proportion of the total cultivated area is treated. EPA also solicited information from USDA and public commenters regarding the importance of carbofuran for these crops throughout the reregistration process.

For crops where more than 1% of the national acreage is treated with carbofuran and alfalfa and corn, EPA conducted assessments of the impacts of canceling carbofuran. EPA reviewed information from USDA, university extension publications, and other data to determine if cost-effective alternatives are available.

For the purpose of this Notice of Intent to Cancel, EPA has attempted to provide some information as to the upper bound impacts that may occur due to the cancellation of carbofuran based on the cost of the most expensive alternatives or the highest yield loss suggested by the registrant or other commenters. This upper bound provides a maximum potential estimate of the impacts of the loss of carbofuran, but EPA does not believe that most, or even many, growers will suffer this degree of impact. To the extent that growers choose to apply less expensive alternatives, or that pest pressures are lower than anticipated, EPA would expect the impacts to be lower than its upper bound estimates. Moreover, EPA expects that impacts will decrease over time as new cultivation practices are developed and new alternative pesticides are registered.

A. Group 1 - Use Sites with Very Little Information and Minimal Benefits from the Use of Carbofuran

Crops in this group consist of coffee, flax, ornamentals, sugar beets and tobacco. For some crops, usage information is available, but use of carbofuran was not reported or not quantified. What usage information exists indicates that less than 1% of the acreage is treated. The low proportion of area treated suggests that there are cost-effective pesticides available to control the pests that carbofuran would target and/or that the target pests rarely cause sufficient damage to justify treatment. EPA requested comments on this hypothesis. For crops in this group, either no information was submitted to the Agency or comments confirmed the Agency's findings.

i. Coffee. Coffee is produced in Hawai'i and Puerto Rico. According to the Crop Profile for Coffee in Hawai'i (2000), the islands' geographic isolation and quarantine policies have kept it free of the major insect pests of coffee (Ref. 15). The two main pests are the green scale and the black twig borer. Green scale is controlled by either an oil or soap emulsion or a biological agent, the white halo fungus. The female black twig borer makes holes in twigs and cultivates a fungus to feed its larvae. The fungus produces a toxin that kills the twig and leaves. There is no effective insecticide registered; control depends on maintaining healthy trees and pruning and burning infested branches. The Crop Profile for Coffee in Puerto Rico (2003) lists several pests including leafminers, scales, mealybugs, aphids, and nematodes (Ref 16). Registered insecticides include aldicarb, which controls leafminers and nematodes, and disulfuton, which controls leafminers, scale, mealybugs, and aphids. Neither profile mentions carbofuran, nor did EPA receive comments as to the need for carbofuran. In contrast, the University of Hawai'i commented as to the value of carbofuran in banana production (see Section c.ii)

ii. Flax. Flax can be produced for fiber, which is used to make linen, or seed, which produces linseed oil. Most U.S. production is for oil and is concentrated in the Dakotas and Montana where it is rotated with small grains. According to the Crop Profile for Flax in Montana (2002), the main pest is the grasshopper (Ref. 17). Armyworms and cutworms can be a problem at emergence and the aster leafhopper may infect flax with the aster yellow mycoplasm. Aphids are rarely a problem because they generally do not result in economic losses. Wireworms are primarily a pest in cereal grains, but occasionally cause reduced stands in flax. The primary pesticide used in flax is carbaryl. No comments were submitted to EPA regarding the use of carbofuran. Based on the description of pests and the production area, EPA believes that the use of carbofuran in flax production is probably similar to that of small grains, i.e., of minimal benefit (see Section b.v).

iii. Ornamentals. Ornamentals encompass a wide range of plants and production strategies and few data are available on pesticide usage. Comments from the USDA Integrated Pest Management Centers indicated that carbofuran was used very little, if at all, in production but may be used to control root pests. The Crop Profile for Ornamentals in Florida (1995) lists carbofuran at the bottom of the list of insecticides ranked in order of use, while the Crop Profile for Ornamentals in North Carolina (2004) does not mention carbofuran in a list of 44 insecticides registered for use (Refs. 18, 19).

iv. Sugar beet. According to EPA proprietary data, less than 10,000 acres of sugar beets are treated annually, on average, while USDA reports that there are over 1.3 million acres of sugar beets harvested each year. According to EPA data, the root maggot is the primary pest targeted by an application of carbofuran. Terbufos is the most widely used chemical for control of this pest. The most expensive pesticide noted in the data for root maggot control is aldicarb, which is a systemic carbamate like carbofuran. As an upper bound estimate of the national impacts, EPA calculates that if all acres treated with carbofuran were treated with aldicarb instead, the additional costs would total under $260,000 per year. The total value of U.S. sugar beet production averages about $1.2 billion per year, according to USDA.

v. Tobacco. According to EPA proprietary data, on average, less than 1,000 acres of tobacco are treated annually with carbofuran. USDA reports that over 375,000 acres of tobacco are cultivated each year. EPA data indicate that carbofuran may be used against several insects, including wireworm, budworm and flea beetle, as well as nematodes. Acephate is the most widely used insecticide in for the insect pests, while 1,3-dichloropropene is generally used for nematode control. As an upper bound estimate of national impacts, EPA calculates that if all acres treated with carbofuran are fumigated with 1,3-dichloropropene instead, additional production costs would total less than $50,000 per year. The total value of U.S. tobacco production, according to USDA, averages more than $1.4 billion annually.

EPA has not found or received information demonstrating that the available alternatives are not efficacious, or that carbofuran plays a unique role in managing a particular, problematic pest. EPA, therefore, concludes that carbofuran use provides only minimal, if any, benefits to the production of these crops. Consequently, in the absence of carbofuran, growers currently using it would be expected to simply shift to one of the available alternatives, with no appreciable impact on yields or quality and, at most, only minor increases in production costs. Even under the worst case scenarios estimated by EPA, impacts would be extremely small in comparison to the value of the crops and would not have any broader impacts on consumers or processors of these commodities.

B. Group 2 - Use Sites for Which Some Information is Available but There are Minimal Benefits from the Use of Carbofuran

The crops in this group are alfalfa, chili peppers, cotton, grapes, sorghum, soybeans, and small grains (barley, oats, and wheat). Relatively few acres of these crops appear to be treated with carbofuran and cost-effective alternatives are available. EPA has concluded that carbofuran provides only minimal benefits in these crops.

i. Alfalfa. According to recent EPA proprietary data (2002-2006), about 2% of the U.S. alfalfa acreage is treated with carbofuran, on average, every year, or about 400,000 acres. Carbofuran is primarily used to control aphids and weevils in alfalfa. In addition to carbofuran, several insecticides of various chemical classes are registered to control these pests. These include cyfluthrin, chlorpyrifos, and lambda cyhalothrin. All were found to be efficacious, and most were more effective than carbofuran based on comparative performance studies. Further, EPA proprietary data indicated that all are less costly than carbofuran, on average, although in some places or times carbofuran might be the cheaper option. However, comments received by the Agency, a review of USDA crop profiles, and EPA proprietary data indicate that carbofuran remains one of the primary insecticides for control of the alfalfa weevil, suggesting that there are some benefits to its use. Unfortunately, the comments did not provide a clear explanation of the benefits. EPA proprietary data suggests that the Egyptian alfalfa weevil in particular may be controlled with relatively low rates of carbofuran, resulting in cost savings of $5-6/acre compared to lambda cyhalothrin. If this is representative of most situations where carbofuran is preferred, total impacts of cancelling carbofuran would be $2.0-2.4 million annually. As an upper bound estimate of impacts, EPA notes that the review of comparative efficacy studies suggest that yield loss of 5% may occur with the use of chlorpyrifos (Ref. 11). Were that to occur on the acres treated with carbofuran, total impacts could be as high as $6.9 million per year. The average value of alfalfa production is over $7.1 billion and ranges from $6.7 to 7.5 billion, so even if yield losses were so high, the impact of cancelling carbofuran would be indistinguishable from normal year-to-year variations in yields and price and would not have broader economic impacts.

ii. Chili Pepper. Carbofuran is applied at planting to approximately 10% of the U.S. chili pepper acreage, although more than 40% of New Mexico's chili pepper acreage, on average, is treated annually with carbofuran. A number of cost-effective, efficacious alternatives of varying chemistries are available to control all of the major pests. These include both foliar and at-planting systemic insecticides, such as acephate, dimethoate, dinotefuran, disulfoton, imidacloprid, esfenvalerate, endosulfan, and methomyl. Of the identified alternatives, EPA expects that growers would use another systemic at-plant insecticide such as imidacloprid or dinotefuran, because they control the same spectrum of pests as carbofuran, are systemic, and can be applied at planting. In addition, thiamethoxam and imidacloprid provide residual control for 4-6 weeks after emergence, as compared to carbofuran, which only provides residual control for 2 weeks after emergence.

EPA does not expect yield or quality losses from these alternatives. Consequently, changes in operating costs associated with the price of carbofuran's alternatives are the sole source of grower level impacts, if carbofuran were no longer available. The likely at-plant alternatives for carbofuran, thiamethoxam and imidacloprid, are more expensive, ranging from $5 -$54 more per acre.   This would result in a decrease in net operating revenues of 2% or less. Given the small percentage change in net operating revenues, and the fact that the alternatives provide longer residual control, EPA concludes that most chili pepper producers derive relatively small benefits from the availability of carbofuran.

Carbofuran is used on approximately 3,000 acres or 10% of U.S. chili peppers, according to EPA proprietary data (2002-2006) and USDA National Agricultural Statistics Service (NASS) Surveys. The most expensive alternatives cost about $54/acre more than carbofuran, implying that impacts would be no more than $174,000 if carbofuran is cancelled. The total value of chili pepper production averages about $114 million per year, ranging from $103 million to $123 million.

iii. Cotton. Carbofuran is registered for use at planting and according to recent EPA proprietary data (2003-2006)[9] is used on less than 12,000 acres per year, on average, and declining. The major target pest of carbofuran is the thrips complex. Several insecticides of various chemical classes are registered to control thrips. These include aldicarb, imidacloprid, and thiamethoxam. All are considered as effective as carbofuran, based on a review of state recommendations although all are also more expensive. If growers switched to aldicarb, the most expensive alternative, production costs would rise about $13/acre, resulting in total impacts of about $156,000 out of a $6 billion crop. Again, this loss would not result in broader economic impacts.

iv. Grapes. The primary pest for which carbofuran is used on grapes is phylloxera, which is most effectively controlled by the use of resistant root stock. Among the registered chemical alternatives are imidacloprid and sodium tetrathiocarbonate, which are considered equally or more efficacious than carbofuran according to the Pest Management Strategic Plan of California (PMSP) (2004) (Ref. 26). Imidacloprid costs less than carbofuran, according to EPA proprietary data, which suggests that carbofuran may also provide some other benefits, such as nematode suppression, that growers find desirable. Carbofuran is used on less than 0.5% of the California grape crop or about 3,000 acres, according to the California Department of Pesticide Regulation. California accounts for more than 95% of the U.S. grape crop. At worst, if growers must use both imidacloprid and a nematicide, it would cost about $45-50 more per acre, for a total impact of about $160,000 out of a total value of production of about $3 billion per year.

v. Small Grains (barley, oats, wheat). The primary pests for which carbofuran is labeled on these use sites are grasshoppers, mites, and aphids. Registered alternatives in several chemistries are available, including organophosphates, other carbamates, and synthetic pyrethroids. EPA proprietary data (2002-2006) indicate that only about 50,000 acres of small grains are treated with carbofuran. Alternatives are only about $2-3/acre more expensive, implying impacts of no more than $150,000 if carbofuran is cancelled. The total value of production for small grains averages about $8 billion per year, ranging from $6.5 billion to $8.9 billion.

vi. Sorghum. EPA received generic comments indicating that carbofuran may be needed for resistance management, but pests were not specified. Several insecticides of various chemical classes are registered to control all of the major sorghum pests. Synthetic pyrethroids, such as lambda-cyhalothrin, followed by organophosphates, such as chlorpyrifos and terbufos, appear to be the primary insecticides used. EPA proprietary data (2002-2006) indicate that only about 12,000 acres of sorghum are treated with

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[9] EPA did not include 2002 in estimating acres treated because several states had a Section 18 exemption for a foliar use of carbofuran, and the Section 18 usage cannot be disaggregated from total carbofuran use on cotton. This exemption was available for only one or two states in later years.

carbofuran. The most expensive alternatives cost about $5-6/acre more than carbofuran, implying that impacts would be no more than $72,000 if carbofuran is cancelled. The total value of sorghum production averages about $850 million per year, ranging from $740 million to $965 million.

vii. Soybeans. Comments identified a need for carbofuran, mainly for resistance management, for two relatively new soybean pests, the soybean aphid and the red-banded stink bug. For aphids, recommendations by university extension agents include organophosphates, such as acephate and chlorpyrifos, and synthetic pyrethroids, such as cyfluthrin. Carbofuran may offer an additional class of chemistry for resistance management purposes, but there may be other control options as well. Currently, acephate is the only recommended product for control of the red-banded stink bug, but according to comments, trials indicate that other organophosphates, a few synthetic pyrethroids and several carbamates may provide control comparable to acephate. Carbofuran is used on approximately 22,000 acres of US soybeans, according to EPA proprietary data (2002-2006). In the absence of carbofuran, control cost may increase by at most $2-3/acre, implying maximum total impacts of $65,000/year, out of a total crop value of $17.6 billion.

c. Group 3 - Use Sites for Which Use of Carbofuran Has Some Benefits

Crops in this group are artichokes, bananas and plantains, pine seedlings (Southeastern United States only), spinach grown for seed, sugarcane, and sweet corn. EPA obtained or received information claiming that carbofuran was important for these crops, either because it filled a unique role in controlling a particular pest or because the existing alternatives were ineffective. For these crops, the Agency conducted an assessment or evaluated comment to identify the available alternatives and the potential economic impacts from the loss of carbofuran on the individual use sites.

i. Artichokes. Approximately 12-20% of the crop nationally is treated with carbofuran to treat the cribrate weevil, the proba bug, and aphids. Registered alternatives include differing chemistries, such as pyrethroids and a chitin synthesis inhibitor (diflubenzuron). However, because registered alternatives have been reported to be not as effective as carbofuran or cannot be applied with sufficient frequency for season long protection, EPA believes carbofuran provides moderate to high benefits to artichoke growers as it is likely that some growers could be faced with losses in excess of 100% of their net operating revenue. Data, however, are sparse and there is substantial uncertainty surrounding the estimated impacts of cancelling carbofuran.

Carbofuran is one of the chemicals commonly used against the cribrate weevil. Bifenthrin, which is the other chemical most commonly used against this pest, appears not to be as effective as carbofuran, costs four times as much, and has a long reentry interval (5 days). Diflubenzuron is as effective as carbofuran against the cribrate weevil, but the label directions for the timing of application is targeted primarily to control the artichoke plume moth, and applications may only be made every 15 days. Thus diflubenzuron may not ultimately provide the same level of control. In the absence of carbofuran, growers are expected to substitute bifenthrin to control cribrate weevil. Bari (2006) estimates that substituting bifenthrin would result in yield losses of 5-10% (Ref. 7).

Carbofuran is also commonly used on artichokes to control the proba bug. Control of this pest requires 6 to 7 applications of insecticides during the growing season to obtain adequate control (Ref. 7). For resistance management purposes, applications of at least three chemicals per season are currently required. Methidathion, which like carbofuran, is currently used from May through July, is also effective against proba bugs (Ref. 53). Thiamethoxam, the primary alternative, has been used pursuant to an emergency exemption, from August to November, and is limited to two applications per season. In the absence of carbofuran to control proba bugs, growers may lack season-long control and Bari (2006) estimates that yield losses of 10-15% could occur (Ref. 7).

Carbofuran is also used to control aphids. Thiamethoxam, the primary alternative, provides equivalent control and yields, but costs twice as much as carbofuran.

In the absence of carbofuran, EPA estimates that individual grower impacts could range from $20/acre or 4% of total net operating revenue, if only an aphid infestation occurs, to $700/acre or a 135% decrease in total net operating revenue if there is a proba bug infestation. The worst-case situation of a proba bug infestation would result in total losses of about $1.12 million. According to NASS, the total value of fresh artichoke production is about $36.2 million annually (2004-2006)[10].

ii. Bananas and Plantains. EPA did not find usage data to indicate carbofuran use on bananas. However, the Agency received comments stating that carbofuran is needed to control the banana root borer (also known as the banana weevil) in Hawai'i and is useful as a post-plant treatment for nematodes. The Hawai'ian Crop Profile for Banana supports this information. EPA also examined the Crop Profile for Bananas and Plantains in Puerto Rico, which indicated the weevil is a widespread problem and is generally controlled by a nematicide with insecticidal activity, but did not specify if carbofuran was used. Ethoprop is the only currently registered alternative available to control the banana root borer; however, no University of Hawai'i publication describes it as an alternative, and commenters claim that growers are unsure of its efficacy. In addition, the need for engineering controls may limit adoption of this alternative. Some cultural practices, such as deep planting offshoots from a mother plant, field sanitation and covering the banana plant with soil after pruning or harvesting are recommended to minimize damage, but EPA does not know the extent to which these practices may prevent the need for an insecticide.

Since several independent sources describe carbofuran as important to banana production in Hawai'i, EPA believes that growers obtain benefits from carbofuran use on bananas in Hawai'i. The at-plant use may be particularly important, as young plants are most at risk of death from banana root borer. However, data are not available to estimate

[10] The farm-gate price of artichoke declined sharply between 2003 and 2004. EPA believes the recent period better reflects the current outlook for artichoke producers.

the extent of damage and economic loss to individual growers in Hawai'i if carbofuran were not available. EPA has reported that less than 1% of the banana crop is treated with carbofuran, but data are sparse and could be biased since banana plants may produce for multiple years. Only about 1000 acres of banana are cultivated in Hawai'i and about 11,000 acres of banana and 27,000 acres of plantain are grown in Puerto Rico. Consequently, EPA concludes that carbofuran provides some benefits to growers and, depending on how widely it is used, to the local industry as well. However, imports supply the vast majority of bananas consumed in the United States, so no national level impacts would be expected from a cancellation of carbofuran.

iii. Pine Seedlings. According to comments received, carbofuran is applied to pine seedlings to control the pales weevil and the pitch eating weevil. EPA does not have data concerning the number of acres treated with carbofuran. In the Southeast, the pales weevil is considered the most serious pest, as infestations commonly result in 30-60% mortality in first year seedlings, and mortality of 90% or more has been recorded. Agronomic practices, such as delayed replanting (1-2 years) in an infested area, can prevent the damage to seedlings. Where this is not possible, a number of alternatives of various chemistries are registered to control these pests, including phosmet, chlorpyrifos, acephate, esfenvalerate, lambda-cyhalothrin, gamma-cyhalothrin. Pine seedlings are planted in remote areas and carbofuran is applied as a root dip at the time of planting and is taken up systemically by the seedlings. The alternatives are applied to the foliage, which requires additional treatments and may not be as effective due to improper timing.

Because of the limitations to the alternatives, EPA concludes that carbofuran may provide benefits in pine production, at least in the Southeastern United States. However, EPA lacks sufficient data to estimate the magnitude of these benefits.

v. Spinach grown for seed. (granular formulation only) According to the USDA Crop Profile (2005), carbofuran is applied at plant on 75% of the crop in Washington to control European crane fly larva and springtail (Ref. 20). These are sporadic soil pests capable of causing yield losses of up 100%. No alternatives have been identified to control either pest. Consequently, EPA believes that carbofuran provides high benefits to growers of spinach grown for seed. Given that the crop is produced for seed, there could be large impacts downstream on spinach production. About 2000 to 3000 acres are grown each year in and Washington, accounting for about 75% of U.S. spinach seed with an annual value of $24 million.

vi. Sugarcane. Carbofuran is used on approximately 1-2% of the Florida sugarcane crop, primarily to treat two pests, the yellow sugarcane aphid and the lesser cornstalk borer. According to USDA statistics for 2002-2007, Florida produces nearly half of all U.S. sugarcane on about 45% of the harvested acres. Based on the available information, it appears that carbofuran may be more effective than the available alternatives in controlling the yellow sugarcane aphid. A few synthetic pyrethroids are currently available for control of this pest, but it appears that they provide less control than carbofuran. Accordingly, in the short-term, some growers may experience some adverse impacts from the loss of carbofuran. Yellow sugarcane aphids can cause yield losses of up to 19% (Ref. 58).

For the lesser cornstalk borer, carbofuran is the only insecticide currently recommended by the University of Florida Insect Control Guide. Other insecticides are registered for use on sugarcane, but EPA does not know if any are effective against the pest.

In the absence of carbofuran, growers may not be able to control these pests. If all the area treated suffers a 19% yield loss, total losses in Florida could be up to 0.4% of production, or 61,000 tons, with a value of $1.8 million per year. The average annual value of sugarcane Florida production is $475 million.

vii. Sweet Corn. About 20,000 acres of sweet corn are treated with carbofuran, according to EPA proprietary data (2002-2006). Carbofuran is the only known effective chemical control that is labeled for use on sweet corn against the wheat curl mite, which transmits High Plains disease, in several western states. High Plains disease can result in yield losses of 50% or more (Ref. 37). Host resistance and cultural controls, such as weed control, early planting of corn, and delayed planting of winter wheat (an alternate host) can help to prevent or mitigate damage in many cases (Ref. 59). Without chemical alternatives, however, there may be severe economic impacts to individual growers. Carbofuran is applied to 3-4% of US sweet corn (USDA NASS, 2001, 2003, 2005, 2007), but states with High Plains disease have rarely been surveyed for chemical usage in sweet corn (Ref. 58). Less than 5% of fresh sweet corn is grown in Colorado and Texas (NASS, 2007); acreage and production in other states with High Plains disease have not been reported (Ref. 58). Therefore, EPA is unsure how many acres would be affected, but it is unlikely to be a substantial portion of national production.

d. Group 4 - Use Sites for which EPA Reviewed Benefit Assessments Submitted by the Registrant

Group 4 consists of crops for which the registrant submitted benefits information: corn, potato, sunflower, and melons (cantaloupe, honey dew, and watermelon). EPA had previously conducted assessments for corn, potato, and cucurbits, including cucumber, pumpkin, and squash as well as melons. EPA reviewed the registrant's assessments and gathered additional data on field trips to Illinois, Indiana, and Iowa.

The registrant also submitted an assessment of the benefits to carbofuran in cotton production that focused on foliar applications for aphid control. The foliar application use pattern for aphid control is not currently registered, nor is there a pending application for registration; consequently this Notice does not address it.

i Corn. *At-plant and mid-season foliar use.* In EPA's 2006 assessment, the Agency estimated that carbofuran was applied to about 537,000 acres of corn, on average (2002-2004), or about 0.7% of cultivated acres. There are three major pests against which these particular use patterns are applied: the European corn borer, the southwestern corn borer, and the corn rootworm. For all three of these pests, several alternatives of varying chemical classes are registered that are both more efficacious and either equally or less costly than carbofuran. Consequently, minimal economic impacts would be expected to result from the loss of this compound for this use pattern.

Corn Borers. Bt corn varieties are demonstrated to be efficacious against corn borers, and include "stacked" varieties with activity against both the European and southwestern borers. However, for resistance management purposes, non-*Bt* varieties must be cultivated on at least 20% of a grower's corn acreage. Control with carbofuran entails a foliar application.

Lambda cyhalothrin was similarly found to be more effective than carbofuran against the European corn borer in comparative efficacy trials, and costs $4 less per acre, on average. For the southwestern corn borer, the registered alternatives also include permethrin, esfenvalerate, and chlorpyrifos. All were rated equally efficacious, and the average chemical costs ranged between $7 less per acre and $2 more per acre than carbofuran. Costs may be higher – an additional $11 an acre – on a portion of the acreage in the Southwest, where bifenthrin appears to be the likely alternative.

Corn Rootworm. Varieties of *Bt* corn are also very effective against rootworm, but as with varieties aimed at borers, at least 20% of a grower's acreage must be cultivated in non-Bt varieties. Chemical control includes seed treatments and at-plant applications of an insecticide, where carbofuran is one option. EPA's review of efficacy trials shows that registered alternatives are similar in efficacy to carbofuran, although some are slightly more expensive. For example, tefluthrin was judged to be the most effective in most comparative efficacy trials, although it is slightly less effective in the northeastern states. Tefluthrin resulted in numerically higher yields in 91% of comparisons in the corn belt, as well as in 83% of southern, lake, and plains states, which would be expected to mitigate its higher cost of $4 more per acre, on average. Chlorpyrifos was also judged to be equally efficacious across all geographic areas, and costs about $2 more per acre.

EPA estimated the potential economic costs to growers in Nebraska, Iowa, and Pennsylvania if growers had to apply the most expensive alternative in place of carbofuran for at-plant control of corn rootworm, resulting in a $4 per acre increase in costs. Any impacts would result only from increased insecticide costs, and range from 3.3% of net operating revenue in Nebraska, to 6.8% in Pennsylvania, depending on the alternative chosen. However, the analysis was conducted using data from the past several years that do not reflect recent increases in the price of corn, and therefore impacts as a percent of net operating revenue may ultimately be lower.

Mid to late season "rescue" treatment. Corn rootworm may also be controlled with an application timed to rootworm emergence. This situation would most likely occur where *Bt* corn is not utilized or on the 20% of the *Bt* corn acreage that is set aside as refugia. An estimated 250,000 acres of corn are treated annually with carbofuran in this manner. EPA received substantial comments and information to support the claim that carbofuran occupies a special niche as a mid or late season rescue treatment for corn rootworm larvae. Historically, an insecticide application could be made at the time corn was cultivated, or mechanically weeded, which was around the period of rootworm emergence, and an insecticide could be incorporated into the soil. Current farming practices, however, rarely include post-emergence cultivation, so an insecticide treatment must depend on rain or irrigation to move it into the soil. Treatment may also be delayed until rootworm larvae are observed, often when the corn is too tall for a cultivation time treatment (i.e., when the corn is 18-60 inches). This practice is often referred to as a "rescue" treatment to distinguish it from the preventative treatments at planting or at cultivation. As a result of the comments, EPA has conducted a detailed analysis of this particular use pattern that takes all of the submitted information into account.

A large amount of uncertainty remains regarding the efficacy and yield benefits of carbofuran rescue treatments. Some extension publications recommend against the use of such carbofuran rescue treatments, particularly broadcast applications, on the grounds that they are ineffective or unreliable and that their cost is not warranted because of the erratic results observed when rescue treatments are applied. The authors of these publications base their conclusions on observations in the field, previously conducted efficacy tests, the reduced concentration of carbofuran in the soil when broadcasted onto a field with a closed canopy, and the fact that damage has often occurred before symptoms are observed (Refs. 38, 41, 69, 74, 74). Contact with experts in the field and review of extension publications suggest that carbofuran rescue treatments are most effective when watered into the soil after application and thus are more likely to be used by growers with irrigation systems (Refs. 39, 41, 51, 55, 69).

EPA reviewed an impact assessment submitted by the registrant and gathered information during two field visits to Illinois, Indiana, and Iowa, which included presentations organized by the registrant. The information has been useful, but has not altered EPA's ultimate conclusions.

Of the three pests EPA identified, corn rootworm appears to be the main driver for the use of carbofuran on corn. EPA acknowledges that in some situations, field corn growers have a genuine need for a "rescue" treatment, meaning after the cultivation period. A corn rootworm rescue treatment may be warranted if: (1) a seed treatment fails (e.g., because of high population pressure); (2) an at-plant treatment fails (e.g., because of poor weather conditions); or (3) there was no at-plant treatment at all (e.g., grower error or unexpected outbreak). Other insecticides, chlorpyrifos and bifenthrin, are even less reliable than carbofuran in these situations because they are even more dependent on rainfall or irrigation. Thus, despite the uncertainties, carbofuran is the best option currently available for a late-season application without irrigation. With carbofuran, some growers may avoid yield losses, if seed or at-plant treatments fail, and some growers may forego a seed or at-plant treatment, knowing they have an option if a problem emerges later in the season.

The registrant estimates that use of carbofuran can improve yields by 23 bushels per acre in late-season "rescue" situations. This estimate is based on a comparison of a few recent demonstration plots. However, based on the data submitted by the registrant from replicated university studies conducted in the mid-1990's, EPA concludes that average yield losses of 13-16 bushels per acre may be more realistic. Although EPA does not usually attempt to evaluate losses at the farm-enterprise level because of the enormous variation between farms in terms of area cultivated and diversity of production, in this situation, there are a few commonalities that help to place these estimated losses in context. Post-plant treatments for rootworm with carbofuran occur on very few acres (less than 250,000 acres out of 70 million acres cultivated over the past three years, according to the registrant's assessment). This is true at the farm level as well. Rootworm problems are likely to occur only in the areas planted in non-Bt varieties, i.e., the refuge areas that must be at least 20% of the grower's corn acreage. Assuming an acre of corn represents the entire farm, yield loss would occur on only a fraction of the acre so that, overall, yield loss would be around 3-4 bu/acre. In value, the loss would be around $8-10/acre or about 2.5-3.0% of net operating revenue. Even if yield loss were 23 bu/acre, as estimated by the registrant, the overall loss would be $10-13/acre or 3-4% of net operating revenue.

In terms of national losses in corn production, even if both the yield losses and economic costs that the registrant suggests were correct, the calculated loss in production is only about 0.05% of national production. Such a loss at the national level is so small compared to year-to-year variation in production that downstream industries would not be noticeably affected. Consequently, EPA concludes that carbofuran does not provide high benefits to growers and the benefits at the national level are negligible.

ii. Cucurbits EPA assessed the impacts of the loss of carbofuran to growers of cucumbers, squash, pumpkin, and watermelon and stated that these conclusions also applied to growers of other cucurbits like cantaloupe and honeydew melons. Carbofuran is applied on approximately 2 to 7% of the U.S. acreage in these crops, although usage can be 10% or higher in the Midwest and mid-Atlantic states. However, it is used on less than 1% of the acreage of cantaloupe and honeydew melons, which are mainly produced in Arizona and California. Carbofuran is a systemic insecticide registered for use on cucurbits through multiple Special Local Needs labels to control striped and spotted cucumber beetle. Most cantaloupe and honeydew melons are cultivated in Arizona and California, where cucumber beetles are not a major pest. Early season control of cucumber beetles is important in minimizing damage from direct feeding and from bacterial wilt which is vectored by cucumber beetles. Soil insecticides applied at planting, such as the neonicotinoids imidacloprid and thiamethoxam, are the best alternatives for carbofuran for many cucurbits. EPA does not expect yield or quality losses from the use of these alternatives on cucurbits. The Agency received a number of comments indicating that carbofuran is important for resistance management because the most likely alternatives are both neonicotinoids. For cucurbits that are resistant or are less susceptible to bacterial wilt, such as watermelons, foliar insecticides, such as synthetic pyrethroids, may be used by some growers in place of carbofuran. The neonicotinoids are more expensive than is carbofuran, so growers may face higher production costs of $34 to $60 per acre. This represents about 5% of net operating revenue, which does not account for fixed costs.

The registrant submitted an assessment of the impacts of cancelling carbofuran on melons in which they estimate a 20% yield loss, a 10% loss in average price due to relatively heavier losses in the early season when prices are highest, and an increase in production costs due to the use of more expensive alternatives. However, the yield loss estimates were based on comparisons with untreated control plots, not with plots treated with alternative insecticides. Therefore, EPA's conclusion remains that an increase in production cost is the sole impact of the cancellation of carbofuran.

Imidacloprid is more costly, but the cost difference estimated by the registrant is not supported by sufficient methodology to assess the quality of their data. The best available data indicate that difference amounts to about $39/acre. Given the registrant's estimates of total impacts and average impacts per acre, it appears that about 12,000 acres of melons are treated annually with carbofuran. While greater than EPA's original estimate, it may be more reasonable as it is based on data from more states. As an upper bound estimate, EPA calculates that total industry costs of cancelling carbofuran may thus be about $500,000 annually, representing less than 0.1% of the total value of melon production in the U.S. and is highly unlikely to result in any broader economic impacts.

Carbofuran is used on approximately 29,500 acres or 6% of all US cucurbits, according to EPA proprietary data (2002-2006) and USDA NASS Surveys. The most expensive alternatives cost about $34-$60/acre more than carbofuran, implying that impacts would be no more than $1.8 million annually if carbofuran is cancelled. The total value of cucurbit production averages about $1.4 billion per year, ranging from $1.3 billion to $1.5 billion.

iii. Potatoes Several insecticides of various chemical classes are registered that provide cost effective control for all of the potato pests targeted by carbofuran, both for at-plant treatments for early season pests, and as foliar applications for late season pests. For example, the pyrethroids, neonicotinoids (imidacloprid and thiamethoxam), and spinosad are all considered to be at least as effective as carbofuran in controlling the Colorado potato beetle, and all are less costly on average. In addition, spinosad has longer residual activity, and is considered relatively safe to beneficial insects.

Similarly, for the at plant or early season application of carbofuran to control the potato flea beetle, green peach aphid, and wireworms, several alternatives of various chemistries are registered. For example, both the neonicotinoids and phorate are considered to be at least as efficacious as carbofuran, although they are both more expensive. For the potato tuberworm, several pyrethroids (cyfluthrin, esfenvalerate, and permethrin) are equally efficacious as carbofuran, are less costly, and are more widely used. Indoxacarb, an oxadiazine compound, is another likely alternative against this pest.

The registrant submitted additional information in support of its claim that carbofuran is essential to potato production in the Pacific Northwest states. However, no compelling information was presented that EPA had not previously considered as part of its original assessments, or that weakened EPA's conclusion that a number of cost-effective, equally efficacious alternatives are currently available. The information presented did not demonstrate that carbofuran addressed unique conditions from any particular area, production method, or pest, or otherwise functioned in any manner that suggests existing alternatives would not adequately address pest pressures on potatoes for the foreseeable future. For example, claims were recently presented to the Agency that carbofuran is essential for green peach aphid control. EPA consulted the 2007 Pest Management Strategic Plan for potatoes grown in the Pacific Northwest, which rated carbofuran as "poor" for the control of the green peach aphid.

Few economic impacts are anticipated to result from the loss of the foliar use of carbofuran. EPA estimated that a possible 1-7% decline in per acre net operating revenues ($6-$37) could occur from the loss of the at-plant use, depending on the production system and the choice of alternative. However, given that carbofuran usage has become less important over past 5 years (from 13 to 4% of area cultivated), it is unlikely that the loss of carbofuran would result in substantial negative economic impacts at the national level. This is also true in the Pacific Northwest, which is the major production region but where currently less than 10% of the potato acreage in any state is treated with carbofuran. According to recent figures from EPA proprietary data (2002-2006), approximately 28,000 acres of potato are treated with carbofuran. If growers used the most expensive alternative, at $37/acre more, total impacts would be just over $1 million per year out of a total crop value of over $2 billion annually.

iv. Sunflower. Carbofuran is applied on approximately 2% of the US sunflower acreage, according to EPA proprietary data (2002-2006). The primary use of carbofuran in sunflower is an at-plant application to control the sunflower stem weevil, which is primarily a problem in Colorado, Kansas, and Minnesota. A number of efficacious alternatives of varying chemistries are registered to control this pest. These alternatives include the pyrethroids (cyfluthrin, lambda-cyhalothrin, esfenvalerate, deltamethrin, and gamma-cyhalothrin), a carbamate (carbaryl) and an organophosphate (chlorpyrifos). Of the area treated for stem weevil, carbofuran is applied to approximately 20-30%; in Minnesota, over 60% of the area treated for stem weevil is treated with carbofuran. The alternatives are all foliarly applied, and are only recommended when greater than 8 weevils are found on 25 plants. Although these are efficacious, scouting is difficult as weevils may drop to the ground when movement is sensed. Cultural practices may also be used to control the pest. Growers may delay planting, but this offers a very short window for planting as quality and yield loss may occur if planting is delayed too long. Finally, the sunflower stem weevil has a number of natural enemies, but it is unclear whether the use of natural enemies alone will provide adequate control.

The registrant submitted an assessment in which they estimated yield losses of 300-500 lb/acre in the absence of carbofuran. They extrapolated this figure, assuming over 175,000 acres of sunflower treated with carbofuran in Colorado, Kansas, Nebraska, and South Dakota, to calculate national losses of $7.9-13.2 million per year. EPA concludes that the registrant's assessment overstates the benefits of carbofuran in sunflower production. In particular, the assessment did not consider the use of synthetic pyrethroids as an alternative to carbofuran when estimating yield loss and misinterpreted information regarding the acres treated with carbofuran. However, EPA continues to believe that carbofuran fills a niche for sunflower producers because it is the only at-plant systemic insecticide registered for sunflower stem weevil control.

Given the difficulty in scouting, the lack of at-plant alternatives, and the use of carbofuran despite its higher costs, EPA believes that carbofuran likely fills a niche in sunflower production areas in which the sunflower stem weevils are a problem. Consequently, without carbofuran, some growers may have difficulty achieving adequate control of sunflower stem weevils. Data submitted by the registrant in their assessment of the benefits of carbofuran on sunflowers, show a wide range of yield differences, but the most relevant data indicate losses of around 100-120 lb of seed per acre, or a 5-10% reduction in yield, with the use of a synthetic pyrethroid. Such a yield loss translates into a loss of $8-10/acre, accounting for the less expensive alternative. EPA estimates the impact of cancelling carbofuran to be around 15-25% of net operating revenue for irrigated and non-irrigated production, respectively, based on crop budgets from Colorado, Kansas, and Nebraska. Nationally, EPA data indicate that, on average, less than 30,000 acres of sunflower are treated annually. Therefore, EPA calculates that the total impact of cancelling carbofuran would less than $300,000 annually in sunflower production, from a crop valued at over $330 million.

Conclusion

EPA concludes that carbofuran provides only minimal benefits to the producers of most crops for which it is registered. EPA bases this conclusion on its analyses that show very low percentage of a crop treated with carbofuran and/or the availability of cost-effective alternatives for pest control. EPA acknowledges that use of carbofuran may benefit individual growers of cucurbits, field corn, sugarcane, sunflower, and sweet corn because alternatives are more costly or less effective in controlling certain pests. However, the need for carbofuran appears to be relatively sporadic as less than 5% of these crops are treated and impacts at the national level would be lost in normal year-to-year variations in yields, production, and prices. Growers of bananas and plantains and foresters planting pine seedlings in the Southeastern U.S. also obtain benefits from the use of carbofuran as there are few suitable alternatives. There could be local or regional impacts, but EPA has been unable determine how widely carbofuran is used for these sites. Finally, carbofuran provides moderate to high benefits to producers of artichoke and spinach grown for seed and a substantial proportion of acreage in these crops could be affected by the cancellation of carbofuran.

VII. Conclusions as to Carbofuran's Safety and Risk Benefit Balance

The applicable standard for cancellation under section 6 of FIFRA in this proceeding is whether carbofuran, in accordance with widespread and commonly recognized practice, generally causes unreasonable adverse effects on the environment. The term "unreasonable adverse effects on the environment" is defined in section 2(bb) of FIFRA. As that provision makes clear, there are two independent prongs to the definition. The first prong involves a consideration of the economic, social, and environmental costs and benefits of the use of the pesticide; if the risks to man or the environment of the use of the pesticide are not justified by the benefits of the pesticide, the pesticide causes unreasonable adverse effects on the environment under this prong. The second prong addresses whether the human dietary risks from the use of the pesticide meet the "reasonable certainty of no harm" safety standard in section 408 of the FFDCA. In order to meet the standard for pesticide registration, a pesticide must pass both prongs of section 2(bb); cancellation is appropriate if a pesticide fails to meet either prong. In the case of carbofuran, EPA finds that use of carbofuran fails both prongs of section 2(bb).

After having evaluated the information concerning the risks of consuming food and water containing carbofuran residues, EPA has concluded that aggregate dietary exposure from registered uses of carbofuran is not "safe" as that term is defined in section 408 of the FFDCA. This finding alone is sufficient to compel EPA to cancel all existing registrations of carbofuran and to revoke all related tolerances. But in addition, based on the available information concerning the risks and benefits associated with continued use of carbofuran, EPA has determined that even if the benefits were substantially higher than EPA's estimates, the benefits of continued use would not outweigh the remaining occupational and ecological risks of continued use of carbofuran. In the long run, there is insufficient evidence to support a finding that the risk/benefit balance for any particular use site is appreciably different than the overall risk/benefit balance so as to justify continued registration on any individual site. Accordingly, EPA has concluded that all carbofuran products, when used in accordance with widespread and commonly recognized practice, generally cause unreasonable adverse effects on the environment, and therefore warrant cancellation.

A number of considerations underlie these conclusions.

Carbofuran is a highly potent chemical, and small amounts can have significant consequence for a number of individuals in terms of both human and ecological exposures.

The dietary risks from food alone substantially exceed safe levels for the most sensitive segments of the population—infants and children. EPA is especially mindful of the fact that at the upper percentiles of exposure, relatively low residues in a small percentage of food samples result in estimated exposures that significantly exceed EPA's level of concern for children's subgroups. Although EPA's analyses are, to some extent, overestimates as a result of the high LOD, EPA's exposure estimates are otherwise highly refined, and cannot therefore be considered unduly conservative. This is further supported by the fact that when a more sensitive, or lower, LOD has been used residues have been detected. Moreover, even using assumptions that underestimate the potential exposure, EPA's analyses show that children between ages of 1-5 years are currently exposed to levels that substantially exceed the safe daily dose. This analysis also indicates that at the upper percentiles of exposure, infants and children between the ages of 6-12 years are exposed to levels that are almost equivalent to the aPAD, which means that any additional source of exposure, such as through drinking water, can be a cause for concern.

The risks are even greater for those people exposed to carbofuran through their drinking water. For those whose drinking water is derived from ground water in a vulnerable area, exposure from drinking alone exceeds EPA's level of concern by several orders of magnitude. While there is more uncertainty concerning EPA's estimated exposures from drinking water derived from surface water, the uncertainty is not so great that the risks can ultimately be dismissed. Even using the registrant's suggested calculation to account for the percent of the crop treated in a particular watershed, it is clear that carbofuran in drinking water from vulnerable watersheds contributes significantly to the dietary risks. Moreover, it is clear that using the registrant's calculation underestimates exposure for certain watersheds and for certain crops, where the percent crop treated is higher.

Exposures from food and water to the US population at the upper percentiles of exposure substantially exceed the safe daily levels. And it is particularly significant that under every analysis EPA has conducted, the levels of carbofuran significantly exceed the safe daily dose, especially for infants and children. Based on these findings, registered uses of carbofuran fail to meet the first prong of FIFRA section 2(bb), and therefore warrant cancellation.

It is further cause for concern that occupational risks substantially exceed EPA's levels of concern as well, and suggest that on a routine basis, workers are exposed to levels with significantly reduced margins of safety. The consequences associated with exposures to carbofuran are further confirmed by the incident data, which document that small mistakes can have serious consequences for a large number of individuals. These incident data further demonstrate that even stringent safety restrictions cannot fully reduce these risks, as poisoning incidents continue to occur.

Finally, carbofuran's high risk to large numbers of avian and aquatic non-target species is cause for serious concern in its own right. Not only does carbofuran pose a risk of death from acute poisoning, but it also presents significant concerns for the survival of large numbers of avian species. These risks are well-documented by two extensive assessments, and confirmed by field and monitoring data, as well as numerous significant, recurring incidents occurring over several decades. These data demonstrate that the potential for adverse effects is real, and spread across numerous species. Terrestrial field studies and monitoring confirm that bird mortality occurs at typical to low-end application rates. And as the incident data conclusively demonstrates, just as is the case with worker risks, mistakes are inevitable, and when they occur, given carbofuran's potency, they can have serious consequences for a large number of any non-target species that happens to be exposed.

Ultimately, the benefits of continued carbofuran use do not outweigh either the occupational or ecological risks. The majority of carbofuran uses provide minimal, if any, benefits either to the individual grower or at a national level. Although a few uses have higher benefits, none of these provides sufficient benefits either to individual growers, or at the national level, to outweigh the substantial combined occupational and ecological risks. Additionally, the Agency expects carbofuran benefits to decline over time as new cultivation practices are developed and new alternative pesticides are registered. Based on these findings, registered uses of carbofuran fail to meet the second prong of FIFRA section 2(bb), and therefore warrant cancellation.

FIFRA section 6(b) requires EPA to determine whether alternatives to cancellation exist that will mitigate the risks to acceptable levels. On December 13, 2007, FMC submitted a conditional proposal to cancel certain uses of carbofuran. Leaving aside the conditional nature of the proposal, the aggregate exposure from food alone from the remaining uses in that proposal still exceeds the FFDCA section 408 safety standard. In addition, although some measures have been identified that might significantly decrease some of the risks arising from exposure to contaminated drinking water, (Ref. 10), ultimately, the evidence does not demonstrate that these measures would adequately mitigate all of the dietary risks from the combined exposure to residues in food and drinking water. Further, a number of significant uncertainties remain regarding the efficacy of the measures intended to mitigate the risks from exposures through drinking water. For example, it is not clear that the label restrictions adequately identify the location of vulnerable ground water, not least because it is unclear whether the tool used to identify the location of vulnerable ground water was appropriate. Moreover, EPA does not believe that no-application buffers that are not constructed and maintained for the purpose of reducing pesticide movement can successfully mitigate carbofuran runoff. Finally, even if all of the dietary risks could be eliminated for any individual use site (or group of use sites), the occupational and ecological risks associated with each use site are such that the risks cannot be mitigated to a level where the benefits outweigh the risks, particularly over the long term. Because all uses fail the risk-benefit prong of section 2(bb), EPA has not evaluated every theoretically possible crop combination to determine whether any isolated use(s) of carbofuran might pass the dietary risk prong of section 2(bb) if all other uses were canceled.

EPA has determined that all registered uses of carbofuran generally cause unreasonable adverse effects on the environment (pose an unreasonable risk to man and the environment). The human dietary risks resulting from the currently-registered uses of carbofuran are inconsistent with the safety standard of section 408 of the FFDCA. In addition, a substantial question exists as to the safety of carbofuran products, when they are used in accordance with widespread and commonly recognized practice, and the benefits of carbofuran use overall are generally minimal. Accordingly, EPA has concluded that the risks of continued use of carbofuran outweigh the benefits of continued carbofuran use.

VIII. Existing stocks

FIFRA section 6(a) allows the Agency to permit the continued sale and use of existing stocks of pesticide whose use has been canceled, to the extent the Administrator determines that such sale or use would not be inconsistent with the purposes of this Act.

As described above in Unit V, the Agency has determined that certain uses of carbofuran present moderate benefits to growers. These uses are: artichokes, spinach grown for seed, sunflowers, and pine seedlings in the Southeastern U.S. The Agency believes that currently, there are not enough affordable alternatives for these uses. Accordingly, in order to facilitate growers' transition to alternatives for these uses, EPA has determined that it would be appropriate to allow a short period to allow growers to use up existing stocks of carbofuran products. In addition, the Agency believes that allowing growers to use up remaining stocks would be preferable to having them disposed of in a landfill. EPA believes, however, that with the development of newer chemistries and other alternative pest control practices, the benefits of these uses will decrease. Therefore, an existing stocks period of three years, with some additional restrictions to ensure the risks are reduced to acceptable levels, would be appropriate, given the current risk/benefit analyses.

In making this determination, EPA was guided by the fact that none of these uses are expected to contribute significantly to dietary risk, or to ground or surface water contamination. These uses are also sufficiently small in geographic scope that, when taken with the additional label restrictions EPA will impose to mitigate ground and surface water contamination, EPA does not consider the ecological and worker risks to be unreasonable, given the limited period of time the uses would be permitted.

The Agency also has dietary risk concerns posed by exposure from drinking water sources. Modeling estimates of residues in surface and ground water from all uses result in residue values above EPA's level of concern. In addition, recent USGS NAWQA monitoring data show multiple detections at low concentrations. The Agency recognizes that shallow, slightly acidic groundwater sources are the most vulnerable to carbofuran contamination. Such groundwater sources are located primarily in portions of the Southeast and the east coast of the United States. The uses for which EPA is proposing to allow existing stocks are those that are not expected to significantly contribute to groundwater contamination since they are limited in spatial extent of production (artichokes), applied in arid regions or in areas where pH is higher (sunflowers), or limited due to method of treatment (pine seedling dip). Cancellation of all other uses will reduce the amount of carbofuran applied from approximately 1 million pounds annually to approximately 19,500 pounds of use remaining for three years.

EPA originally considered a phase-out for cucurbits, based on its 2006 analysis that indicated growers would face substantial increases in the cost of pest control, although yield and quality losses were not expected. Further analysis in 2007, including a review of the assessment submitted by the registrant for melons alone, confirmed EPA's findings that yield and quality losses would not occur with the use of alternatives. Further, while the alternatives are more costly, the impacts are estimated to be less than that for the crops listed above, representing about 5% of growers' net operating revenue, based on crop budgets for the affected states

EPA also originally considered a phase out for chili peppers. However, based on EPA's assessment for chili peppers, the Agency does not expect yield or quality losses from the registered systemic at plant alternatives imidacloprid and dinotefuran (registered in 2005). Although the alternatives are more expensive, this would result in a decrease in net operating revenues of 2% or less. Therefore, the Agency now concludes that most chili pepper producers derive relatively small benefits from the availability of carbofuran, and that available existing stocks should instead be diverted to higher benefit uses.

Based on these findings, I am authorizing continued sale and use of existing stocks of carbofuran for these uses for a period of no longer than 3 years from the date of the publication of this Notice. This period will not be extended to account for the amount of time that would be required to complete any cancellation hearing. Product that was released for shipment prior to the date of this notice, that is currently labeled for use on other crops may continue to be sold and distributed, if it has been relabeled for use solely on these four crops, consistent with EPA's order today.

IX. Procedural Matters

This Notice announces the Agency's intention to cancel each registration containing carbofuran. This unit explains how eligible persons may request a cancellation hearing, the consequences of requesting or failing to request such a hearing, and the procedures that will govern any hearing in the event one is requested.

A. How to Request a Hearing

A registrant or any other person who is adversely affected by the cancellation described in this notice may request a hearing. A request for a hearing must be submitted in writing within 30 days after the date of receipt of this notice, or within 30 days after publication of this notice in the Federal Register, whichever occurs later. Any other person adversely affected by the Agency's intent to cancel may request a hearing within 30 days of the date of publication of this Notice in the Federal Register. Although any adversely affected party may request a hearing, EPA will not hold a hearing unless (1) the registrant has either also requested a hearing, or has effectively authorized the requestor to pursue a challenge on its behalf, or (2) the requestor indicates an intention to themselves become a registrant of a carbofuran product.

All persons who request a hearing must comply with the Agency's Rules of Practice Governing Hearings, 40 CFR part 164. These procedures establish the following requirements: (1) Each hearing request must specifically identify by registration or accession number each individual pesticide product concerning which a hearing is requested, 40 CFR 164.22(a); (2) each hearing request must be accompanied by a document setting forth specific objections which respond to the Agency's reasons for proposing cancellation as set forth in this Notice and state the factual basis for each such objection, 40 CFR 164.22(a); and (3) each hearing request must be received by the Office of the Hearing Clerk within the applicable 30-day period (40 CFR 164.5(a)). Failure to comply with any one of these requirements will invalidate the request for a hearing and result in final cancellation of registration for the product in question by operation of law.

Requests for hearing must be submitted to: Hearing Clerk (A-110), U.S. Environmental Protection Agency, 1200 Pennsylvania Ave, N.W., Washington, DC 20460.

B. Consequences of Failure to File a Hearing Request

If no valid hearing request is submitted regarding a specific registration of a product containing carbofuran, the cancellation of registration for that product will be final and effective 30 days after receipt of this Notice by the registrant, or 30 days after publication of this Notice, in the Federal Register whichever comes later.

C. Consequences of Filing a Hearing Request

If a hearing concerning any product affected by this Notice is requested in a timely and effective manner, the hearing will be governed by the Agency's Rules of Practice Governing Hearings, 40 CFR part 164, and the procedures set forth in this Notice. In the event a hearing is held concerning a particular product, cancellation or denial of the registration for that product will not become effective except pursuant to an Order by the Administrator or his Judicial Officer. Any hearing will be confined to the specific registrations or applications concerning which the hearing is requested. All prehearing conferences and evidentiary or other hearings in any proceeding held pursuant to this Notice shall be conducted in the Washington, D.C. metropolitan area unless all parties stipulate to, and the presiding Administrative Law Judge approves, a different location.

D. Hearing Procedures

Any hearing concerning cancellation of or denial of registration for any pesticide product containing carbofuran will be held in accordance with FIFRA section 6(d). I am establishing a mandatory timetable for completion of any cancellation or denial hearing held pursuant to this Notice. The first prehearing conference concerning any cancellation or denial hearing must be held within 45 calendar days from the date of publication of this Notice or 15 days calendar days from the date of issuance of a final order concerning the issue of cancellation, whichever is later. The evidentiary phase of the hearing must be completed and the Administrative Law Judge must forward his recommended decision to me within 15 months of the date of the first prehearing conference. I or my judicial officer will then issue a final order concerning the issue of cancellation and/or denial within 90 days, as provided by FIFRA section 6(d).

As noted above, each hearing request must include specific objections which respond directly to the Agency's statement of reasons for cancellation and/or denial set forth in this notice. Requests for leave to amend objections after that time shall be ruled upon by the presiding Administrative Law Judge pursuant to 40 CFR 164.22(b), except that no party may be granted leave to amend his or her objections within 45 days of the scheduled commencement of the evidentiary hearing unless the presiding Administrative Law Judge determines that the information which provides the factual basis for such amendment was not available to that party and could not have been available to that party through the exercise of due diligence prior to 45 days before the scheduled commencement of the evidentiary hearing. The Administrative Law Judge shall by order dismiss any objections which have no bearing on whether use of the product(s) identified in the request for hearing, when used in accordance with widespread and commonly recognized practice, generally causes unreasonable adverse effects on the environment, and shall exclude any evidence offered by any petitioner which is not relevant and material to the issues raised by the remaining objections.

E. USDA and SAP Review

When the Agency intends to issue a Notice of Intent to Cancel, it must furnish a draft of that notice and an analysis of the impact of the proposed action on the agricultural economy to the Secretary of the Department of Agriculture (USDA)for comment at least 60 days prior to issuing the notice (FIFRA section 6(b)). In addition, the Agency must within the same time period submit the proposed cancellation action to the FIFRA Scientific Advisory Panel (SAP) for comment concerning the impact of the proposed action on health and the environment (FIFRA section 25(d)).

In the event that written comments are received from the USDA or the SAP within 30 days of such referral, the Agency must publish those comments and the Agency's response to the comments with the cancellation notice.

F. Separation of Functions

EPA's Rules of Practice forbid anyone who may take part in deciding this case, at any stage of the proceeding, from discussing the merits of the proceeding *ex parte* with any party or with any person who has been connected with the preparation or presentation of the proceeding as an advocate or in any investigative or expert capacity, or with any of their representatives (40 CFR 164.7).

Accordingly, the following EPA offices, and the staffs thereof, are designated as the judicial staff to perform the judicial function of EPA in any administrative hearing on the issue of cancellation: the office of the Administrative Law Judge, the office of the Judicial Officer, the Administrator, the Deputy Administrator, and the members of the staff in the immediate office of the Administrator and Deputy Administrator. None of the persons designated as the judicial staff may have any *ex parte* communication with the trial staff or any other interested person not employed by EPA on the merits of any of the issues involved in this proceeding, without fully complying with the applicable regulations.

The public docket containing the above references is located at . The references can be viewed from 8 a.m. to 4 p.m., Monday through Friday, except legal holidays.

Dated: _______________, 2008

____________________________________, Administrator.

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