NEW YORK CITY DEPARTMENT OF
HEALTH AND MENTAL HYGIENE
Mary T. Bassett, MD, MPH
Commissioner

Technical Memorandum

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New York City Comprehensive Mosquito Surveillance and Control

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A. INTRODUCTION AND OVERVIEW

In 1999, the New York City Department of Health and Mental Hygiene (DOHMH) detected an unusual cluster of encephalitis in north Queens. In collaboration with the U.S. Centers for Disease Control and Prevention (CDC) and the New York State Department of Health (NYSDOH), an epidemiologic investigation was initiated which identified the cause as the West Nile virus, a mosquito-borne disease never before detected in the Western Hemisphere. In response to this unprecedented outbreak, DOHMH began developing a Comprehensive Mosquito Surveillance and Control Plan (Comprehensive Plan) with the long-term goal of preparing for the prevention and control of all mosquito-borne diseases that pose a threat to public health. The Comprehensive Plan was to emphasize routine surveillance and control of potential mosquito breeding sites to prevent adult mosquitoes from proliferating in the City (Routine Program), and the control of adult mosquitoes to prevent disease throughout the City (Adult Mosquito Control Programs). In 2000 and 2001, DOHMH conducted a full environmental review of both of these programs under City Environmental Quality Review (CEQR). An Environmental Assessment Statement (EAS) concluded that the Routine Program—which included public education, mosquito surveillance and widespread application of pesticides targeting mosquito larvae (larvicides)—would not result in predicted significant adverse environmental impacts and DOHMH subsequently issued a negative declaration with respect to this action. The Adult Mosquito Control Programs—focusing on City-wide applications of pesticides targeted to adult mosquitoes (adulticides)—was determined to have the potential to result in significant adverse impacts, leading to a positive declaration under CEQR and the subsequent issuance of a comprehensive Final Environmental Impact Statement (FEIS) in July 2001. The results and conclusions of the FEIS informed the development of the City's comprehensive plan which has been further refined over the years since its initial implementation in response to the initial West Nile virus outbreak. This plan has thus far targeted the *Culex* species of mosquito, the vector for West Nile virus.

Since 1999, West Nile virus has been the only locally acquired mosquito-borne disease in New York City. However, on February 1, 2016, the World Health Organization declared Zika virus a Public Health Emergency of International Concern, and New York City began studying the potential threat posed by Zika to New York City.

Zika virus is transmitted to humans in the Western Hemisphere primarily via the *Aedes aegypti* mosquito, a species not found in New York City. However the related *Aedes albopictus* mosquito is present in New York City and laboratory studies suggests that this species may also be an effective vector for the disease. Based on the significant risk that Zika poses to human health, NYSDOH issued an emergency regulation (effective March 17, 2016) requiring local health departments to adopt and implement a "Zika Action Plan as a condition of State aid for public health activities." [1]

[1] 10 NYCRR 40-2.24.

In 2016, DOHMH initiated the Zika Mosquito Control Plan targeting the *Aedes albopictus* mosquito. For the 2017 season, Zika prevention efforts have been incorporated into the Comprehensive Plan. However, since there has been no evidence of Zika transmission by *Aedes albopictus* in the United States or elsewhere, Zika response activities in the City will be reduced in comparison to the 2016 mosquito season.

In an effort to update and to further refine its longstanding Comprehensive Mosquito Surveillance and Control Plan to address both West Nile virus and Zika virus, DOHMH will consider the application of certain larvicides and adulticides that were not specifically analyzed in the 2000 EAS and 2001 FEIS. Through updated and new literature reviews of the relevant active ingredients contained in the currently proposed larvicides and adulticides, a review of anticipated means and methods for application, and a re-examination of the previous risk assessments, this Technical Memorandum determines whether the proposed modifications would result in any potential predicted significant adverse environmental impacts not previously identified and considered in the 2000 EAS and 2001 EIS.

B. ZIKA VIRUS

The Zika virus is a flavivirus (from the family Flaviviridae) that was first identified in 1947 in a rhesus monkey in Uganda and later recovered from the mosquito *Aedes africanus* in 1948. It was first identified in humans in 1952 in Uganda and the United Republic of Tanzania. The first large outbreak of Zika began in 2007 in the Pacific Island of Yap in the Federated States of Micronesia, where an estimated 73% of the island's population had been infected (Imperato 2016); in 2013 and 2014, outbreaks occurred in four other groups of Pacific islands. In 2015, Brazil confirmed that Zika was circulating throughout the country, and began reporting an unusual increase in the number of cases of microcephaly in newborns later that year (WHO 2017a). Microcephaly is a neurological condition in which an infant's head is much smaller than the heads of other children of the same age and sex (Mayo Clinic 2016a). This condition can be severe, and children with microcephaly can experience a range of problems, including developmental delays and seizures (CDC 2016). The Zika outbreak in Brazil also led to increased reports of Guillian-Barre syndrome, a disorder where the body's immune system attacks its nerves, causing weakness and tingling and sometimes more severe symptoms (Mayo Clinic 2016b). In July 2016, the CDC announced a likely local mosquito-borne Zika virus transmission in the continental United States (USFDA 2017). Since then, local mosquito-borne Zika transmissions have only occurred in Florida and Texas.

Zika is transmitted to humans primarily by infected *Aedes aegypti* mosquitoes (not present in New York City), though other species of mosquitoes may also transmit the virus, such as *Aedes albopictus* (present in New York City) (Hart et al. 2017, VDCI 2017). *Aedes aegypti* also transmit dengue, yellow fever virus, and chikungunya virus. Recent data suggests a 3 to 14 day incubation period after a person is infected with the virus before they become symptomatic. Those who develop symptoms more than 2 weeks after travel or a recent positive test result should be evaluated for other forms of transmission, such as sexual transmission, or local vector-borne transmission (Krow-Lucal et al. 2017), as the Zika virus usually only remains in the blood of an infected person for about a week (CDC 2017). Approximately 80% of people infected will not develop any symptoms; those that do most commonly develop a fever, rash, headache, joint pain, conjunctivitis, and/or muscle pain (CDC 2017). The symptoms are usually minor and most people do not require hospitalization. The primary public health concern is the infection of pregnant women because of potential severe outcomes associated with congenital infection, including microcephaly and other birth defects. Zika can be passed from a pregnant woman to her fetus at any point during the pregnancy and result in a number of birth defects or problems later in life (CDC 2016).

The virus is thought to spread widely during an outbreak. The number of cases of symptomatic Zika infection in the United States jumped from 61 in 2015 to 5,102 in 2016. In 2015, no cases were acquired through local mosquito-borne transmission. In 2016, 224 of the 5,102 total reported cases were presumed to be acquired through local mosquito-borne transmission in Florida and Texas, while 48 cases were acquired through either sexual transmission, laboratory transmission (only 1 case) and person-to-person transmission (also only 1 case) (WHO 2017b). The number of symptomatic cases reported so far

exclusively in 2017 (up until May 24th) is 121, with no cases yet presumed to be a result of local mosquito-borne transmission (WHO 2017b).

Zika virus is different from West Nile virus in a number of ways, and thus requires a different public health response than what has been developed for West Nile. West Nile is primarily spread by the *Culex* sp. mosquito, while Zika is spread mainly by *Aedes* mosquitoes. Those at greatest risk for infection and subsequent severe consequences from Zika are the developing fetus, while those at greatest risk for West Nile virus are individuals over 60 years of age and those who are immunocompromised.

A quarter of all infants born with birth defects associated with Zika (n=16) in the United States were from women residing in New York City (Santora 2017). These cases were all associated with travel to a country where Zika is transmitted locally, with 11 cases a result of sexual transmission with someone who had traveled to Zika affected countries (Santora 2017). Since January 2016, 402 pregnant women, and 23 newborns in New York City have shown laboratory evidence of Zika infection. While local transmission within New York City is not likely at this time, the virus is active in areas where New York City residents travel to, such as Central America, South America, the Caribbean, the Pacific Islands, Mexico, Puerto Rico, and Southeast Asia.

C. PROPOSED MODIFICATIONS TO COMPREHENSIVE MOSQUITO SURVEILLANCE AND CONTROL PROGRAM

The development and implementation of the City's Comprehensive Mosquito Surveillance and Control Plan was informed by the results and conclusions of the 2001 FEIS and has been modified over time since 2001 as a result of additional knowledge gained through further investigations and accumulated through many years of practical control practices. The current plan is based on the principles of Integrated Pest Management. Key components include:

- Public Education and Community Outreach;
- Human Surveillance and Provider Education;
- Mosquito Surveillance;
- Larval Mosquito Control;
- Adult Mosquito Control;
- Surveillance of Potential Adverse Health Effects from Pesticide Exposure; and
- Research and Evaluation.

In 2016, DOHMH initiated a Zika Mosquito Control Plan drawing upon the longstanding Mosquito Surveillance and Control Plan, and with a goal to identify, characterize and control *Aedes* species mosquitoes, treating them as a public nuisance and a potential Zika disease vector. Several factors related to Zika prompted the consideration of modifications to the approach used thus far to control the spread of West Nile virus. These include the limited sensitivity of Zika testing, the lag in the period of time when a person may transfer viable virus to mosquitoes, the risk of locally transmitted disease and the consequences of infection, specifically the known potential for *Aedes* mosquitoes to transmit Zika virus between humans, the aggressive breeding and biting behavior of Aedes mosquitoes, the anticipated large pool of imported human cases into NYC in future years and the devastating consequences of infection of pregnant women and their infants.

DOHMH is currently proposing modifications to the Comprehensive Plan in order to optimize the control of both the *Culex* and the *Aedes* species. Any modifications proposed to the education and outreach, surveillance activities and research and evaluation aspects of the plan would not require environmental review. However, DOHMH is proposing the use of certain larvicides (for larval mosquito control) and adulticides (for adult mosquito control) that were not specifically considered in the 2000 EAS and 2001 FEIS. These products are registered with the U.S. Environmental Protection Agency (EPA) and the New York State Department of Environmental Conservation (NYSDEC). DOHMH will only apply products

that are permitted by NYSDEC. The following sections summarize the additional products being considered.

ADDITIONAL REGISTERED PRODUCTS PROPOSED FOR USE

ADULTICIDES

There are typically two primary constituents found in adulticide products: the "active" ingredient, and "inert" ingredients. Since the "active" ingredient in an adulticide product is the chemical component in the adulticide that is intended to target and eradicate the adult mosquito, it is of primary significance for the environmental impact assessments. The two classes of adulticides registered for community-scale use in New York State and analyzed in the 2001 FEIS were organophosphates and pyrethroids. At this time, DOHMH is considering the use of two additional pyrethroid products that were not analyzed in the 2001 FEIS: Duet and DeltaGard. The active ingredients in Duet include sumithrin (also known as d-phenothrin or phenothrin) and prallethrin with the synergist Piperonyl Butoxide (PBO), and the active ingredient in DeltaGard is deltamethrin. It should be noted that sumithrin was previously analyzed in the 2001 FEIS as the active ingredient in the product Anvil 10+10.

Table 1 provides a summary of the additional proposed pyrethroid products.

Table 1
Additional Proposed Pyrethroid Adulticides Products

Adulticide	Active Ingredient (% in Product)	Maximum Application Rate (lbs/acre)	Maximum Application Rate per Year (lbs/acre)	Application Technique	Label Limitations
Duet	Sumithrin (5) $C_{23}H_{26}O_3$	0.0036	0.01	ULV Spray; Backpack, aircraft, truck, ground; Outdoor residential/ recreational areas, Vegetation surrounding parks, woodlands, swamps, marshes, overgrown areas, golf courses	Do not apply over bodies of water except when necessary to target areas with adult mosquitoes; Do not contaminate water when disposing or cleaning equipment; Apply only when wind> 1 mph, temperature>50F; Do not exceed 0.1 lb/acre per year
	Prallethrin (1) $C_{19}H_{24}O_3$	0.00072	0.02		
	Piperonyl Butoxide (5) $C_9H_{30}O_5$	0.0036	0.1		
DeltaGard	Deltamethrin (2) $C_{22}H_{19}Br_2NO_3$	0.00134	0.036	ULV Spray; Handheld, backpack, truck, no aircraft	Do not apply over bodies of water except when necessary to target areas with adult mosquitoes; Do not exceed 0.036 lb/acre at one site per year

Sources: EPA and NYSDEC registration labels.

LARVICIDES

As stated in the Comprehensive Plan, DOHMH currently uses biological larvicides with the active ingredients *Bacillus sphaericus* and/or *Bacillus thuringiensis var. israelensis* (*Bti*) and/or the chemical larvicide methoprene. *Bacillus sphaericus* and *Bti* are naturally occurring soil bacteria that produce toxins which control mosquito larvae, but lack toxicity to humans and other non-target organisms. Methoprene is an insect growth regulator used to control many types of insects. Following the reduction of mosquito breeding areas and modification of habitat, larviciding of mosquito breeding habitat (catch basins, storm drains, borders of stagnant freshwater ponds, freshwater wetlands and saltmarshes) is the most efficient method of controlling adult mosquitoes. While not a required commitment based on the 2001 FEIS

analyses, as presented in the Negative Declaration for the DOHMH Proposed Routine Comprehensive Arthropod-Borne Disease Surveillance and Control Program (2000, CEQR Number 00DOH001Y), DOHMH initially applies only biological larvicides at locations with the potential to affect freshwater and tidal water bodies and sensitive aquatic natural resource habitats. Chemical larvicides such as methoprene would only be applied when the biological larvicides are determined to have been ineffective, on the basis of surveillance data. No extended release larvicides such as methoprene briquettes or pellets are currently placed in freshwater or tidal wetlands under the jurisdiction of the NYSDEC. The application of liquid methoprene to these areas would require the submission of additional information to the NYSDEC. Similarly, for catch basins that allow stormwater to infiltrate into soil (i.e., seepage basins) or that discharge directly to surface waters, biological larvicides are currently applied initially. Should mosquito populations develop resistance to the biological larvicides, DOHMH needs to be able to apply chemical larvicides in order to effectively control mosquito populations and minimize the need for adulticides. Thus far, DOHMH has used methoprene only when the biological larvicides have not produced the desired results, and in briquet form (a block that is placed in the water where mosquitoes breed, releasing larvicide slowly over weeks to months). These applications have only occurred in catch basins that do not discharge directly to surface waters or infiltrate to ground water. At this time, DOHMH is beginning to use Altosid XR-G (an extended-release methoprene-based larvicide granule) and Vectoprime (a biological larvicide containing methoprene) in granular form, and potentially by aircraft in non-residential and residential areas where biological controls have been shown to be ineffective. Two additional larvicides not considered in the 2000 EAS are also being considered: NyGuard, containing the active ingredient pyriproxyfen; and Natular DT, containing the active ingredient spinosad.

Table 2 provides a summary of the additional proposed larvicide products.

Table 2
Additional Proposed Larvicide Products

Larvicide	Active Ingredient (% in Product)	Maximum Application Rate (lbs./acre)	Application Technique	Label Limitations
Altosid XR-G	Methoprene (1.5) $C_{19}H_{34}O_3$	0.3	Granular; Aircraft, ground; Marshes, wetlands, large container, ponds, pools, standing water	Do not apply to drinking water; Do not contaminate water when disposing or cleaning equipment.
VectoPrime	Methoprene (0.1) $C_{19}H_{34}O_3$	0.02	Granular; Aircraft, ground; Marshes, wetlands, large container, ponds, pools, standing water	Do not apply to drinking water; Do not contaminate water when disposing or cleaning equipment.
NyGuard	Pyriproxyfen (10) $C_{20}H_{19}NO_3$	0.223	ULV Spray; Backpack, handheld; Contained water (drains, catch basins)	No truck or aerial application; No natural or active waterways.
Natular DT	Spinosad (7.48) $C_{41}H_{65}NO_{10}$ (Spinosyn A) $C_{42}H_{67}NO_{10}$ (Spinosyn D)	0.5	Tablet; 1 tablet/50 gallons; Contained water (drains, catch basins);	No public waterways; No drinking water; Do not contaminate water when disposing or cleaning equipment; Reapply every 60 days; Only to artificial water containers that cannot be drained; try draining first.

Sources: EPA and NYSDEC registration labels.

These proposed modifications to the Comprehensive Plan are analyzed below.

D. ENVIRONMENTAL ANALYSIS

FRAMEWORK OF ANALYSIS

In analyzing the potential environmental impacts associated with application of larvicides and adulticides, the 2000 EAS and 2001 FEIS considered the various products (including active ingredients and inerts) that could be applied, where and how they would be applied, and what exposure scenarios for individuals and biota would be created by the application.

The 2000 EAS concluded that the application of the larvicides to be used as part of the Comprehensive Plan would not result in any significant adverse environmental impacts. The currently proposed modifications would introduce additional larvicide products and methods of application to the plan and these modifications are therefore considered in this Technical Memorandum.

The framework of the analysis used in the 2001 FEIS was based on the following:

- Examination of Products;
- Drift/Deposition Modeling;
- Environmental Types;
- Representative Areas for Analysis; and
- Exposure Scenarios

The proposed modifications would include products that were not previously analyzed in the 2000 EAS or 2001 FEIS. This Technical Memorandum will focus on the active ingredients found in these products, as outlined in Tables 1and 2 above. While drift/deposition models have been updated since the FEIS was completed, the maximum predicted concentrations would be expected to be similar and within the same order of magnitude of the conservatively predicted concentrations presented in the FEIS.

The environment types considered in the 2001 FEIS included residential, parks and publicly open spaces, natural resources, community facilities and institutional uses, commercial uses and industrial uses. The FEIS also selected representative areas for analysis to include the full range of environment types found in New York City. These analysis assumptions would not change with the proposed modifications.

As noted in the 2001 FEIS, an exposure scenario describes the way by which a person or biota can potentially be exposed to adulticides as a result of spraying. Exposure scenarios are defined by the potential "populations" (public health) and "receptors" (natural resources) that may be exposed, and the "pathways" by which they may be exposed. The proposed modifications would not introduce any new populations and receptors that could be exposed, or any new pathways by which they may be exposed.

The following are other key reasonable worst case application assumptions used in the 2001 FEIS:

- Frequency of application (reasonable worst-case)
    - Day 1—Day 4—Day 14—Day 17—Day 27—Day 30—Day 40—Day 43—Day 53—Day 56
- Distance to Receptor
    - 25-600 ft (at 25 foot intervals), 750 ft, 1000 ft, 2000 ft
- Time of Day
    - near dusk, overnight, or at dawn
- Buffer around Open Waterbodies
    - 100-foot (by truck), 300-foot (by aircraft)

These reasonable worst case assumptions have informed the practices outlined in the Comprehensive Plan since 2001, and with the exception of the buffer around open waterbodies, these assumptions remain in place and would not be affected by the proposed modifications. With respect to the buffer around open waterbodies, DOHMH has increased the buffer to be more protective around open waterbodies, to a distance of between 300-350 feet for both ground and aerial adulticide applications.

SCREENING

As mentioned above, the 2000 EAS concluded that the application of the larvicides to be used as part of the Comprehensive Plan would not result in any significant adverse environmental impacts.

The 2001 FEIS examined in detail the potential for environmental impacts from the application of adulticides with regard the following areas of concern: land use, community facilities, public policy and zoning; public health; natural resources; water supply; water quality; infrastructure; hazardous materials; socioeconomic conditions; open space resources; cultural resources; visual resources; transportation; air quality; noise; energy; and growth inducing aspects.

Potential significant adverse impacts were identified in the areas of natural resources, water quality and noise. The potential predicted significant adverse natural resources impact was related to the application of malathion (an organophosphate adulticide), to crustaceans from runoff after application over large land areas that drain to Jamaica Bay and other inlet bays. The predicted significant adverse water quality impact was also related to the use of malathion, resulting in exceedances of the water quality standard from runoff. Potential significant adverse noise impacts were predicted from aircraft and police escort/truck operations. The proposed modifications to the Comprehensive Plan would not alter the conclusions of the 2001 FEIS in these areas. If DOHMH were to consider the use of malathion (an organophosphate product) in controlling adult mosquito populations, the potential for these significant adverse impacts would occur and the proposed mitigation measures outlined in the 2001 FEIS would apply. It should be noted that since 2001, only pyrethroid products have been used by DOHMH for adult mosquito control. With respect to noise, potential impacts from aircraft and police escort/truck operations would continue with or without the proposed modifications.

There were no significant adverse impacts found in the areas of: land use, community facilities, public policy and zoning; infrastructure; hazardous materials; socioeconomic conditions; open space resources; cultural resources; visual resources; transportation; air quality; energy; and growth inducing aspects. The proposed modifications would not affect the conclusions of the 2001 FEIS in these areas.

While the 2000 EAS and 2001 FEIS did not identify any significant adverse impacts with respect to public health, the the currently proposed modifications to the Comprehensive Plan would introduce additional products that were not previously examined. Therefore, as with the 2001 FEIS, the key analysis areas of this Technical Memorandum are public health, natural resources (including water quality) and water supply.

The following analyses address whether the proposed modifications to the Comprehensive Plan would result in any new significant adverse impacts in the areas of public health and natural resources not already identified in the 2000 EAS and 2001 FEIS.

NATURAL RESOURCES AND WATER QUALITY

SUMMARY OF FINDINGS FROM THE 2001 FEIS

Natural Resources

The 2001 FEIS assessed the potential effects to the City's natural resources from the application of certain pesticides registered to be applied as extremely small droplet sizes or Ultra-Low Volume (ULV) droplets to kill mosquitoes in flight (i.e., adulticides). The assessment characterized the natural resources within the Representative Areas to identify the potential receptors (i.e., organisms or habitats that could be exposed to pesticides) within the City. Then, an ecological risk assessment was conducted to determine the likelihood that the pesticides would adversely impact wildlife survival and fitness, and environmental quality.

The methodology used for the ecological risk assessment consisted of the following:

- Literature Review—The existing literature was reviewed to provide information on the physical and chemical characteristics of the pesticides, to assess the toxicity to natural resource species, to characterize the fate and effects of the pesticides in the environment, to evaluate the results of empirical studies of the effects to natural resources from the application of adulticides in the natural environment.

- Screening Level (Tier I) Risk Assessment—The objective of the screening-level risk assessment was focus the overall ecological risk assessment process by eliminating from consideration those possibilities that do not have the potential for resulting in adverse effects to plants or animals.
- The Detailed (Tier II) Risk Assessment—The Tier I assessment identified those stressors and pathways which would require additional investigation prior to making decisions regarding potential ecological risk. The purpose of the focused or detailed (Tier II) risk assessment was to evaluate the areas needing further assessment under more realistic conditions and assumptions to better reflect the City's current conditions, such as those found within the Representative Areas.

A weight of evidence approach that incorporated the results of empirical studies and conclusions drawn from the risk assessments was then used to assess the potential effects of the active ingredients to the City's natural resources.

As presented in the 2001 FEIS, the Tier I ecological risk assessment identified the potential for adverse effects to certain biological groups that needed to be addressed on a more detailed level in the Tier II assessment:

- Terrestrial receptors (Insects with Direct Exposure—Non-target beneficial insects exposed to any of the adulticides;
- Aquatic receptors in ponds exposed to drift—All groups exposed to adulticides except (a) mollusks exposed to permethrin and (b) crustaceans exposed to sumithrin;
- Aquatic receptors in wetlands exposed to runoff—In freshwater, all groups exposed to all adulticides except (a) mollusks exposed to permethrin and (b) crustaceans exposed to sumithrin. In salt water, all groups exposed to all adulticides;
- Receptors exposed through the terrestrial-based food chains—There was a slight possibility of adverse effects for grass-eating mammals exposed to permethrin; and
- Receptors exposed through aquatic-based food chain bioaccumulation—There was a slight possibility of adverse effects for mammals exposed to naled, and possible risk to birds and mammals exposed to permethrin and resmethrin[2], from consuming fish that have bioconcentrated these adulticides.

The Tier II assessment analyzed these risks within the context of the resources found within the City, further refining the assumptions to represent the existing conditions. The Tier II analysis concluded that there would be no potential significant adverse impacts on organisms exposed to the active ingredients through food chain bioaccumulation. While the Tier II assessment concluded that several of the risks identified in Tier I would not result in adverse effects to the City's natural resources, it also concluded that certain of the pathways identified in Tier II did have the potential to adversely affect certain natural resources within the City.

The habitats and characteristics of these Representative Areas were utilized to assist in the evaluation of the potential Citywide impacts on natural resources from the Proposed Action. Screening level (Tier 1) and focused (Tier II) ecological risk assessment methods were used to assess the potential adverse impacts on biological receptors from the Proposed Action. In addition, assessments were performed to determine the potential impacts from the operations of the mechanical equipment (such as trucks, all-terrain vehicles and aircraft) on natural resources. The risk assessment calculations were weighted with results from empirical studies, and best professional judgment, to assess the effects and significance of potential impacts of the various active ingredients on resources found in the Representative Areas (and

[2] While resmethrin was previously considered a product for the Comprehensive Plan, after December 31, 2015, resmethrin registrants will no longer be able to sell and distribute resmethrin products. However, users will be able to continue using any product they have purchased.

therefore, in the City), in accordance with guidelines in the CEQR Technical Manual for determining significance.

Jamaica Bay, included as one of the Representative Areas, was identified as containing natural resources particularly susceptible to potential effects from the application of adulticides because it is nearly completely enclosed by land with only a narrow inlet to the Atlantic Ocean (between the Rockaway Peninsula and Brooklyn); and approximately 36,700 acres of Brooklyn and Queens, most of which is fully developed, drain to the bay through combined sewer overflows (CSOs) and storm sewers. These impacts could occur if significant portions of the drainage area in Brooklyn and Queens were subject to adulticiding actions, and significant rainfall follows within a short period after the applications, resulting in the transport and discharge of adulticides into Jamaica Bay.

While Jamaica Bay is a unique ecosystem and the only Critical Environmental Area in New York City, there may be other inlet bays in New York City (e.g., Little Neck Bay in Northern Queens) that exhibit similar characteristics with respect to limited tidal flushing and large storm water discharges. These inlet waterbodies may also experience potential significant adverse impacts on crustaceans like those predicted for Jamaica Bay from the runoff of malathion.

The 2001 FEIS concluded that application equipment, including trucks or aircraft applying adulticides would not result in significant adverse impacts to natural resources. Additionally, the inerts present in the adulticides would not result in significant adverse impacts to natural resources.

Analyses Which Identified Terrestrial and Aquatic Organisms with No Potential for Adverse Impacts
Based on the results of the Tier I and II analyses, the review of empirical studies, and best professional judgment, the 2001 FEIS identified several pathways where there would be no potential effects on major groups of terrestrial and aquatic organisms. These pathways and biota are summarized below.

<u>All Active Ingredients</u>

- Birds and mammals by direct inhalation of adulticides.
- Birds by ingestion due to preening of adulticides which could have deposited on their feathers.
- Pets by direct inhalation or drinking water from puddles formed by rainfall after application of adulticides.
- Birds and mammals ingesting adulticides indirectly through the terrestrial-based food chain (including feeding on grass, seeds, or insects that could have adulticides deposited on them), and predators such as raptors feeding on mammals which have ingested adulticides.
- Birds and mammals ingesting adulticides indirectly through the aquatic food chain (including raptors feeding on fish that may have accumulated active ingredients from runoff into the water column).
- Organisms in the large water bodies of New York Harbor, including the East River, New York Harbor, Hudson River, and Harlem River, with the exception of Jamaica Bay or other inlet bays with limited tidal flushing and large stormwater discharges.
- Endangered Species—The Federally listed piping plover and seabeach amaranth occupy beach areas that would not be subject to spraying. The endangered shortnose sturgeon and sea turtles that occasionally occupy the waters of the New York area are not expected to be adversely impacted by application of the active ingredients. Potential impacts to species of special concern would be minimized by observance of the City's voluntary no-spray setbacks for wetlands and waterbodies.
- Wildlife Habitat—The application of adulticides would not result in any major physical disturbance or permanent loss of habitat or affect habitat function.

<u>Organophosphates</u>

- Malathion—Fish from runoff, and amphibians via drift in freshwater habitats;

- Naled—Aquatic insect larvae, mollusks, and fish via drift, and crustaceans, brown algae, fish, and mollusks from runoff.

Pyrethroids

- Permethrin—Aquatic insect larvae, mollusks, and fish, in ponds via drift, and fish and mollusks from runoff;
- Resmethrin—Aquatic organisms in ponds via drift, and crustaceans, fish and mollusks, and species in streams, after consideration of dilution and partitioning to sediments or plant material.
- Sumithrin—Organisms in ponds, wetlands, and estuarine habitats from drift or runoff.

Synergist PBO—Organisms in ponds, wetlands, and estuarine habitats from drift or runoff.

Groups of Terrestrial and Aquatic Organisms Which Could Be Adversely Affected By the Application of Adulticides

Based on Tier I and II risk assessment calculations, the 2001 FEIS identified several groups of terrestrial and aquatic organisms with the potential to be adversely affected by the application of adulticides by one of three pathways:

- drift and deposition onto freshwater ponds;
- direct contact with airborne adulticides; or
- runoff of adulticides from rainfall after application.

All Active Ingredients

Non-target insects and other terrestrial arthropods from direct contact with airborne adulticides.

Organophosphates

- Malathion—Organisms, including crustaceans and aquatic insect larvae, in ponds, wetlands, and estuarine habitats through deposition of drift or from runoff.
- Naled—Crustaceans in ponds via deposition from drift; aquatic organisms from runoff entering wetlands.

Pyrethroids

- Permethrin—Crustaceans, in ponds via deposition from drift, aquatic organisms from runoff entering wetlands, and crustaceans from runoff entering Jamaica Bay or tidal creeks, such as Lemon Creek.
- Resmethrin—Crustaceans and fish from runoff entering wetlands.

The 2001 FEIS concluded that while there may be some adverse effects and losses of individual non-target organisms as a result of the adult mosquito control program, these potential adverse effects are for the most part not considered to be significant adverse impacts.

Non-Target Insect and Other Arthropod Terrestrial Wildlife Impacts

The 2001 FEIS concluded that while there may be some adverse effects and losses of individual non-target organisms as a result of the adult mosquito control program, these potential adverse effects are for the most part not considered to be significant adverse impacts. While there would be individual losses of non-target insects and other arthropods in the areas near the application of adulticides, especially for night flying arthropods, such diminutions of the insect populations immediately, during, and after the adulticide application are not considered to be significant adverse impacts. The application of adulticides would be limited temporally and spatially, would not occur for the full spring, summer, and fall periods, and large areas would be exposed to far fewer than the 10 applications per year assumed in the technical analysis of effects of multiple applications. Potential adverse impacts to non-target organisms, primarily arthropods other than mosquitoes, are likely to be limited to those species that fly or are active during the nighttime hours. Nighttime flying insects would likely be exposed to adulticides in the same way in which mosquitoes would be exposed. Arthropod populations from neighboring unsprayed communities would

be likely to repopulate neighboring areas that have experienced short-term losses from the application of adulticides. Insects that fly and are active during the day, such as butterflies and bees (i.e., beneficial pollinators of plants), would likely have less exposure, other than potential residues on plants, to adulticide applications.

Deposition of Drift into Ponds

Results of the Tier I and Tier II studies indicated that direct drift into ponds would not result in potential adverse impacts on most aquatic organisms. The exceptions were on crustaceans for permethrin and naled, and on crustaceans, insect larvae, and possibly fish for malathion. While the ecological risk assessment studies indicated these possible adverse impacts, results of empirical studies suggest that the actual environmental exposure from direct application for mosquito control may not result in adverse effects in ponds. Additionally, the analyses performed for the FEIS used conservative assumptions that resulted in an overestimate of the exposure concentration (i.e., it did not account for all potential sources of adulticide degradation that would reduce the environmental concentration), as demonstrated by the results of water quality sampling conducted by the City in 2000 during adulticiding operations which generally did not find detectable levels of sumithrin and PBO following spray events. The potential for drift and deposition of adulticides onto ponds would not be expected to have a significant adverse impact on aquatic species in most cases.

Potential Runoff into Streams, Wetlands and Other Water Bodies

The 2001 FEIS identified a potential for individual losses of aquatic organisms in the waterbodies of New York, due to runoff from rainfall after application of adulticides. These potential effects would largely occur at and near the point of discharge into a waterbody, with malathion having the greatest potential for adverse effects, followed by naled, permethrin, resmethrin, PBO and sumithrin. While there may be some losses of individual non-target organisms as a result of the Proposed Action, these potential adverse impacts are not considered to be reflective of a significant adverse impact because of the limited temporal and spatial extent of the potential losses, the ability of benthic communities to recover quickly following the cessation of spraying activities. Additionally, the analyses performed for the FEIS used conservative assumptions that resulted in an overestimate of the exposure concentration (i.e., it did not account for all potential sources of adulticide partitioning such as to plant material, sediment, and organic matter in CSOs and storm sewers) that would reduce the environmental concentration. Further, many of the receiving waters such as the East River, New York Harbor, Hudson River, and Harlem River are fairly rapidly flushed and have a sufficient volume to significantly reduce the concentration of these active ingredients.

Potential Significant Adverse Impacts from The Proposed Action

The 2001 FEIS did identify a potential for application of malathion to result in significant adverse impacts to crustaceans in inlet bays, such as Jamaica Bay. Potential concentrations of malathion (due to runoff if a storm event occurs after application of malathion over a large land area that drains to Jamaica Bay) could be well above the estimated no effect levels for crustaceans in Jamaica Bay, particularly in the shallower, near shore areas. Field monitoring data of measured malathion levels in waterways after application of the adulticide in other parts of the country support the determination that malathion has the potential to become entrained into storm water and discharged into urban water bodies. Other inlet bays, such as Little Neck Bay, which receive a significant amount of stormwater runoff and have limited tidal flushing, may also have significant impacts predicted for crustaceans.

Water Quality

The 2001 FEIS assessed the potential for application of adulticides under the Mosquito-Borne Disease Control Program to affect water quality within the representative study areas and the primary surface-water bodies of the City. Of the adulticides evaluated in the FEIS, only malathion has a water quality standard for certain NYSDEC Surface Water Classification (0.1 µg/L for certain classes). On the basis of the estimated environmental concentrations (EEC) from the Tier I and Tier II risk assessments and results of empirical studies, the FEIS concluded that the application of malathion has the potential to impact water quality and exceed the State standard in surface water that does not have large flow volumes,

particularly in small water bodies receiving stormwater runoff, as well as waterbodies such as Van Cortlandt Pond, tidal basins of Jamaica Bay, and tidal systems such as Jamaica Bay and Lemon Creek that receive stormwater discharges. The application of malathion under the Mosquito-Borne Disease Control Program would have little potential to result in surface water malathion concentrations that exceed the standard for the larger water bodies surrounding the City such as the Hudson River, East River, New York Harbor, and Raritan Bay. Similarly, on the basis of the EECs calculated in the Tier I and Tier II risk assessments, the other organophosphate pesticide evaluated, naled, was also determined to have a potential to adversely affect ponds and water bodies with restricted tidal exchange that receive stormwater discharges, but was not determined to have the potential affect water quality of the larger tidal waters surrounding New York City.

Due to the affinity of the pyrethroids evaluated (permethrin, sumithrin, and resmethrin) to bond to soil particles, organic material and other particulates in the water column, and to sediment, and taking into consideration the setback required to protect water bodies during adulticide application, the application of the pyrethroid adulticides were determined to have little potential to result in significant adverse impacts to water quality of surface waters within and surrounding New York City. This conclusion was supported by the results of the post-application water quality sampling and observations during the spray events conducted by the City from July through September 2000. In order to address the risk of impacts to natural resources, NYSDEC requested that the City sample specific water bodies within the spray zones before and after the spray event; inspect the specified water bodies within 24 hours of spraying to check for fish kills or other impacts; establish for aerial applications a 300-foot no-spray setback from open water bodies, surface waters with emergent marsh vegetation, and tidal regions; establish for ground applications a 100-foot no-spray setback around water bodies; and prevent ground spraying on approaches and bridges over surface waters. Out of the 68 post-application samples collected by the City, only two had concentrations of either sumithrin or PBO greater than the 0.5 µg/L Practical Quantitation Limit (PQL) and neither of these two exceedances had corresponding observations of fish kills or other observations of adverse impacts to aquatic biota.

LITERATURE REVIEW

The 2001 FEIS included an assessment of potential impacts to natural resources from the implementation of the DOHMH adult mosquito control program. The natural resource assessment included a literature review assessing the effects of pesticides to natural resources based on peer-reviewed articles, and government documents and databases. The information review compiled information on the chemical and physical characteristics of the active ingredients, toxicity to animals and plants, and fate and effects in the environment. Databases used as sources included:

- United States Environmental Protection Agency (USEPA) including the Office of Pesticide Programs;
- U.S. Geological Survey (USGS);
- EXTOXNET;
- U.S. Department of Agriculture (USDA);
- National Library of Medicine-National Institute of Health (NIH); and
- World Health Organization (WHO).
- Government documents were accessed via the National Technical Information Service (NTIS).

Many of these databases and websites are still updated or have been replaced in-kind, and were consulted to update the literature review conducted for the adulticide Anvil 10 + 10 (active ingredient sumithrin with synergist piperonyl butoxide [PBO]) evaluated in the 2001 FEIS and for the following adulticides and larvicides that are the subject of this technical memorandum:

- The adulticide DUET (active ingredients sumithrin and prallethrin and synergist PBO) which was not evaluated in the 2001 FEIS but used in 2016 and proposed for use in the Zika Mosquito Control Plan;

- The adulticide DeltaGard (active ingredient the pyrethroid deltamethrin);
- Airborne application of the granular formulation of the larvicide methoprene—a growth regulator;
- The larvicide pyriproxyfen—an insect growth regulator; and
- The larvicide spinosad—a naturally derived insect neurotoxin.

Government documents previously only available through NTIS are now readily searchable and accessible through the NIH, USEPA, and WHO.

The literature review updated the previous assessment on effects of sumithrin/d-phenothrin and PBO on natural resources, and conducted a new assessment of potential effects of prallethrin, methoprene pyriproxyfen and spinosad. Information compiled included environmental fate and effects, physical and chemical properties, bioconcentration factors, toxicity to natural resource species, and surface water quality standards. Databases consulted included:

- USEPA Office of Pesticide Programs (OPP) Pesticide Chemical Search (https://iaspub.epa.gov/apex/pesticides/f?p=chemicalsearch:1) USEPA OPP Ecotoxicity Database (http://www.ipmcenters.org/ecotox/), USEPA ECOTOX knowledgebase (https://cfpub.epa.gov/ecotox/)
- WHO Pesticide Evaluation Scheme (WHOPES) (http://www.who.int/whopes/en/);
- National Pesticide Information Center (http://npic.orst.edu/);
- NIH and U.S. National Library of Medicine Toxicology Data Network Hazardous Substances Data Bank (HSDB) (https://toxnet.nlm.nih.gov/newtoxnet/hsdb.htm);
- NIH PubChem Database (https://pubchem.ncbi.nlm.nih.gov);
- 6 NYCRR Part 703.5 for New York State surface water quality standards (https://govt.westlaw.com/nycrr); and
- USEPA National Recommended Water Quality Criteria for surface water standards for aquatic life (https://www.epa.gov/wqc/national-recommended-water-quality-criteria-aquatic-life-criteria-table).

Tables 1a through 1c summarize the results of this literature review for the adulticides, larvicides, and the synergist PBO that are the subject of this technical memorandum.

Pyrethroid Adulticides

Deltamethrin, prallethrin, and d-phenothrin (sumithrin) are synthetic pyrethroid adulticides. All pyrethroids share similar modes of action. Pyrethroids impact the peripheral and central nervous systems of adult mosquitos, ultimately causing paralysis and death (EPA 2013). Because of their shared functionality and possible risks, the USEPA is evaluating pyrethroids as a class instead of by individual chemical (EPA 2016). The active ingredients in Anvil 10+10 are sumithrin and PBO. The active ingredients in Duet are sumithrin, PBO, and prallethrin. The active ingredient in DeltaGard is deltamethrin. **Table 3** summarizes the environmental fate information for pyrethroids.

- Sumithrin is likely to partition to soil and organic matter due to its high Koc[3] value of 141,000 and its Kow[4] value of 1.03E6. The terrestrial field dissipation half-life of sumithrin is less than one day. The

[3] Soil Organic Carbon-Water Partitioning Coefficient (Koc)—Koc measures the mobility of a substance in soil, considering the organic content of the soil and potential for the contaminant to adsorb on to soil particles. Adsorption of chemicals on soils or sediments is a major factor in the transportation and eventual degradation of chemicals. The value of Koc indicates where a chemical is likely to end up, whether in surface water or ground water). Chemicals with large Koc values tend to adsorb onto soil and have a low potential for contaminating surface water.

[4] Kow (octanol/water partition coefficient) is the ratio of a chemical's concentration in octanol divided by its concentration in water; these are usually expressed as logKOW. This partition coefficient is an indicator of the environmental fate of a chemical as it gives a general idea of how a chemical will be distributed in the environment; chemicals with large Kow values can be adsorbed in soils and living organisms.

aerobic soil metabolism half-life ranges from 18.6 to 25.8 days. The anaerobic soil metabolism half-life is recorded as 173 days. In soil, the photolysis half-life of sumithrin is recorded as 18 days. On surfaces, the photolysis half-life is 6 days where it is insecticidally active for the first two days. Sumithrin is not very soluble in water (0.0097 ppm). The low solubility of sumithrin coupled with its high affinity for organic matter suggest that sumithrin would likely transport to waterbodies during a runoff event. Sumithrin has the potential to persist in aquatic environments. It is stable to aqueous hydrolysis at pH 5-9. In seawater, the aqueous hydrolysis half-life ranged from 22-89 days at pH 9 to 192-393 days at pH 5.The aerobic aquatic metabolism half-life of sumithrin is 7.2 days and the anaerobic aquatic metabolism is 61.9 days. In a model pond, sumithrin persisted for 120 years, in a model river sumithrin persisted for 7 days, and in a model lake sumithrin persisted for 81 days. Sumithrin has a bioconcentration factor of 645 in edible tissues, suggesting a high possibility to bioaccumulate in aquatic food chains. However, pyrethroids undergo substantial biotransformation in organisms and this would likely not be an issue in the field. Sumithrin exists in both the vapor and particulate phase in the atmosphere. Its vapor pressure is recorded as 1.43E-7 mmHg and the Henry's Law Constant[5] for sumithrin is 6.80E-6 atm-m^3/mole. Sumithrin is not expected to volatize from surfaces. The vapor phase half-life of sumithrin ranges from 38 minutes (ozone) to 4 hours (OH radicals).

- Prallethrin—Prallethrin is not expected to substantially partition soil and organic matter due to its logKow value of 4.49 and its Koc values ranging from 1318-3082. The aerobic soil metabolism half-life for prallethrin is recorded as 9 days. The photolysis half-life in soil is recorded as 29 days. Prallethrin would likely not runoff to surface waters because of its high solubility in water (8.03 ppm) and its low Koc value. Prallethrin has the potential to persist in aqueous environments. After 28 days, prallethrin was not biodegradable in an aqueous environment. It is stable to hydrolysis at pH 5 and 7, but at pH 9 the hydrolysis half-life of prallethrin is recorded as 4 days. The photolysis half-life is recorded as 0.57 days, suggesting that prallethrin degrades quickly in water when exposed to light. In a model pond, prallethrin persisted for 10 years, in a model river prallethrin persisted for 40 days, and in a model lake prallethrin persisted for 299 days. Prallethrin has an average bioconcentration factor of 1160, suggesting a high possibility to bioaccumulate in aquatic food chains. However, pyrethroids undergo substantial biotransformation in organisms and this would likely not be an issue in the field. The vapor pressure of prallethrin is less than 1.0E-7 mmHg. At room temperature, prallethrin is a liquid. Its Henry's Law Constant is 4.92E-9 atm-m^3/mole. The vapor phase half-life of prallethrin ranges from 18 minutes (OH radicals) to 2 hours (ozone).

[5] Henry's Law Constant (HLC) is a measure of the concentration of a chemical in air over its concentration in water. This constant is generally expressed in one of two ways: H = Concentration of chemical in air/Concentration of chemical in water (unitless) or H'= Liquid vapor pressure/chemical solubility (atm-m3/mol). Knowing the Henry's law constant value is an integral part in calculating the volatility of a chemical. Chemicals with a high HLC will volatilize from water into air and be distributed over a large area. These chemicals need to be handled in such a way so that the vapors do not escape into the atmosphere. Chemicals with a low HLC tend to persist in water and may be adsorbed onto soil.

Table 3
Pyrethroid Environmental Fate Information

Property		Sumithrin			Prallethrin			Deltamethrin		
		Temp (°C)	Value	Source	Temp (°C)	Value	Source	Temp (°C)	Value	Source
Boiling point		>290	760 mmHg	1, 2	313.5	760 mmHg	10, 11, 12		Decomposes below boiling point	13
Melting point			Liquid	3	25	Liquid	11, 12	100-102		13
Water solubility (ppm)		25	0.0097	3, 4	25, pH=5.5	8.03	10, 11	20	0.0002	14
Organic solubility (ppm)	Hexane	25	> 4.96E+06	3, 5		>500	12			
	Methanol	2525	>5.00E+06	3, 5		>500	12		8150	13
	Xylene	25	1.00E+06	2		>500	12		1.5E5-2.0E5	13
Photolysis half-life (days)	Soil		18	4		29 days	10		9	14
	Soil								Stable	15
	Water		5-6.5	6, 4		0.57 days	10, 11		64-84	14, 15
	Surfaces		6 days	7						
	Surfaces		Insecticidally active up to 2 days	7						
Vapor pressure (mmHg)		21.4	1.43E-7	4	23.1	<1.0E-7 mmHg	10	25	9.32E-11	14
Predominant phase			Vapor, particulate	2					Particulate	16
Henry's Law Constant (atm-m^3/mol)		25	6.80E-6	4, 5	20, pH=7	4.92E-9 atm m3/mol	10		3.1E-7	14
Atmospheric degradation	OH radicals		4 hr	8, 5	25	18 min	12	25	0.46 days	15
	Ozone		38 min	8, 5	25	2 hr	12	25	51.4 days	15
Log10 Kow			6.75	4	25	4.49	10, 12		4.53	14
Kow			1.03E6	3					2.42E4	14
Koc			141000	4		1318-3082	12		3.92E5-4.6E5	14
Field (soil) dissipation half-life (days)			≤1	4		Not available	10		14-231	14
Half-life (microbial) in soil	Aerobic (days)		18.6-25.8	4, 3		9 days	10		20-55	14
	Anaerobic (days)		173.3 days	3		Not available	10		32-47	14
Aqueous hydrolysis half-life (days)	pH 5		Stable	4, 3		Stable	10, 11, 12		Stable	14
	pH 7		Stable	4, 3		Stable	10, 11, 12		Stable	14
	pH 9		Stable	4, 3		4	10, 11, 12		2.5	14
Seawater hydrolysis half-life (days)	pH 5		192 to 393	9						
	pH 7		86 to 185	9						
	pH 9		22 to 89	9						
Total aqueous persistence (days)						Not biodegradable in 28 days	12			
Total aqueous half-life (days)	Aerobic		7.2	6					25.9-120	14, 15
	Anaerobic		61.9	6					Not available	
	Model river		7 days	8		40 days	12			
	Model pond		120 years	8		10 years	12			
	Model lake		81 days	8		299 days	12			
Bioconcentration factor (Fish/Water)*	Non-edible		4000	3, 4		3130			3630	15
	Edible		645	3, 4					198	14, 15
	Whole fish		1805	3, 4		1160	10, 12		698	14, 15

Notes: 1. WHO 2002 2. HSDB 2001 3. USEPA RED 2008 4. USEPA 2012 5. NCBI 2016 6. Sid Abel USEPA 2000 7. WHO 1990 8. HSDB 2016a 9. USEPA Pre-2001 10. Sternberg and Zhong 2012 11. WHO 2004 12. HSDB 2016b 13. WHO 2011 14. USEPA 2010 15. USEPA 2013 16. NCBI 2017

* The bioconcentration factor (BCF te) is the accumulation of a chemical in living organisms (biota) compared to the concentration in water. BCF is a good indicator of where a chemical will be distributed. If BCF is high, the chemical will generally have low water solubility, a large Kow (octanol/water partition coefficient), and a large Koc (soil adsorption coefficient). In addition, BCF is an indicator of a chemical's ndency to accumulate in the living organism.

- Deltamethrin—Deltamethrin is likely to partition to soil and organic matter due to its high Kow value of 34,200 and high Koc value of 449,000. Deltamethrin has the potential to persist in terrestrial environments as evident by a terrestrial field dissipation half-life of 14-231 days and aerobic soil metabolism half-life of 20-55 days. In soil, deltamethrin is considered stable to photolysis. In the field, deltamethrin remains mostly in the top 0-15 cm of the soil profile. Deltamethrin is not likely to leach to subsurface soil environments or groundwater but has the potential to be transported to surface waters through soil picked up in a run-off event due to its low solubility (0.0002 ppm) and high affinity for soil and organic matter. It has the potential to persist in aquatic environments. The aerobic aquatic metabolism of deltamethrin ranges from 26-120 days and anaerobic soil metabolism is recorded as 34 days. It would likely partition to soil and organic matter due to its high KOW value of 34,200 and high KOC value of 449,000, potentially impacting benthic organisms. Deltamethrin has low solubility in water with a solubility of 0.0002 ppm. In water, it is stable at pH 5 and pH 7, but the aqueous hydrolysis half-life of deltamethrin at pH 9 is 2.5 days. The aqueous photolysis half-life of deltamethrin is 64-84 days, which suggests that it does not photodegrade quickly in water. Deltamethrin has a bioconcentration factor of 198 in edible tissues, suggesting a high possibility to bioaccumulate in aquatic food chains. However, pyrethroids undergo substantial biotransformation in organisms and this would likely not be an issue in the field. Deltamethrin exists primarily in the particulate phase the atmosphere. Its vapor pressure is recorded as 9.32x10^-11 mmHg and the Henry's Law Constant for deltamethrin is 3.1x10^-7 atm-m^3/mole. Deltamethrin is not expected to volatilize substantially from surfaces. The vapor phase half-life of deltamethrin ranges from 0.46 days (OH radicals) to 51.4 days (ozone).

Synergists

PBO is a synergist used in Duet and Anvil 10+10. On its own, PBO has no pesticide properties and is never used alone. It is used in combination with other insecticides in order to enhance their effectiveness against mosquitoes. PBO inhibits the ability of mosquitoes to break down and deactivate the insecticides with which it is formulated, thus enhancing the toxicity of those insecticides (EPA 2006), such as in DUET and Anvil 10+10. **Table 4** summarizes the environmental fate information for PBO,

PBO would moderately partition to organic matter and soil with a Koc of 399-830 and a log10 Kow value of 4.95. PBO is moderately persistent in the environment. The aerobic metabolism half-life of PBO in soil is recorded as 14 days. On surfaces, the photolysis half-life for PBO is 95 days with 96-98% of the pesticide remaining on surfaces after 7 days. As in the case of soil photodegradation, PBO would likely not runoff to surface waters because of its high solubility in water (14.34 ppm) and its low Koc value. PBO degrades rapidly in water with an aqueous photolysis half-life of 8.4 hours. Other tested routes of degradation, such as hydrolysis, aerobic and anaerobic aqueous metabolism, are very slow or have questionable rates due to experimental difficulties, PBO is not expected to bioaccumulate in fish with a bioconcentration factor of 27 for the whole fish. PBO is not expected to volatize from soil or water. PBO may enter the atmosphere as an aerosol when sprayed. PBO is a liquid at room temperature. However, it degrades rapidly in the atmosphere with a vapor phase half-life of deltamethrin ranges from 3.4-3.6 hours (OH radicals). Its vapor pressure is less than 1.0E-7 mmHg and its Henry's Law Constant is recorded as 8.9E-11 atm-m^3/mole.

Larvicides

Pyriproxyfen

Pyriproxyfen is a larvicide used in NyGuard. It controls the mosquito population by targeting larvae and does not affect adult mosquitoes. It is a juvenile hormone analog and insect growth regulator. Mosquito larvae produce juvenile hormone as part of their life cycle. Molting into adult stages of life is triggered in larval mosquitoes when the production of juvenile hormone slows. If production of juvenile hormone continues, the insect will not molt into an adult. Pyriproxyfen inhibits mosquito larvae from developing into adult mosquitoes by mimicking juvenile hormone so the larvae cannot molt. Therefore, the use of pyriproxyfen prevents immature mosquitoes from developing into reproducing and vector-carrying adults (Sullivan 2000, EPA 2011). **Table 5** summarizes the environmental fate information for pyriproxyfen.

Table 4
Synergist Environmental Fate Information

Property		Piperonyl butoxide		
		Temp (°C)	Value	Source
Boiling point		180	1.0mmHg	1, 2
Melting point		10- 25	Liquid	3
Water solubility (ppm)		25	14.34	2, 4, 5
Organic solubility (ppm)	Methanol		Completely miscible	2, 4
Photolysis half-life (days)	Water		8.4 hr	2, 4, 3
	Surfaces		95, 96-98 % remain after 7 days	1
Vapor pressure (mmHg)		25	<1 E-7 mmHg	2
Henry's Law Constant (atm-m^3/mol)			8.9X10-11 atm m3/mole	5
Atmospheric degradation	OH radicals	25	3.4-3.6 hr.	2, 5
	Particulate phase half-life		Loss by gravitational settling	1
Log10 Kow			4.95	2, 4
Koc			399 to 830	2, 4, 5, 6
Half-life (microbial) in soil	Aerobic (days)		14 days	6, 5
Aqueous hydrolysis half-life (days)	pH 5	25	Stable	5, 6, 3
	pH 7	25	Stable	5, 6, 3
	pH 9	25	Stable	5, 6, 3
Bioconcentration factor (Fish/Water)	Whole fish		27	6

Sources: 1. HSDB 2001 2. USEPA RED 2006 3. WHO 2011 4. USEPA 2005 5. NCBI 2016 6. HSDB 2016

Pyriproxyfen is likely to partition to soil and organic matter due to its high KOC value of 34,200 and high KOW value of 2.36E5 (EPA 2011). It is not expected to persist in terrestrial environments, and has terrestrial field dissipation half-life of 3.5 to 16.5 days (Sullivan 2000). In soil, pyriproxyfen is not persistent and breaks down quickly when exposed to light with a photolysis half-life of 7 to 9 days. It has an aerobic soil half-life of 6 to 9 days. The low solubility of pyriproxyfen in water (0.37 ppm) coupled with its high affinity for organic matter suggest pyriproxyfen has the potential to be transported to surface waters through soil picked up during a run-off event. The relatively high soil/water partitioning of pyriproxyfen indicates that the overall runoff loading potential of pyriproxyfen will be limited, and that its leaching potential is low. Pyriproxyfen can contaminate surface water by spray drift and through runoff and sediment transport during rainfall events.

When exposed to light, pyriproxyfen is not persistent in water and would be expected to degrade quickly. The aqueous photolysis half-life ranges from 4 to 6 days. However, pyriproxyfen is more persistent in darker conditions. Pyriproxyfen is stable to aqueous hydrolysis at pH 5 to 9. The aerobic aquatic metabolism half-life ranges from 6.4 to 21 days. It is more persistent under anaerobic conditions with an anaerobic aquatic metabolism half-life of 750 days. Pyriproxyfen has low potential to volatize from water. It is expected to degrade rapidly in clear, shallow waters but be more persistent in turbid or deep water (EPA 2011). Due to its affinity for soil and organic matter, in the aquatic environment it is expected to be found in sediments. After settling into sediment, pyriproxyfen could be released back into the aquatic environment if the sediment is disturbed. Pyriproxyfen has an approximate bioconcentration factor of 1800 in fish, suggesting a high possibility to bioaccumulate in aquatic food chains (EPA 2011).

Pyriproxyfen is not expected to volatilize from dry soil surfaces. Pyriproxyfen exists in the particulate phase in the atmosphere. Its vapor pressure is recorded as 1.00E-7 mmHg and the Henry's Law Constant for pyriproxyfen is 6.3E-10atm-m^3/mole. The vapor phase half-life of pyriproxyfen ranges from 48 minutes (OH radicals) to 4.6 hours (ozone).

Methoprene

Methoprene is a larvicide used in VectoPrime FG and Altosid XR-G. Methoprene, like pyriproxyfen, is a juvenile hormone analog and insect growth regulator. Methoprene targets mosquito larvae by mimicking

juvenile hormone, preventing the larvae from developing into adult mosquitoes. **Table 5** summarizes the environmental fate data for methoprene.

Methoprene would not be expected to substantially partition to sediment with a Koc value of 2300 and a log10Kow value of 5.50. The aerobic metabolism half-life in soil is recorded as 10-14 days and the anaerobic soil metabolism is recorded as 14 days, suggesting that methoprene breaks down quickly in the environment. Within 6 hours, only 24% of methoprene remained in soil and methoprene rapidly degrades via photolysis on surfaces. The solubility of methoprene in water (1.39 mg/L) coupled with its Koc value suggests that methoprene would not be transported to surface waters during a runoff event.

Methoprene degrades quickly in light with an aqueous photolysis half-life of less than one day. Methoprene degrades within 13 days when applied to pond water exposed to sunlight. Methoprene is more persistent in dark conditions. In darkness, aerobic aquatic metabolism half-life ranges from 28 to 35 days, with methoprene persisting in both freshwater and saltwater for up to 132 days. Methoprene is stable to hydrolysis at pH 5-9 for 21-30 days. In a model pond, methoprene persisted for 278 days, in a model river methoprene persisted for 32 hours, and in a model lake methoprene persisted for 15 days. In seawater, the total aqueous half-life for methoprene is recorded as 28-35 days. Methoprene would be expected to moderately concentrate in fish tissue with a BCF of 457. However, methoprene is quickly metabolized in vivo and would not be expected to cause adverse effects in terrestrial organisms consuming the fish.

Methoprene has the potential to volatize from wet surfaces. Its vapor pressure is recorded as 2.37E-5 mmHg and the Henry's Law Constant for methoprene is 6.9E-6 atm-m^3/mole. The vapor phase half-life of methoprene ranges from 48 minutes (OH radicals) to 4.6 hours (ozone).

Spinosad

Spinosad is a larvicide used in Natular DT. It is mixture of two compounds, spinosyn A and spinosyn D, which are biologically derived from the fermentation of bacteria (*Saccharopolyspora spinosa*). Spinosyn A makes up 85% of spinosad while spinosyn D comprises the other 15% of the larvicide. Mosquito larvae are exposed to spinosad through direct contact, treated surfaces, or by ingestion. Ingestion is the most effective route of exposure. Spinosad impacts the nervous system of mosquito larvae, eventually leading to paralysis and death of the larvae. By controlling larval populations, spinosad prevents reproducing and vector-carrying adult mosquitoes from developing (EPA 2016). **Table 5** summarizes the environmental fate data for spinosad.

Spinosad degrades quickly in water when exposed to light. The aqueous photolysis half-life for spinosad ranges from 0.82 to 0.92 days. It is more persistent in darker conditions. Spinosad is stable to hydrolysis at pH 5 and pH 7; the hydrolysis half-life at pH 9 ranges from 200-259 days. The aerobic aquatic metabolism half-life ranges from 91 to 102 days (EPA 2016).

Spinosad has a high affinity for sediment and quickly partitions to the soil and organic matter as evident by its high KOC value of 35838 and KOW values ranging from 54.6 to 90 (Kollman). Spinosad is short-lived in terrestrial environments as evident by a terrestrial field dissipation half-life of 0.3-5 days. The aerobic soil metabolism half-life of spinosad ranges from 9.4 to 17.3 days. The soil photolysis half-life ranges from 13.6 to 41.3 days.

Spinosad is not expected to volatilize from surfaces. Its vapor pressure ranges from 1,60E-10 to 2.40E-10 mmHg and the Henry's Law Constant for spinosad ranges from 4.87E-7 to 9.82E-10 atm-m^3/mole.

Table 5
Larvicide Environmental Fate Information

Property		Methoprene			Pyriproxyfen			Spinosyn A			Spinosyn D		
		Temp (°C)	Value	Source	Temp (°C)	Value	Source	Temp (°C)	Value	Source	Temp (°C)	Value	Source
Boiling point		100	0.05 mmHg	1, 2, 3	318		8						
Melting point			Liquid	3	45-47		9, 10	84-99.5		12	161.5-170		12
Water solubility (ppm)		25	1.39-1.40	1, 2, 3		0.37	9, 11	20	89.4	12	20	0.495	12
Organic solubility (ppm)	Hexane		>500	4	20-25	4.00E+05	10						
	Methanol		>500	4	20-25)	2.00E+05	10						
	Xylene				20-25	5.00E+05	10						
Photolysis half-life (days)	Soil		6 hrs, 24%	1, 2		6.8-8.5	9, 11		13.6-73.7	12		41.3	12
	Soil								8.68	13		9.44	13
	Water		13, >80%	4, 1, 2		4-6	11		0.93	12		0.82	12
	Water					3.72-6.23	9, 8						
	Surfaces		Rapid	4, 5									
Vapor pressure (mmHg)		20	2.37E-5	1, 2, 3	20	1.0E-7	11		2.40E-10	12		1.60E-10	12
Predominant phase						Particulate	10						
Henry's Law Constant (atm-m^3/mol)			6.9x10-6	1		6.3E-10	11		9.82E-10	13		4.87E-7	13
Atmospheric degradation	OH radicals	25	4.6 hr	4, 6									
	Ozone	25	48 min	4, 6									
Log10 Kow		25	5.50	1, 2, 4, 6		5.3	11		3.91	12		4.38	12
Koc			2300	1, 2		4.980-34,200	11		11543	12			
Field (soil) dissipation half-life (days)			No data	1, 2		3.5-16.5	9		0.3-4.4	12		1.1-5.0	12
Half-life (microbial) in soil	Aerobic (days)		10-14	1, 2, 5		6-9	11		9.4-17.3	12, 13		14.5	12, 13
	Anaerobic (days)		14	1, 2, 5									
Aqueous hydrolysis half-life (days)	pH 5		Stable, 21-30	1, 2, 4		Stable	9, 11		Stable	12		Stable	12
	pH 7		Stable, 21-30	1, 2, 4		Stable	9, 11		Stable	12		Stable	12
	pH 9		Stable, 21-30	1, 2, 4		Stable	9, 11		200	12		259	12
Total aqueous persistence (days)			132	1, 2									
Total aqueous half-life (days)	Aerobic	4.5	28-35	1, 2		6.4-21	11		161	12		250	12
	Anaerobic					750	11		102	12		91	12
	Model river		32 hr	4									
	Model pond		278	4									
	Model lake		15	4									
Total seawater half-life (days)		4.5	28-35	1, 2									
Bioconcentration factor (Fish/Water)	Non-edible								28.8	12		42	12
	Edible		457	6, 1, 2, 7					7.5	12		20.5	12
	Whole fish		3400	1, 2		1620 (est)	10		21.1	12		41.9	12

Notes: 1. Rexrode and Abdel-Sahab 2008 2. Rexrode and Abdel-Sahab 2011 3. USEPA 2013 4. HSDB 2016 5. USEPA RED Update 2001 6. NCBI 2016 7. USEPA RED 1991 8. WHO 2006 9. Sullivan 2000 10. NCBI 2017 11. USEPA 2011 12. USEPA 2016 13. Kollman

ECOLOGICAL RISK ASSESSMENT

In order to assess the potential for the adulticides and larvicides that are the subject of this technical memorandum to adversely affect natural resources when applied as part of the DOHMH Comprehensive Mosquito Surveillance and Control Plan, the ecological risk was assessed following the methodology employed in the 2001 FEIS. As presented in the 2001 FEIS, the ecological risk assessment is organized in two tiers. Tier I is the screening-level assessment. The purpose of the screening-level assessment is to focus the overall ecological risk assessment process by eliminating from consideration those possibilities that do not have the potential for resulting in adverse effects on plants or animals from the Proposed Action. Therefore, if by applying worst-case conservative assumptions to the screening-level (Tier I) analysis, the results show no potential predicted significant adverse impacts for a particular stressor (e.g., active ingredient) or pathway, then those stressors or pathways can be eliminated from further assessment. If the Tier I assessment does identify a potential adverse effect for a particular stressor or pathway, then a detailed second tier (Tier II), or focused assessment, would be performed to evaluate these effects under less conservative conditions and assumptions. The Tier II risk assessment results are then used in conjunction with empirical results from monitoring and other field investigations to evaluate the potential predicted significant adverse impacts on natural resources within each of the Representative Areas.

The methodology employed for the Tier I and II analyses followed that of the 2001 FEIS with the exception of the use of Uncertainty Factors. To account for uncertainty in this assumption, an uncertainty factor is applied in risk characterization. Following the USEPA ecological risk assessment guidance used in the 2001 FEIS (USEPA 1998), when assumptions had to be made in using a toxicological endpoint (benchmark concentration) for a component of the ecological risk assessment, an uncertainty factor (UF) was employed to add a level of conservatism to the calculation of the Risk Quotient (RQ). An RQ is calculated in order to characterize risk to non-target organisms by comparing toxicity benchmarks established through laboratory studies to the modeled environmental exposure concentration (EEC). Calculation of RQs is based upon ecological effects data, pesticide use data, fate and transport data, and estimates of exposure to the pesticide. The RQ is an estimate that identifies high- or low-risk situations for non-target organisms exposed to pesticides.

RISK QUOTIENT = EXPOSURE / TOXICITY BENCHMARK

Screening-level RQs are typically calculated with readily available exposure and toxicity data. Uncertainty factors are used to approximate toxicological benchmarks from available benchmarks when the needed test endpoint is not available. In the 2001 FEIS, the toxicological benchmark concentrations used to calculate the RQ was were calculated by dividing test endpoint concentrations (TEC) by uncertainty factors (UF). RQs greater than 1 indicated the potential for adverse ecological effects.

For the ecological risk assessment conducted for this technical memorandum, the calculated RQ is compared to the USEPA's Level of Concern (LOC) (USEPA 2014) which the USEPA established after the publication of the 2001 FEIS. The USEPA uses LOCs to interpret the RQs and to analyze potential risk to non-target organisms. LOCs differ depending on type of organism and type of evaluated risk. Acute risk poses concerns for mortality of the organism and chronic risk poses concerns for reproductive success of the organism. If the RQ is less than the LOC, the potential for risk is low for the evaluated non-target organism. If the RQ exceeds the LOC, there is a potential for risk to the evaluated non-target organism and it is evaluated further. The ecological LOCs used in this risk assessment are listed below in **Tables 6 through 9**.

Table 6
Risk Presumptions for Birds

Risk Presumption	RQ	LOC
Acute risk	EEC/LC50 or LD50/ft2 or LD50/day	0.5
Acute restricted use	EEC/LC50 or LD50/ft2 or LD50/day or LD50 < 50 mg/kg	0.2
Acute endangered species	EEC/LC50 or LD50/ft2 or LD50/day	0.1
Chronic risk	EEC/NOEC	1.0
Sources: USEPA 2004		

Table 7
Risk Presumptions for Wild Mammals

Risk Presumption	RQ	LOC
Acute risk	EEC/LC50 or LD50/ft2 or LD50/day	0.5
Acute restricted use	EEC/LC50 or LD50/ft2 or LD50/day or LD50 < 50 mg/kg	0.2
Acute endangered species	EEC/LC50 or LD50/ft2 or LD50/day	0.1
Chronic risk	EEC/NOEC	1.0
Sources: USEPA 2004		

Table 8
Risk Presumptions for Aquatic Animals

Risk Presumption	RQ	LOC
Acute risk	EEC/LC50 or EC50	0.5
Acute restricted use	EEC/LC50 or EC50	0.1
Acute endangered species	EEC/LC50 or EC50	0.05
Chronic risk	EEC/NOEC	1.0
Sources: USEPA 2004		

Table 9
Risk Presumptions for Bees

Risk Presumption	RQ	LOC
Acute risk	EEC/Acute oral LD50	0.4
Chronic risk	EEC/Chronic adult oral NOAEL	1.0
Sources: USEPA OPP 2014		

Tier I Risk Assessment Summary

Conceptual models

Adulticides. As was presented in the 2001 FEIS, the conceptual model for the Tier I screening-level risk assessment identifies potential sources, pathways, and receptors. The primary source of the adulticides pesticides is the spraying to control mosquito-borne disease. In terrestrial habitats, mosquitoes and other organisms (honeybees, other non-target terrestrial organisms, mammals, birds, and plants) will experience direct exposure to the spray. The possible routes into terrestrial organisms directly exposed can include dermal absorption; inhalation; and consumption of food, water, and soil.

The pesticides are designed and selected to be effective against insects, and the group of organisms most susceptible to direct exposure to the pesticide spray is the arthropods, the phylum that contains insects. Of the insects, toxicological information exists only for bees. Honeybees are the most commercially and recreationally important insect in the New York area. Therefore, the screening-level assessment addresses honeybees used toxicological information from honeybees as a surrogate for other non-target insects.

Mammals, birds, and most plants have been shown to be very resistant to the direct effects of the pesticides chosen for use in controlling adult mosquitoes and mosquito larva. Birds and mammals are

largely protected from dermal exposure by feathers and fur, respectively. Exposure by inhalation is of very short duration, and, although it may produce irritation, exposure by inhalation at concentrations used to kill mosquitoes has not been shown to cause acute mortality in these groups. Even so, risks to birds and mammals exposed to pesticides by inhalation of the spray were evaluated as was done in the 2001 FEIS. Birds can also be exposed from the spray by preening their feathers and ingesting the pesticide. Risks from this route of exposure were also addressed. Inhalation is presumed not to be a route of exposure for larvicides.

Dogs or cats can be exposed to pesticides by drinking from puddles when rain occurs during or after spraying. This assessment addresses the risks of such behavior. Dogs have been used as toxicological test species and are therefore selected as the representative pet species.

Exposure for birds and mammals through food is typically much greater than exposure through drinking water (in which the pesticides are usually very diluted). One route of pesticide exposure by ingestion is through the terrestrial-based food chain—spray that falls on grasses, seeds, and insects that are then consumed by birds, mammals, and invertebrates. The screening-level assessment examined possible risks to birds and mammals that eat grass, seeds, or insects.

In aquatic habitats, runoff from precipitation that follows an application (a secondary source) or drift from an application (a primary source) can transport pesticides to ponds, streams, and wetlands. The effects of drift and runoff are represented in the screening-level assessment by a pond that receives drift from spraying and a wetland that receives runoff directly through overland flow or through storm sewers. The receptors in both scenarios are the aquatic organisms that come into direct contact with the water. The screening-level risk assessment addresses fish and aquatic invertebrates exposed through both pond water receiving spray drift and application of larvicide and wetlands receiving runoff.

Fish-eating birds and mammals are also potentially exposed by ingestion through the aquatic-based food chain, particularly in the case of repeated applications. In this case, fish are assumed to bioaccumulate the pesticide and then to be consumed by birds or mammals. This screening-level scenario is very conservative because the pesticides used for controlling mosquitoes degrade quickly both in nature and in fish so that the chances that a piscivore could feed over an extended period on contaminated fish are extremely small.

Predators that eat warm-blooded organisms (birds and mammals) are not considered in the conceptual model. In New York City, these predators would most likely be represented by raptors, such as peregrine falcons, and domestic cats. These pesticides tend to be detoxified and eliminated rather quickly by mammals, so that food chain accumulations are prevented. Birds are also thought to eliminate these pesticides quickly.

In addition to the effects listed above, there are also “indirect” effects. Where spraying effectively kills mosquitoes and non-target insects, the species that would have preyed on those insect populations, such as some birds, frogs, other insects, and bats, may be adversely affected by starvation. In addition, reducing populations of species that prey on mosquitoes (e.g., dragonflies) or compete with them may also cause mosquito populations to rebound from what has been called release of predation. Little specific information exists on such effects, however, and indirect effects will be addressed from results of empirical studies.

Larvicides. Spinosad is a larvicide applied as an extended-release tablet every 60 days to artificial water containers, including drains and stormwater catch basins. In accordance with the Natular label, it can only be applied to waters that do not drain into public waterways. Given that it is known that the application of spinosad in the natural environment will result in significant adverse impacts to aquatic biota, and as a consequence the use of this larvicide is restricted to contained artificial systems as indicated on the label, there was no need to evaluate the ecological risk of this larvicide in this technical memorandum. Spinosad should only be applied to contained waters that do not discharge to natural systems.

As described previously, when exposed to light, spinosad degrades quickly (half-life less than 1 day). It is more persistent in darker conditions. In a catch basin, spinosad would be exposed to limited light. Spinosad is stable to hydrolysis at pH 5 and pH 7, and the hydrolysis half-life at pH 9 ranges from 200-259.

Similar to spinosad, pyriproxyfen is a larvicide applied in liquid form to large containers, including drains and stormwater catch basins. Pyriproxyfen may not be applied to natural holding waters or active waterways (NyGuard label). Therefore, pyriproxyfen may not be applied to catch basins that drain to public waterways. Given that it is known that the application of pyriproxyfen in the natural environment will result in significant adverse impacts to aquatic biota, and as a consequence the use of this larvicide is restricted to contained artificial systems as indicated on the label, there was no need to evaluate the ecological risk of this larvicide in this technical memorandum. Pyriproxyfen should only be applied to contained waters that do not discharge to natural systems.

As described previously, when exposed to light, pyriproxyfen is not persistent and degrade quickly. The aqueous photolysis half-life ranges from 4 to 6 days. It is more persistent in darker conditions, such as those in catch basins. Pyriproxyfen is stable to aqueous hydrolysis at pH 5 to 9. The aerobic aquatic metabolism half-life ranges from 6.4 to 21 days (EPA 2011).

Methoprene is a larvicide applied in granular form to marshes and other wetlands, large containers, ponds, pools and standing water. DOHMH only uses larvicides containing methoprene when biological larvicides are ineffective at controlling mosquito populations. In addition, extended release methoprene use must be approved on a case-by-case basis by NYSDEC. The safety data sheet for Altosid XR-G stipulates that the product should be kept "out of public waterways except as permitted by applicable government authorities.[6]" Methoprene degrades quickly in light with an aqueous photolysis half-life of less than one day and degrades within 13 days when applied to pond water exposed to sunlight. Methoprene is more persistent in dark conditions. In darkness, aerobic aquatic metabolism half-life ranges from 28 to 35 days, with methoprene persisting in both freshwater and saltwater for up to 132 days. Methoprene is stable to hydrolysis at pH 5-9 for 21-30 days (EPA 2008, 2011). Because methoprene is applied directly to standing water, the following pathways have been eliminated from this analysis because there is no reasonable route of exposure:

- Birds and mammals exposed to methoprene through inhalation;
- Mammals exposed to methoprene by drinking from puddles created by runoff;
- Marine and estuarine organisms exposed to methoprene through runoff; and
- Birds and mammals exposed to methoprene through the terrestrial food chain.

DOHMH applies mosquito-control pesticides only when conditions meet the following criteria:

- between dusk and dawn (for adulticide application);
- wind velocity is from 2 to 10 mph (for adulticide and larvicide application);
- air temperature exceeds 60 0F; and
- there is less than a 50% chance of heavy rain four hours before and four hours after the time of application (for adulticide application).

Inhalation by mammals

Terrestrial mammals could be exposed to pesticides by inhaling air that contains the sprayed pesticides. Inhalation is assumed not to be a route of exposure for larvicides. The Tier I assessment indicated that non-target mammals would not be at risk after inhalation of air containing the pyrethroids or PBO. The

[6] NYSDEC would need to approve any such application.

RQs for terrestrial mammals exposed to the adulticides and PBO did not exceed the LOC for acute risk or the LOC for acute risk to endangered species. Therefore, as concluded in the 2001 FEIS, the application of adulticides and PBO as part of the Comprehensive Mosquito Surveillance and Control Plan do not have the potential to result in predicted significant adverse effects to mammals.

Inhalation by birds

Terrestrial birds could be exposed to pesticides by inhaling air that contains the sprayed pesticides. Inhalation was assumed not to be a route of exposure for larvicides. The Tier I assessment indicated that non-target birds would not be at risk after inhalation of air containing the pyrethroids or PBO. The RQs for birds exposed to the adulticides and PBO did not exceed the LOC for acute risk or the LOC for acute risk to endangered species. Similarly, the RQs for birds exposed to the adulticides and PBO did not exceed the LOC for chronic risk. Therefore, as concluded in the 2001 FEIS, the application of adulticides and PBO as part of the Comprehensive Mosquito Surveillance and Control Plan do not have the potential to result in predicted significant adverse effects to birds.

Preening

Direct exposure to birds from the deposition of the active ingredients on feathers was evaluated because of the potential of the pesticide to be ingested by the bird through the preening process. Feathers could be coated with sprayed adulticides and the adulticides could be consumed by a bird while preening its feathers. Methoprene could also be consumed should a granule be trapped in the feathers and consumed while preening. Preening was assumed not to be a route of exposure for spinosad and pyriproxyfen since these larvicides would be applied directly to contained water, such as water in drains and catch basins.

The RQs for birds exposed to the pesticides while preening did not exceed the LOC for acute risk or the LOC for acute risk to endangered species. Similarly, the RQs for birds exposed to the adulticides and PBO did not exceed the LOC for chronic risk. However, the RQ for birds exposed to methoprene during preening exceeded the LOC for chronic risk.

Therefore, as concluded in the2001 FEIS, the adulticides and PBO do not have the potential to result in adverse effects to birds due to ingestion during preening. Methoprene would not have the potential to result in adverse effects to birds due to ingestion during preening. Potential chronic risk to birds due to ingestion of methoprene is discussed further in the Tier II analysis.

Mammals drinking from puddles

Mammals could be exposed to pesticides by drinking from puddles when rain occurs during or after spraying. The puddle was assumed to be derived from runoff. The larvicides would not be expected to runoff to wetlands due to their direct application to standing water or contained water, so mammals would not be exposed to the larvicides through puddles formed from runoff water. The Tier I assessment indicated that non-target mammals would not be at risk after drinking from puddles containing the pyrethroids or PBO. The RQs for mammals exposed to the adulticides and PBO for 1-2 days did not exceed the LOC for acute risk or the LOC for acute risk to endangered species. Similarly, the RQs for mammals exposed to the adulticides and PBO did not exceed the LOC for chronic risk. Therefore, as concluded in the 2001 FEIS, the application of adulticides and PBO would not have the potential to result in predicted significant adverse impacts to mammals due to drinking from puddles.

Non-target insects

Because these pesticides are formulated to kill insects, insects represent a sensitive receptor group with the potential for adverse effects. For non-aquatic insects and life stages, the most commonly tested non-target insect species is the honeybee. Spinosad and pyriproxyfen would be applied directly to contained water, such as water in drains and catch basins that do not drain to natural waterbodies, and no route of exposure was assumed for non-target terrestrial insects to these larvicides.

As concluded in the 2001 FEIS, the RQs exceeded the acute risk LOC for honeybees exposed to the adulticides. However, the RQ for honeybees exposed to PBO or methoprene did not exceed the LOC for acute risk. PBO is a synergist that does not have any insecticidal properties when not formulated with other pesticides. Methoprene is a larvicide. Toxicity endpoints are derived from analyses of adult insects,

on which methoprene would have limited impact. Therefore, the application of methoprene and PBO do not have the potential to result in predicted significant adverse impacts to non-target insects. Potential risk to non-target insects exposed to the adulticides is discussed further in the Tier II analysis.

Aquatic receptors in ponds exposed to adulticide drift and direct application of larvicides

Aquatic receptors in ponds would be potentially exposed when drift from spraying settles on a pond surface and enters the pond after a single application, and from direct application of larvicide to the pond surface. Because release methods require that label methods be followed and those methods preclude direct spraying of adulticides over water, risk to aquatic organisms in ponds due to drift of adulticides would be minimal in practice. In addition, a 100 foot buffer was assumed for the 2001 FEIS modelling of drift deposition; however, DOHMH actually implements a 300-350 feet buffer around waterways when applying pesticides. Spinosad and pyriproxyfen would be applied directly to contained water that does not drain to natural waterbodies. Therefore, no route of exposure for aquatic receptors in ponds was assumed for these two larvicides. **Table 10** summarizes the potential risk to freshwater species in ponds exposed to a single application of pesticide.

Table 10
Freshwater aquatic receptors for which calculated RQs exceed LOCs after single application to freshwater pond.

Active Ingredient	Acute	Acute Endangered
Sumithrin	No risk	Crustaceans
PBO	No risk	Fish
Prallethrin	No risk	No risk
Methoprene	No risk	Crustaceans
Deltamethrin	Crustaceans	Crustaceans, fish

Notes: LOC for acute risk to aquatic organisms was 0.5. LOC for acute risk to aquatic endangered species was 0.05.
Sources: Tier I risk assessment.

With the exception of deltamethrin for crustaceans, a one-time application of sumithrin, PBO, prallethrin, or methoprene would not have the potential to result in predicted significant adverse impacts to freshwater aquatic organisms. The result for sumithrin is different from the Tier I evaluation for aquatic biota in ponds evaluated in the 2001 FEIS. In the 2001 FEIS, the Tier I risk assessment identified sumithrin as having the potential to result in adverse effects to aquatic biota with the exception of crustaceans. Potential acute risk to freshwater crustaceans exposed to deltamethrin through spray drift is discussed further in the Tier II analysis. All but prallethrin have the potential to result in adverse impacts to aquatic endangered species due to a one time application. Potential impacts to aquatic endangered species are addressed in this technical memorandum under "Endangered Species."

Aquatic receptors in ponds exposed to multiple applications of adulticides

Freshwater aquatic organisms in ponds would be potentially sensitive to repeated application of adulticides over the course of a few weeks (i.e., Day 1, Day 4, Day 14, Day 17, Day 27, Day 30, Day 40, Day 43, Day 53, Day 56). Adulticides could potentially be repeatedly applied in the same area while active ingredients were still present within the water bodies. Because release methods require that label application restrictions be followed which include precluding direct spraying of adulticides over water, risk to aquatic organisms in ponds due to drift of adulticides would be minimal in practice. Extended release methoprene products continue to release active ingredient for weeks after application. The label for Altosid XR-G, with active ingredient methoprene, specifies that the product is effective for 21 days and should only be applied every 21 days as needed. Therefore, the application schedule for methoprene products would not be similar to that of adulticides and was not evaluated for repeated application. Spinosad and pyriproxyfen would be applied directly to contained water that does not drain to natural waterbodies. Therefore, no route of exposure for aquatic receptors in ponds was assumed for these larvicides.

The Tier I analysis evaluated the impact of 10 repeated applications (the reasonable worst case assumption used in the 2001 FEIS) of the same pesticide to a freshwater pond over the course of 90 days following a specific schedule. The maximum concentration of pesticide within 96 hours, the maximum concentration of pesticide over 90 days, and average concentration of pesticide over the course of 90 days were used to calculate RQs for freshwater aquatic species. The pesticide application schedule did not allow enough time between applications for the pesticide to degrade in the pond. For all of the adulticides and PBO the RQs exceeded the LOC for acute risk for all species.

In practice, the repeated application of adulticides to the same areas would be restricted by permit and label instructions. Product labels restrict the application of adulticides directly over water bodies, reducing the exposure to aquatic organisms. In addition, the multiple application analysis did not consider partitioning to organic sediment within the pond. Partitioning would remove the adulticides from the water column, reducing the concentration of pesticide in the pond water.

Product labels also restrict the amount of pesticide active ingredient that can be applied to the same treatment area over various time frames. These restrictions include the following:

- Over the course of a year, no more than 0.1 pounds per acre of sumithrin and PBO can be applied in any site.
- When rotating products containing PBO, no more than 2 pounds of PBO can be applied per acre per year.
- No more than 0.02 pounds per acre of prallethrin can be applied in any site in one year.
- No more than 0.036 pounds per acre of deltamethrin can be applied in one year.

Therefore, Duet or Anvil 10+10 can be applied up to 27 times to the same treatment area in one year. Duet can be applied to the same treatment area three times in any seven day period. DeltaGard can be applied 25 times to the same treatment area in one year; however, DeltaGard can only be applied 10 times to the same site in a year if animals are present onsite. DeltaGard can only be applied once in any three day period.

Label restrictions would restrict risk to non-target organisms exposed to repeat application of adulticides.

Aquatic receptors in wetlands exposed to runoff

Aquatic receptors in small water bodies that receive runoff are exposed when precipitation follows spraying, washes the adulticide from surfaces or from the air, and carries it to storm drains and then to receiving water bodies. Methoprene is not expected to runoff to wetlands due to its direct application to standing water. Spinosad and pyriproxyfen would be applied directly to contained water that does not drain to natural waterbodies. Therefore, no route of exposure for aquatic receptors in wetlands was assumed for these larvicides. **Table 11** summarizes the potential risk to marine/estuarine aquatic organisms exposed to pesticides carried to wetlands in runoff and **Table 12** summarizes the potential risk to freshwater aquatic organisms exposed to pesticides carried to wetlands in runoff.

Table 11
Marine/estuarine aquatic receptors for which calculated RQs exceed LOCs after runoff to wetland

Active Ingredient	Acute	Acute Endangered
Sumithrin	Crustaceans, fish	Crustaceans, fish
PBO	No risk	Crustaceans, mollusks
Prallethrin	Crustaceans, fish	Crustaceans, fish
Deltamethrin	Crustaceans, fish, mollusks	Crustaceans, fish, mollusks

Notes: LOC for acute risk to aquatic organisms was 0.5. LOC for acute risk to aquatic endangered species was 0.05.
Sources: Tier I risk assessment

Table 12
Freshwater aquatic receptors for which calculated RQs exceed LOCs after runoff to wetland

Active Ingredient	Acute	Acute Endangered
Sumithrin	Crustaceans, fish	Crustaceans, fish
PBO	Fish	Crustaceans, fish
Prallethrin	Crustaceans, fish	Crustaceans, fish
Deltamethrin	Crustaceans, fish	Crustaceans, fish

Notes: LOC for acute risk to aquatic organisms was 0.5. LOC for acute risk to aquatic endangered species was 0.05.
Sources: Tier I risk assessment

All of the adulticides have the potential to result in adverse impacts to aquatic endangered species (crustaceans, fish and mollusks) in wetlands exposed to runoff following a one time application. Atlantic sturgeon and shortnose sturgeon are known to inhabit the Hudson River estuary in New York City. Potential acute risk to Atlantic sturgeon and shortnose sturgeon from runoff containing sumithrin, prallethrin, and deltamethrin is discussed further in the Tier II analysis. Similar to the 2001 FEIS, pyrethroids were identified as having the potential to result in acute risk to crustaceans from runoff containing sumithrin, prallethrin, or deltamethrin; fish from runoff containing sumithrin, prallethrin, or deltamethrin; and mollusks from runoff containing deltamethrin are further discussed in the Tier II analysis. Potential impacts to aquatic endangered species are addressed in this technical memorandum under "Endangered Species."

Receptors exposed through terrestrial-based food chains

For some natural resource species, the source of food (such as grass, seeds, and fruit) could be directly exposed during pesticide application. The food could then become an exposure pathway. Terrestrial-based food chain exposure would occur primarily when herbivores or omnivores eat plants and plant organs that were sprayed. The terrestrial-based food chain is not presumed to be a route of exposure for larvicides. The Tier I assessment indicated that non-target mammals would not be at risk after consumption of grass, seeds, or fruit contaminated with the pyrethroids or PBO. The RQs for terrestrial mammals exposed to the adulticides and PBO do not exceed the LOC for acute risk or the LOC for acute risk to endangered species. Therefore, as concluded in the 2001 FEIS, the application of adulticides evaluated in this technical memorandum and PBO due not have the potential to result in predicted significant adverse impacts to mammals due to consumption of plant food contaminated with these pesticides.

Receptors exposed through aquatic-based food chains

Aquatic species exposed to pesticides could accumulate the pesticides in their tissues. Aquatic-based food chain exposure would occur if carnivores eat fish that bioaccumulated pesticides in their tissues. **Table 13** summarizes the potential risks to terrestrial birds and mammals exposed to pesticides through the aquatic-based food chain.

Table 13
Receptors Exposed through Aquatic-Based Food Chain for which RQs exceed theLOC

Active Ingredient	Acute	Acute Endangered
Sumithrin	No risk	Birds, mammals
PBO	No risk	No risk
Prallethrin	Birds, mammals	Birds, mammals
Methoprene	No risk	Birds
Deltamethrin	Mammals	Mammals

Notes: LOC for acute risk to terrestrial organisms was 0.5. LOC for acute risk to terrestrial endangered species was 0.1.
Sources: Tier I risk assessment

Exposure of endangered species to PBO and spinosad through the aquatic-based food chain does not have the potential to result in adverse effects to federally-listed birds or mammals. Potential acute risks to federally-endangered birds exposed to sumithrin, prallethrin, and methoprene are discussed further in the Tier II analysis. Potential impacts to aquatic endangered species are addressed in this technical memorandum under "Endangered Species."

PBO, methoprene, or spinosad do not have the potential to result in adverse effects to birds and mammals through the aquatic-based food chain. Pesticides not evaluated in the 2001 FEIS were determined to have the potential to adversely affect mammals or birds through the aquatic food chain. These include potential acute risks from the aquatic-based food-chain to mammals and birds exposed to prallethrin and mammals exposed to deltamethrin. These potential risks are discussed further in the Tier II analysis.

Tier II Risk Assessment Summary

Potential risks that were identified during the Tier I Risk Assessment and are evaluated further in the Tier II Risk Assessment include:

- Chronic risk to birds exposed to methoprene through preening
- Acute risk to non-target insects exposed to pyrethroids
- Acute risk to freshwater crustaceans in ponds exposed to deltamethrin through spray drift
- Acute risk to endangered marine/estuarine fish in wetlands exposed to runoff containing pyrethroids. Acute risk to marine/estuarine fish and crustaceans in wetlands exposed to runoff containing pyrethroids. Acute risk to marine/estuarine mollusks in wetlands exposed to runoff containing deltamethrin.
- Acute risk to endangered birds exposed to sumithrin, prallethrin, and methoprene through the aquatic-based food chain. Acute risk to birds exposed to prallethrin and spinosad through the aquatic-based food chain. Acute risk to mammals exposed to prallethrin and deltamethrin through the aquatic-based food chain.

Preening

The Tier I screening-level risk assessment identified a potential chronic risk to birds exposed to methoprene through preening. RQs for the pyrethroids and PBO were below the LOC. Methoprene would be applied in granular form directly to waterbodies. If the application of methoprene is inaccurate, birds on the shoreline of a waterbody could inadvertently consume granules while preening granules caught in their feathers. While unlikely and circumstantial, the potential for birds to consume methoprene via this route of exposure was assessed.

As a conservative analysis, the Tier I assessment of risk for chronic consumption of granular methoprene is assumed that the bird was coated with ULV spray of pesticide. This overstates the exposure of the bird to a granular pesticide like methoprene, and thus overstates the risk. In fact, methoprene is considered practically non-toxic to birds (USFWS Final Mosquito Management Plan and Environmental Assessment). It is metabolized quickly in birds and degraded into natural biochemical in the body (March 1999 Report for the Ministry of Health Environmental and health impacts of the insect juvenile hormone analogue, S-methoprene).

Therefore, the application of methoprene to the natural environment would not have the potential to result in adverse effects to birds due to consumption through preening.

Bees and other non-target insects

The Tier I screening-level RQs for bees exposed to the insecticides are high. The high risk quotients obtained from available data as well indicates that bees should be considered at risk from mosquito pesticides. USEPA (2016 Ecological Risk Management Rationale for Pyrethroids in Registration Review) identifies pyrethroids as acutely toxic to bees and other insects. The document states that uses, including for mosquito control, that would result in exposure to bees would be expected to pose an acute risk to bees and other non-target insects (EPA 2016). This risk is consistent with the results of the 2001 FEIS.

In addition to being exposed at the time of spraying, bees can be exposed to pesticides that have settled on surfaces even after the spray drift has past. For example, sumithrin has been reported to remain insecticidally active for up to 2 days (WHO 1990, in summary for permethrin). Some toxicological benchmarks for bees may indicate a greater sensitivity than might be present in nature when bees are exposed to pesticides on surfaces. In the laboratory, bees can be exposed by microapplicator, which insures a uniform method of toxicant delivery. In nature, bees walking on sprayed surfaces may have lower exposure, and thus receive lower doses than were calculated in Tier1. Even so, screening-level risk quotients are high enough to suggest that individual bees will be at risk where any of the pesticides are sprayed.

Risks to larval bees and non-target insects from larvicides are not well understood. Available toxicological benchmarks for larvicides assess their effect on adult honeybees. Larvicides do not affect the vitality of adult insects and thus would not be considered toxic to adult honeybees. Larvicides would be expected to negatively impact larval non-target insects. More data are necessary to better understand the toxicity of larvicides to non-target insect larvae.

Risks to kept bees can be reduced through institutional and risk management controls.

As identified in the 2001 FEIS, other beneficial non-target insects such as butterflies, dragonflies, damselflies may also be adversely affected due to the application of the adulticides evaluated. Toxicological data for terrestrial insects (or terrestrial stages of insects) other than bees are not available. Modeling of spray drift suggests that drift may carry substantial distances. Based on the sensitivity of bees, and the potential for ULV spray to drift, as identified in the 2001 FEIS, non-target insects can be assumed to be at risk to spray drift, even though the risk cannot be well quantified.

As concluded in the 2001 FEIS, while there may be some adverse effects and losses of non-target insect individuals as a result of the Comprehensive Plan, these potential adverse effects are for the most part not considered to be significant adverse impacts. While there would be individual losses of non-target insects and other arthropods in the areas near the application of adulticides, especially for night flying arthropods, the application of adulticides would be limited temporally and spatially, would not occur for the full spring, summer, and fall periods, and large areas would be exposed to far fewer than the 10 applications per year assumed in the technical analysis of effects of multiple applications. Potential adverse impacts to non-target organisms, primarily arthropods other than mosquitoes, are likely to be limited to those species that fly or are active during the nighttime hours. Arthropod populations from neighboring unsprayed communities would be likely to repopulate neighboring areas that have experienced short-term losses from the application of adulticides. Insects that fly and are active during the day, such as butterflies and bees (i.e., beneficial pollinators of plants), would likely have less exposure, other than potential residues on plants, to adulticide applications.

Aquatic receptors in ponds exposed to adulticide drift and direct application of larvicides

The Tier I screening-level risk assessment indicated the need for further investigation into the risks to aquatic natural resources exposed to pesticide drift and direct application of larvicides. The RQ exceeded the LOC for freshwater crustacean in ponds exposed to spray drift containing deltamethrin, a pyrethroid.

The screening level-risk assessment did not take into account the buffer zones around ponds or wetlands used in adulticide application or the decrease in deposition away from the spray source. Although partitioning in a pond would not take place immediately, it would affect the equilibrium concentration, and partitioning to sediments was also not considered in Tier I screening. Turtle Pond in Central Park is used as a representative example of a pond exposed to drift from application of pesticide by truck.

This analysis conservatively assumed a buffer distance of 100 feet from Turtle Pond to estimate a worst-case scenario. In practice, DOHMH implements a buffer zone of 300 to350 feet for ground and aerial application of adulticides. Maximum deposition rates for drift across various wind speeds and atmospheric conditions, and the results of that modeling were used in this analysis. Unlike the pyrethroids which are applied via ULV spray, granular pesticides are not prone to drift because they are applied directly to waterbodies. In practice, pesticides (adulticides and larvicides) would be applied, , when wind

velocity ranges from 2 to 10 mph (for adulticide and larvicide application) and air temperature exceeds 60 F. Furthermore, application of adulticides would occur between dusk and dawn and when there would be less than a 50% chance of heavy rain both 4 hours before and 4 hours after the time of application to prevent runoff.

The effects of partitioning on exposure concentrations are the greatest on the pesticides with the highest values of Koc (deltamethrin, sumithrin). Taking partitioning into account has little effect on concentrations of pesticides with the lowest Koc values (PBO). Surface water sampling of water bodies before and after spraying by DOHMH indicated that concentrations of sumithrin and PBO were below the LOQ of 0.5 µg/L (0.0005 ppm) in waterbodies across the city before and after application from 2014-2016. Modeled water concentrations both considering and not considering partitioning to sediments are well below that LOQ of 0.0005 ppm for all pyrethroids and PBO. Modeled water concentration for methoprene exceeds the LOQ without partitioning at 0.0012 mg/L and slightly exceeds the LOQ with partitioning at 0.00088 ppm. However, the RQ was below the LOC for all freshwater organisms exposed to all evaluated pesticides both when partitioning was considered and when it was not considered. There was also no identified risk for endangered aquatic organisms for any of the pesticides both when partitioning was considered and when it was not considered.

In summary, as concluded in the 2001 FEIS, the Tier II analysis conducted for this technical memorandum did not identify risks to aquatic organisms in freshwater ponds exposed to pesticide drift or the direct application of methoprene.

Aquatic receptors in wetlands exposed to runoff

The Tier I screening level risk assessment indicated the need for further investigation regarding the risks to aquatic natural resources exposed to pesticides through runoff. The Tier I assessment identified potential acute risk to crustaceans from runoff containing sumithrin, prallethrin, or deltamethrin; fish from runoff containing sumithrin, prallethrin, or deltamethrin; and mollusks from runoff containing deltamethrin. The Tier I assessment also identified potential acute risk to endangered marine/estuarine fish exposed to pyrethroids.

Several factors suggest that in any case, the chances of exposure through runoff are small: Pesticides to control mosquitoes are not normally applied during or immediately before rain, and this practice is contraindicated on many product labels. In practice, application would occur when there would be less than a 50% chance of heavy rain both 4 hours before and 4 hours after the time of application to prevent runoff (Bajwa).

The Tier I assessment used conservative assumptions concerning a rainfall amount, and assumed that the rainfall would carry all of the adulticide to the wetland. The screening level assessment did not account for partitioning of the pesticides to soils or other surfaces. Partitioning to soil and surfaces would reduce the concentration of pesticides in runoff, thus reducing potential for adverse effects to aquatic receptors. Pesticides that partition to soil and surfaces would be expected to remain in these surfaces, where they may be susceptible to degradation through photolysis and bacterial metabolism.

The ¼ inch of rainfall assumed in screening was chosen to be enough to transport the pesticides but not so much as to greatly dilute the pesticide concentrations. This depth of rain was chosen to produce highest exposure and risks. The area over which runoff occurred was assumed to be 300 ft long and 3.28 feet wide. Pesticides would partition to carbon in the surfaces over which runoff flows. The ground surface consists of three different surfaces, concrete, asphalt, and soil. Three different distributions were assumed for modeling: all concrete (worst-case because concrete has no organic carbon), equal distribution, and all soil (best-case). Concrete has little to no organic carbon, the surface of asphalt on streets is assumed to be ¾ stone, which has no organic carbon, and ¼ organic material, and soil is 2% organic carbon. The assumed depth of soil coming in contact with the pesticide is 1 cm. The pesticide is assumed not to be diluted in the receiving wetland or stream. No partitioning occurred with wetland sediments, and no degradation by photolysis occurred. The results of this assessment are summarized in **Table 14** and **Table 15** below:

Table 14
Freshwater aquatic receptors for which calculated RQs exceed LOCs after runoff over varied surfaces

Active Ingredient	Acute			Acute Endangered		
	Equal	Concrete	Soil	Equal	Concrete	Soil
Sumithrin	No risk	Crustaceans, Fish	No risk	Crustaceans	Crustaceans, Fish	No risk
PBO	Fish	Fish	Fish	Crustaceans, Fish	Crustaceans, Fish	Fish, amphibians
Prallethrin	No risk	Crustaceans, Fish	No risk	Crustaceans, Fish	Crustaceans, Fish	Crustaceans, Fish
Deltamethrin	No risk	Crustaceans, Fish	No risk	Crustaceans, Fish	Crustaceans, Fish	Crustaceans, Fish

Notes: Equal surface composed of 1/3 soil, 1/3 concrete, 1/3 asphalt
Sources: Tier II risk assessment

Table 15
Marine/estuarine aquatic receptors for which calculated RQs exceed LOCs after runoff over varied surfaces

Active Ingredient	Acute			Acute Endangered		
	Equal	Concrete	Soil	Equal	Concrete	Soil
Sumithrin	Crustaceans	Crustaceans, fish	Crustaceans	Crustaceans	Crustaceans, fish	Crustaceans
PBO	No risk	No risk	No risk	Crustaceans, mollusks	Crustaceans, mollusks	Mollusks
Prallethrin	Crustaceans	Crustaceans, fish	Crustaceans	Crustaceans, fish	Crustaceans, fish, mollusks	Crustaceans, fish
Deltamethrin	Crustaceans	Crustaceans, fish, mollusks	Crustaceans	Crustaceans, fish	Crustaceans, fish, mollusks	Crustaceans

Notes: Equal surface composed of 1/3 soil, 1/3 concrete, 1/3 asphalt
Sources: Tier II risk assessment

The Tier II analysis described above indicates that sumithrin, PBO, prallethrin, and deltamethrin all have the potential to result in predicted significant adverse impacts to freshwater and aquatic biota when applied as ULV for mosquito control. In freshwater systems, the risk is minimal where runoff has the potential to interact with soil and vegetation afford the opportunity for partitioning to soil and organic matter, greatest where runoff only has contact with concrete. For saltwater systems, there is a lesser reduction in risk as crustaceans are still at risk with the opportunity for partitioning to occur. Additionally, this evaluation assumes a generalized wetland that receives runoff from a specific rain event of 0.25 inches. It does not consider any dilution that may occur in the receiving wetlands or stream, or estuary, nor does it consider partitioning that may occur to wetland plants or sediments. It therefore, reflects a conservative risk at the point of discharge to a system and does not reflect the risk downstream from the outfall. The following paragraphs extend the analysis to Jamaica Bay and Lemon Creek, two of the Representative Areas. The pesticide is assumed not to be diluted in the receiving wetland or stream. No partitioning occurred with wetland sediments, and no degradation by photolysis occurred. The results of this assessment are summarized in the table below:

Jamaica Bay

Jamaica Bay is a large water body with a surface area of about 16,000 acres (NYCDEP 1995) and an average depth of about 12 ft (Riepe and Tanacredi undated). Approximately 36,700 acres of Brooklyn and Queens drain to the bay through combined sewer overflows (CSOs) and storm sewers. This analysis assumed pesticides were applied to ¼ of the drainage area. A ¼ rainfall was assumed to occur one day after spraying, and photolysis on surfaces was assumed to occur during one-half day (daylight) of that day. Pesticides in runoff were assumed to partition over a 300-ft length of an equal surface mix of concrete, asphalt and soil because the Jamaica Bay watershed comprises a mix of surfaces. All applied pesticide except that lost by partitioning was assumed to reach the bay. No partitioning to organic carbon in the tidal basins or the main body of the bay was assumed.

The concentration of pesticide in Jamaica Bay ranged from 4.430E-08 mg/L for deltamethrin to 3.182E-05 mg/L for PBO. The RQs were below the acute LOC for both aquatic organism and endangered aquatic organisms exposed to the pyrethroids and PBO. Therefore, the Tier II analysis for Jamaica Bay did not identify acute risks to marine/estuarine aquatic organisms in Jamaica Bay exposed to pesticides in runoff.

Lemon Creek

The analysis for Lemon Creek was intended to provide additional information on potential impacts to aquatic resources in this Representative Area. The analysis extended the Tier II conducted for the generalized wetland (see above) by considering effects of mixing on concentrations and ultimately RQs in Lemon Creek. Concentrations of the various active ingredients downstream of a discharge point selected at Hylan Boulevard were computed using standard engineering equations for the concentration of a chemical discharged into a flowing stream. These equations are described in Fischer et al., 1979. Assumptions implicit in the equations used are: active ingredient does not degrade in the stream, that the stream contains no additional sources of active ingredient except that entering at Hylan Boulevard, that the stream may be approximated by a rectangular channel, and that the active ingredients are well mixed at the point of introduction to the stream. No provision is made for tidal mixing, uptake by plants, or partitioning to sediments.

The average summer storm rainfall event of 0.375 inches was used. The analysis also assumed that a quarter of the Lemon Creek drainage area was sprayed in any particular event, and that the rain event occurred one day after spraying. Based on land use data, the sub-basins used were estimated to consist of approximately 2/3 pervious surface, and one third soil and asphalt. Discharge rates for the 1-year and 5-year flood events were computed in the Blue Heron, Arbutus Creek, and Lemon Creek/Sandy Brook Watershed Drainage Plans Environmental Impact Statement as 262 and 4,242 cfs, respectively. Discharge rates for the 0.375" storm were estimated using a logarithmic ratio between the 24-hour rainfall for a given return period and the discharge for that same return period event as published in the watershed study above. The 24-hour rainfall depths were determined from the widely accepted National Weather Service Publication TP-40 (Hershfield 1961). The assumption is that rainfall and runoff may both be fitted to logarithmic curves. This assumption is widely accepted to be true in hydraulic engineering and can be seen to apply with the data used here. Using this logarithmic ratio, a rainfall of 0.375", or the average summer storm, should produce about 50 cfs of discharge at Hylan Boulevard.

Estimated flow depths for the discharge channels were taken from the watershed studies listed above (p. 5-19). A depth of 2’ was assumed, which is consistent with the 3.48’ depth found for the 1 year storm from the watershed studies. Channel widths were estimated assuming this depth and the 50 cfs flow rate above. Flow velocities, shear velocities, and transverse mixing coefficients were determined using equations in Fischer et al., 1979.

The analysis for Lemon Creek calculated RQs for areas downstream of the point of entry for the pesticide into the creek. At 250 feet downstream of entry, RQs exceeded the LOC for aquatic organisms only for freshwater fish exposed to PBO.

Water quality monitoring following applications of sumithrin and PBO in the City during in 2014-2016 did not measure concentrations of either pesticide greater than the limit of quantification (LOQ) of 0.5 µg/L. The estimated water concentration of PBO 250 feet downstream of the discharge point in Lemon Creek is greater than the LOQ for water quality sampling. While the analysis took partitioning into account with respect to the ground surface, it did not account for any partitioning to organic carbon that would occur within the storm sewer, nor did it account for any partitioning in the receiving water or sediments. The analysis also did not account for degradation within the water body due to photolysis. The aqueous photolysis half-life for PBO is 8.4 hours, and PBO has a moderate affinity for organic sediment with a KOC of 399-830. Were the environmental fate properties of PBO considered, the risk to freshwater fish would have been diminished. In addition, the June 2006 Reregistration Eligibility Decision for PBO did not identify acute risks to freshwater or marine/estuarine fish exposed to PBO. The potential for impacts associated with PBO will be lower than predicted by the risk assessment models due to the characteristics of the aquatic resources and stormwater systems within the City.

Thus, when the analysis considering risk from runoff is extended to consider two representative areas in New York City, Lemon Creek and Jamaica Bay, as concluded in the 2001 FEIS, application of the adulticides and the synergist evaluated in this technical memorandum do not have the potential to result in potential significant adverse impacts to freshwater or saltwater aquatic organisms exposed to runoff.

Receptors exposed through aquatic-based food chains

The Tier I analysis identified potential acute risks from the aquatic-based food-chain to mammals and birds exposed to prallethrin and mammals exposed to deltamethrin. Potential acute risks were also identified from the aquatic-based food chain for federally-endangered birds exposed to sumithrin, prallethrin, and methoprene.

ULV application of pyrethroids for mosquito control has the potential to adversely affect sediment-dwelling invertebrate organisms. Pyrethroids would have the potential to partition to sediment where they could remain for extended periods of time, potentially impacting organisms that rely on those organisms for food (September 30, 2016 Preliminary Comparative Environmental Fate and Ecological Risk Assessment for the Registration Review of Eight Synthetic Pyrethroids and the Pyrethrins). Furthermore, deltamethrin may have the potential to biomagnify in terrestrial food chains, although this property was not confirmed or tested by the EPA (March 23 2010 Environmental Fate and Ecological Risk Assessment Problem Formulation in Support of Registration Review for Deltamethrin). Prallethrin would not likely bioaccumulate because it is quickly metabolized and eliminated in animals without accumulating in tissues (Thurston County Health Department). Pyrethroids, including prallethrin, deltamethrin, and sumithrin, undergo substantial biotransformation when metabolized in living organisms and do not bioaccumulate (March 23 2010 Environmental Fate and Ecological Risk Assessment Problem Formulation in Support of Registration Review for Deltamethrin). Therefore, risk to terrestrial birds and mammals that eat fish that have bioaccumulated pyrethroids would be unlikely.

Methoprene could have the potential to bioaccumulate in the edible tissues of crayfish and bluegill sunfish (Environmental Fate of Methoprene, Angela Csondes, Nov. 18 2004). However, methoprene is metabolized quickly in birds and degraded into natural biochemical in the body (March 1999 Report for the Ministry of Health Environmental and health impacts of the insect juvenile hormone analogue, S-methoprene). Therefore, risk to terrestrial birds and mammals that eat fish that have bioaccumulated methoprene would be unlikely.

Food chain effects to terrestrial organisms due to these pesticides have not been observed in nature. Considering the relatively low level of the screening-level hazard quotients, the conservative assumptions in the screening level, and the lack of observed food chain effects in the past, the ULV application of the adulticides evaluated and the application of the larvicide methoprene are not expected to result in predicted significant adverse impacts to terrestrial wildlife through the aquatic food chain, consistent with the findings of the 2001 FEIS.

Summary of Ecological Risk Assessment Results

The Tier I ecological risk assessment identified the pathways where it was apparent there would be no likely potential adverse effects to a number of biological receptors. However, this initial assessment also identified the potential for adverse effects for certain biological groups that needed to be addressed on a more detailed level in the Tier II assessment. The biological groups needing additional evaluation included:

- Chronic risk to birds exposed to methoprene through preening
- Acute risk to non-target insects exposed to pyrethroids
- Acute risk to freshwater crustaceans in ponds exposed to deltamethrin through spray drift
- Acute risk to endangered marine/estuarine fish in wetlands exposed to runoff containing pyrethroids. Acute risk to marine/estuarine fish and crustaceans in wetlands exposed to runoff containing pyrethroids. Acute risk to marine/estuarine mollusks in wetlands exposed to runoff containing deltamethrin.

- Acute risk to endangered birds exposed to sumithrin, prallethrin, and methoprene through the aquatic-based food chain. Acute risk to birds exposed to prallethrin through the aquatic-based food chain. Acute risk to mammals exposed to prallethrin and deltamethrin through the aquatic-based food chain.

The Tier II assessment analyzed these potential predicted significant adverse impacts within the context of the resources found within the City, further refining the assumptions to represent the existing conditions. The Tier II analysis concluded that there was no potential for predicted significant adverse impact to birds exposed to methoprene during preening, to aquatic biota in ponds exposed to drift during application of adulticides, or to aquatic biota in Jamaica Bay. The Tier II analysis identified a potential risk to non-target terrestrial insects from adulticides, to aquatic biota receiving runoff following application of sumithrin, PBO, prallethrin, and deltamethrin, and to freshwater fish in Lemon Creek due to the application of PBO. Therefore, while the Tier II assessment concluded that several of the potential predicted significant adverse impacts identified in Tier I would not result in adverse effects to the City's natural resources, it also concluded that certain exposures in Tier II did have the potential to affect certain natural resources within the City.

The following sections first discuss ecological risk assessments that have been conducted by the USEPA and other agencies on the mosquito pesticides, and updates the field and monitoring studies that have been performed to assess effects of spraying these active ingredients in areas that support natural resources. It is followed by a section on the potential impacts to natural resources in the Representative Areas, which includes identification of potential measures to reduce these effects.

ECOLOGICAL RISK ASSESSMENTS AND EMPIRICAL STUDIES

Ecological Risk Assessments

The USEPA conducts ecological risk assessments as part of the registration and registration eligibility decisions (RED) for pesticides. The European Union and Canada conduct similar risk assessments as part of pesticide registration. The following sections summarize the findings from these ecological risk assessments for the pesticides evaluated in this technical memorandum.

Sumithrin

The September 2008 RED for d-Phenothrin (sumithrin) included an ecological risk assessment outlining the potential risks of sumithrin use. The ecological risk assessment calculated RQs using ULV application rates for outdoor scenarios, including the 0.0036 lb/acre application rate for mosquito abatement. The results of this risk assessment are summarized in **Table 16**, below.

Table 16
Results of EPA Ecological Risk Assessment for Sumithrin

Assessment Endpoint	Acute RQ	Chronic RQ
Freshwater Fish	<0.05	0.2
Marine/Estuarine Fish	<0.01	No data
Freshwater Invertebrates	<0.07*	0.11-0.55
Marine/Estuarine Invertebrates	**3.20-13.00**	**19.61-99.61**
Freshwater Benthic Organisms	<0.02	<0.16
Birds	No risk^	No risk^
Terrestrial Mammals	No risk^	No risk^
Notes: Bold text indicates the RQ exceeds the LOC. *RQ below LOC for non-listed species, but exceeds LOC for endangered species. ^Considered non-toxic to group and RQ is equivalent to 0.		
Sources: USEPA September 2008 RED for d-Phenothrin		

The results of the risk assessment indicated that ULV application of sumithrin has the potential to result in acute and chronic impacts to marine and estuarine invertebrates.

While at the time of the evaluation there were no data on the toxicity of sumithrin to aquatic or terrestrial plants, there were no reports of incidents occurring during ULV application. The mode of action for

sumithrin and other pyrethroids is not likely to negatively impact vegetation. Therefore, the EPA risk assessment concluded that adverse impacts to plants from sumithrin use are not expected. No ecological incidents involving aquatic or terrestrial sumithrin exposure were reported to the EPA or to the Ecological Incident Information System.

Sumithrin is highly toxic on an acute basis to non-target terrestrial insects including honeybees and is applied during the time of year when honeybees are most active. Therefore, honeybee exposure to sumithrin is likely. Due to the high exposure potential and high toxicity to non-target insects, the EPA risk assessment concluded there is potential for significant adverse impacts to non-target insects, including honeybees.

Risks to endangered freshwater invertebrates are indicated in the EPA risk assessment. However, no federally endangered freshwater invertebrates are located in New York City.

Both acute and chronic risks to marine/estuarine invertebrates are indicated by the EPA risk assessment.

PBO

The June 2006 RED for PBO included an ecological risk assessment identifying potential risks of PBO use. As a synergist, PBO is usually formulated with other compounds, including pyrethroids. However, the 2006 EPA risk assessment analyzed the toxicity of PBO as a single ingredient. The risk assessment calculated RQs using the maximum application rate for mosquito control, 0.08 lb/acre. This application rate is higher than the maximum application rate for PBO of 0.0036 lb/acre in Duet and Anvil 10+10. The results of this risk assessment are summarized in **Table 17**, below.

Table 17
Results of EPA Ecological Risk Assessment for PBO

Assessment Endpoint	Acute RQ	Chronic RQ
Freshwater Fish	<0.05	<1.0-**3.6**
Marine/Estuarine Fish	<0.05	No data
Freshwater Invertebrates	0.15*	<1.0-**5.1**
Marine/Estuarine Invertebrates	0.15*	No data
Amphibians	0.36*	No data
Birds	No risk^	<1.0-**3.1**
Terrestrial Mammals	<0.1	1.0-**4.5**

Notes: Bold text indicates the RQ exceeds the LOC. *RQ below LOC for non-listed species, but exceeds LOC for endangered species. ^Considered non-toxic to group and RQ is equivalent to 0.
Sources: USEPA June 2006 RED for PBO

The USEPA risk assessment indicates a potential acute risk to endangered amphibians and freshwater and marine invertebrates, and to listed and non-listed freshwater fish, freshwater invertebrates, birds and terrestrial mammals on a chronic basis. However, the application rates used to evaluate the chronic risks to these groups ranged from 0.08 to 0.5 lb/acre, which are much larger than the maximum application rate for Duet and Anvil 10+10.

In 2006, the USEPA did not estimate RQs for terrestrial non-target organisms. Therefore, there is no evaluation of risks to honeybees in the EPA risk assessment.

Prallethrin

The September 30, 2016 Ecological Risk Management Rationale for Pyrethroids in Registration Review included an ecological risk assessment identifying potential risks of prallethrin use. The results of this risk assessment are summarized in **Table 18**, below.

Table 18
Results of EPA Ecological Risk Assessment for Prallethin

Assessment Endpoint	Acute RQ	Chronic RQ
Freshwater Fish	<0.01-0.06*	0.02-0.03
Marine/Estuarine Fish	<0.01-0.03	0.01
Freshwater Invertebrates	<0.01-**10.95**	<0.01-0.89
Marine/Estuarine Invertebrates	0.05-**19.47**	**1.40-1.42**
Birds	<0.01	<0.01-0.01
Terrestrial Mammals	<0.01	<0.01
Aquatic plants	<0.01-0.15	N/A
Terrestrial plants	0.3	N/A
Non-target insects	0.02	N/A

Notes: Bold text indicates the RQ exceeds the LOC. *RQ below LOC for non-listed species, but exceeds LOC for endangered species. ^Considered non-toxic to group and RQ is equivalent to 0.
Sources: USEPA, Ecological Risk Management Rationale for Pyrethroids in Registration Review, September 30, 2016

The 2016 EPA risk assessment identified potential acute risks to freshwater and marine/estuarine and chronic risks to marine/estuarine invertebrates. The environmental exposure concentrations used for risk analysis were calculated for agricultural usage; however, the application rates were not specified in this risk assessment.

Methoprene

Label and permit restrictions limit the feasible routes of exposure for non-target organisms birds, non-target insects, freshwater organisms, marine and estuarine organisms, and birds and mammals exposed through the aquatic food chain. The December 28, 2011 USEPA evaluation of Risks of S-methoprene Use to Federally Listed California Tiger Salamander (CTS) (*Angbystollme californiense*) assessed potential risks of methoprene use. The maximum application rate used in the EPA risk assessment was 0.425 lb/acre for granular application to woodland pools, swamps, and irrigated crop lands. The maximum application rate for VectoPrime and Altosid XR-G is 0.3 lb/acre, which is smaller than the evaluated application rate. The results of this risk assessment are summarized in **Table 19**, below.

Table 19
Results of EPA Ecological Risk Assessment for Methoprene

Assessment Endpoint	Acute RQ	Chronic RQ
Freshwater fish	0.01	0.01
Freshwater invertebrate	0.03	0.74
Freshwater plants	0.02	<0.01

Sources: USEPA, Risks of S-methoprene Use to Federally Listed California Tiger Salamander (CTS) (*Angbystollme californiense*), December 28, 2011

There was little acute risk to terrestrial mammals (RQ <0.001-0.001) or terrestrial birds (0-0.006) from exposure to methoprene through the aquatic food chain. Chronic risks to mammals (RQ 0.006-0.05) and birds (0.205-0.485) which consumed fish that had bioaccumulated methoprene were also limited. Therefore, the 2011 EPA risk assessment concluded that risk to terrestrial organisms exposed to methoprene through the aquatic food chain is limited.

The RQ for terrestrial invertebrates did not exceed any LOC. The 2011 EPA risk assessment summarized field studies detailing the impacts of methoprene use on non-target insects. Methoprene is most toxic to dipteran larvae (e.g., mosquitoes, midges) but is also highly toxic to hemipterans (i.e., true bugs), lepidopterans (i.e., butterflies and moths), and coleopterans (i.e., beetles). Therefore, there is a possibility for adverse impacts to non-target insect larvae.

The February 20, 2008 Potential Risks of Labeled S-Methoprene Uses to the Federally Listed California Red Legged Frog (*Rana aurora draytonii*) EPA ecological risk assessment evaluated potential risks to amphibians due to methoprene use. Toxicology data for freshwater fish were used as a surrogate for absent amphibian data. The USEPA concluded that the use of methoprene may affect" but "not likely to adversely affect California red-legged frogs. Extrapolating that conclusion to a higher LOC for non-listed species, no significant impacts to amphibians from methoprene are expected.

No ecological incidents involving terrestrial or plant methoprene exposure were reported to the Ecological Incident Information System, the Aggregate Incident Reports database, or the Avian Monitoring Information System.

A 2006 incident in Australia was reported concerning a link between the application of 15 g/ha (0.0134 lb/acre) of methoprene and oyster mortality. This is a smaller application rate than the maximum application rate evaluated in this Tech Memo for methoprene. Neither the 2011 EPA risk assessment nor the 2008 EPA risk assessment evaluated risks to marine/estuarine organisms.

Pyriproxyfen

Label restrictions on the use of pyriproxyfen restrict routes of exposure for non-target organisms to only aquatic organisms exposed to pyriproxyfen during a CSO event. This is an unlikely scenario because pyriproxyfen should only be applied to catch basins which do not discharge to active waterways; however, it is being considered to be conservative. The EPA has not yet published a risk assessment for pyriproxyfen. The European Food Safety Authority (EFSA), the counterpart for the EPA in the European Union, published a pesticide risk assessment in 2009 for agricultural uses of pyriproxyfen which was updated in 2014. **Table 20** summarizes the results of the EFSA's risk assessment.

Table 20
Results of EFSA Pesticide Risk Assessment for Pyriproxyfen

Assessment Endpoint	Risk
Birds (Herbivores)	Low risk
Birds (Piscivores)	Low risk
Birds (Insectivores)	Low risk
Birds (Contaminated drinking water)	Low risk
Mammals (Herbivores)	Low risk
Mammals (Piscivores)	Low risk
Mammals (Contaminated drinking water)	Low risk
Fish	High risk
Aquatic invertebrates	High risk
Aquatic sediment invertebrates	Low risk
Earthworms	Low risk
Bees	Not final
Aquatic invertebrates	High risk
Aquatic insects	Low risk
Sources: EFSA, *Peer review of the pesticide risk assessment of the active substance pyriproxyfen*, 21 July 2009; EFSA, *Conclusion on the peer review of the pesticide risk assessment of confirmatory data submitted for the active substance pyriproxyfen*, 13 August 2014	

Risks to fish and other aquatic organisms were considered high. The risk to pollinators and other non-target insects was not finalized and considered incomplete (EFSA 2009, 2014).

Spinosad

Label restrictions on the use of spinosad restrict routes of exposure for non-target organisms to only aquatic organisms exposed to spinosad discharged via a storm sewer or CSO event. The June 30, 2016 Preliminary Environmental Fate and Ecological Risk Assessment for the Registration Review of Spinosad outlined potential risks to marine/estuarine organisms from exposure to spinosad. The 0.48 lb/acre

application rate for livestock/feeding lots is the most comparable to the 0.5 lb/acre application rate used for mosquito control in drainage systems, sewage systems, and catch basins. The results of this risk assessment are summarized in **Table 21**, below.

Table 21
Results of EPA Ecological Risk Assessment for Spinosad

Assessment Endpoint	Acute RQ	Chronic RQ
Marine/Estuarine Fish and Amphibians	<0.01	0.008
Marine/Estuarine Invertebrates	0.06*	0.16
Marine/Estuarine Sediment Invertebrates	0.057*	0.03
Freshwater Fish and Amphibians	<0.01	0.04
Freshwater Invertebrates	<0.01	**22**
Freshwater Sediment Invertebrates	0.0012	**1022**

Notes: Bold text indicates the RQ exceeds the LOC. *RQ below LOC for non-listed species, but exceeds LOC for endangered species.
Sources: USEPA, Preliminary Environmental Fate and Ecological Risk Assessment for the Registration Review of Spinosad, June 30, 2016

Risks to endangered marine/estuarine invertebrates are indicated in the EPA risk assessment.

Deltamethrin

The USEPA (2016a) assessed the potential ecological risks associated with labeled uses of pyrethrins and pyrethroids as mosquito adulticides on the basis of environmental fate and ecological risks evaluated for two pyrethroids (permethrin and deltamethrin) for which multiple studies have been conducted and for which there is ample monitoring data, and pyrethrins. Mosquito adulticide applications are done by means of extremely small droplet sizes or Ultra-Low Volume (ULV) droplets, which remain in the air longer than droplets used for agricultural applications and kill mosquitoes in flight, although some residues will reach the ground and water surface. Runoff and soil erosion are also routes of exposure for surface waters.

The USEPA has developed a pyrethroid registration review risk assessment strategy (USEPA 2016b) that will assess the pyrethroids as a class with regard to ecological risks, with the pyrethroids evaluated representing those that were not evaluated, rather than conducting assessments by individual chemical, given their well-established toxicity to aquatic animals and the well-established route of exposure to aquatic animals. The registration review covers all of the pyrethroids proposed for use by the DOHMH: d-phenothrin, deltamethrin, permethrin and prallethrin. Ecological Risk assessments for pyrethroids have indicated a risk to aquatic organisms. Pyrethroids generally do not pose a risk to birds and are generally considered to be non-toxic to birds. Pyrethroids pose some risk to mammals and are acutely toxic to bees and other insects (USEPA 2016b).

Pyrethrins and synthetic pyrethroids are hydrophobic compounds that have a low water solubility, have a high tendency to bind to organic carbon in soil, water and sediments and dissolved organic carbon, or particulate matter in aquatic environments. Pyrethroids are persistent in the environment (i.e., persistent to hydrolysis, aqueous and soil photolysis) with the primary routes of loss comprising metabolism in soil and water, and binding to soil. Synthetic pyrethroids and pyrethrins are generally very highly toxic to freshwater and estuarine/marine fish and invertebrates on an acute basis, with freshwater fish being generally more sensitive than estuarine/marine species on an acute and chronic basis. Freshwater invertebrates appear to be more sensitive to pyrethroids than estuarine/marine invertebrates on an acute basis and are many more times sensitive than fish. Invertebrates that live on the bottom or in sediment tend to be especially sensitive. USEPA concluded that the use of pyrethroids and pyrethrins for adult mosquito control in accordance with the registered labels, has the potential to result in exceedances of acute and/or chronic risk LOCs for freshwater and estuarine/marine invertebrates, and could result in a number of acute and/or chronic risk quotient LOC exceedances for freshwater and/or estuarine/marine fish, but no LOC exceedances for non-listed species on an acute basis.

For deltamethrin, for which only ground application is currently allowed on the label, the ecological risk assessment indicated LOC exceedances occurred for listed and non-listed freshwater fish on an acute basis, and to estuarine and marine fish for listed species on an acute basis. LOC exceedances occurred to freshwater and estuarine and marine invertebrates and benthic invertebrates on an acute and chronic basis for listed and non-listed species, with freshwater invertebrates appearing to be the most sensitive.

Empirical Studies

The empirical studies evaluated in the 2001 FEIS indicated the potential for mosquito adulticides to affect the following groups of organisms:

- terrestrial receptors—impacts observed to non-target insects, primarily bees;
- aquatic receptors in ponds exposed to drift—no detectable mortality of aquatic invertebrates from the application of pyrethroid permethrin;
- Aquatic receptors in wetlands exposed to runoff——potential for ULV application of adulticides for mosquito control to affect marine invertebrates such as lobster.

The following sections update the empirical studies for the adulticides and larvicides.

Terrestrial Receptors with Direct Exposure

The Sacramento-Yolo Mosquito and Vector Control District sprayed a pyrethrin insecticide, Evergreen Crop Protection EC 60-6 (a pyrethrin-based botanical insecticide synergized with PBO), over the urban community of Davis, CA in August 2006 to control the outbreak of WNV. Boyce et al. (2006) monitored the effects of adulticiding on non-target arthropod species. The investigators placed sentinel species, including variegated meadowhawk dragonflies (*Sympetrum corruptum*), yellow garden spiders (*Argiope aurantia*), alfalfa butterflies (*Colias eurytheme*), and honeybees (*Apis mellifera*) in containers within the spray zone. The containers containing the sentinel species were deployed prior to spraying and removed the next morning. At the time of removal, the insects were recorded as live or dead. All of the dragonflies and spiders survived the mosquito control event, and there was no significant difference in survival of butterflies and honeybees in unsprayed and sprayed areas. The diversity and abundance of dead arthropods found on tarps placed on placed on the ground within the pyrethrin spray zone was also recorded. Significantly higher diversity and abundances of non-target arthropods were found dead on the tarps within the treatment sites. The dead species found on the tarps were all small-bodied arthropods, which the investigators attributed to their greater ratio of surface area to body mass. The sentinel species were all relatively large-bodied arthropods compared to the smaller, non-target species found on the tarps (Boyce et al. 2006).

Antwi and Peterson (2008) performed lab experiments to determine the toxicity of sumithrin to non-target insect species. They exposed adult house cricket (*Acheta domesticus*), adult convergent lady beetle (*Hippodamia convergens*), and larval fall armyworm (*Spodeptera frugiperda*) to varying concentrations of sumithrin synergized with PBO. They found that sumithrin was most toxic to house crickets. Lady beetles were more susceptible to sumithrin than fall armyworms. This research provided much needed information on potential adverse impacts to insects other than honeybees (Antwi and Peterson 2008).

Chaskopoulou, et al. (2014) studied the effects of deltamethrin ULV spray applied via helicopter on honeybees (*Apis mellifera*), mealybug destroyers (*Cryptolaemus montrouzieri*), and green lacewings (*Chrysoperla carnea*). Insects were placed in open air containers fit with materials to prevent insects from escaping. Containers with non-target insects were deployed 15 minutes before spraying, removed 30 minutes after spraing, and processed 60 minutes after spraying. The impact of deltamethrin on beehives was also studied. Beehives were monitored before spraying, 12 hours after spraying, and every week after spraying for 10 weeks. The product used contained 2% unsynergized deltamethrin with an application rate of 1 g deltamethrin/hectare (8.92E-4 lb/acre). No significant non-target mortalities were observed and no mortality to bees or beehives was observed. It is important to note that the application rate used in this

study is an order of magnitude smaller than the maximum application rate of DeltaGard (0.00134 lb/acre) (Chaskopoulou, et al. 2014), which is the rate evaluated in this technical memorandum.

Alexander et al. (2001) studied the impact of deltamethrin on two lizard species, *Meroles suborbitalis* and *Pachydactylus namaquensis*, in an arid area of South Africa where deltamethrin is extensively applied for locust control. Deltamethrin was applied directly to lizards via ULV spray from a backpack sprayer at two different application rates: 17.5 g/hectare (0.0156 lb/acre) and 25 g/hectare (0.0223 lb/acre). Lizards exhibited symptoms of pyrethroid poisoning within an hour of treatment. One lizard died within 7 hours of treatment. Surviving lizards seemed to recover the following day; however, the majority of the lizards were dead within two months of the experiment. In a separate trial, lizards were exposed to deltamethrin indirectly. The lizards were placed on soil that had been treated with deltamethrin at these application rates. The lizards were observed every 15 minutes on the day of spraying and then four times per day for the proceeding two days. Lizards exhibited signs of pyrethroid poisoning, although symptoms took longer to manifest and were not as severe as in the direct exposure trials. The lizards seemed to recover the following day; however, the majority of the lizards were dead within two months of the experiment. A field sampling survey was also conducted where prior to a spray event, lizard species abundance and diversity were recorded in treated 1 hectare plots. After the spray event (17.5 g/hectare), lizard species abundance and diversity was surveyed in the week immediately after spraying, during the fourth week after spraying, and during the 18th week after spraying. Lizards were sampled every hour from 8:00 AM until 5:00 PM for three different days within the week. Lizard abundance decreased by 29% for *M. suborbitalis* and by 58% for *P. namaquensis* one week after spraying compared to pre-treatment. Four weeks after spraying lizard abundance decreased by 52% for *M. suborbitalis* and by 72% for *P. namaquensis* compared to pre-treatment. However, by 18 weeks lizard counts returned to pre-spraying levels because of an influx of juvenile lizards. Alexander et al. also found that in all cases the center of field survey plots contained fewer lizards than the edges of the plot at one week and four weeks post-spraying. This study demonstrates the toxicity of deltamethrin to non-target reptiles when exposed both directly and indirectly. It is important to note that the application rate used in this study is an order of magnitude larger than the maximum application rate of DeltaGard (0.00134 lb/acre) (Andereson et al. 2001) which was evaluated in this Technical Memorandum.

Aquatic Receptors in Ponds Exposed to Drift

PBO is applied with pyrethroids, such as sumithrin and prallethrin, in order to enhance the efficacy of the insecticides. In August 2005, the city of Sacramento, CA employed aerial insecticide spraying of pyrethrins and PBO in an effort to combat WNV. Weston et al. (2006) examined the synergistic effects of PBO to preexisting insecticides in creek sediments. PBO spraying from the August 2005 mosquito control plan doubled the toxicity of preexisting pyrethroids found in creek sediments to the non-target amphipod *Hyalella azteca*. This suggests that it is important to consider the potential for PBO to enhance the toxicity of insecticides already in the environment from previous mosquito control events (Weston et al. 2006).

In their January 1999 Program Evaluation Report, the Metropolitan Mosquito Control District of Montana summarized potential effects to non-target species due to its use of methoprene. They found that methoprene is potentially harmful to frogs, toads, and salamanders. However, the low dose rates used in mosquito control were not found to elicit such adverse impacts. Furthermore, they found that the number of organisms, development of, and mortality rates of freshwater shrimp, crayfish, mosquitofish, minnows, and dragonfly naiads were unaffected by methoprene. There was no difference in reproduction and growth of red-winged blackbirds and numbers of aquatic insects in wetlands that had been treated with methoprene compared to those which had not been treated (Office of the Legislative Auditor, State of Minnesota, 1999).

Jones and Ottea (2013) studied the impact of spinosad application on non-target, aquatic insect species in Baton Rouge, Louisiana. Aquatic insects are the most susceptible to non-target effects from larvicide use because these species are found in the same environments as mosquito larvae. Aquatic insects were sampled from a 0.75 acre pond in a residential neighborhood and tested in the lab for their tolerance to spinosad. Non-target insect larvae were exposed to concentrations of spinosad equal to the LC50 calculated for mosquitoes exposed to spinosad (0.031 ppm) and the concentration of spinosad associated with the maximum application rate of Natular 2EC (1.6 ppm). Mayflies were most sensitive to spinosad with 71% mortality of mayflies exposed to the LC50 dose and 99% mortality of mayflies exposed to the maximum label rate. Dragonflies and damselflies were not as susceptible to spinosad, with higher rates of survival for species belonging to the damselfly species present (*Ischnura* sp.) than the dragonfly species (*Pachydiplax longipennis*). These differences could have been attributed to the size weight of the non-target organisms since Odonates are larger than mayflies. Jones and Ottea also noted that spinosad is relatively nontoxic to mammals, is slightly toxic to birds, moderately toxic to fish, and highly toxic to honeybees. Because spinosad degrades quickly in the environment the observed toxicity to non-target organisms decreases quickly (Jones and Ottea 2013).

Aquatic Receptors in Wetlands Exposed to Runoff

A study on tadpoles over the course of 100 days found no adverse effects to tadpole development due to methoprene until the dosage rate was 200 times that which would be used in a normal mosquito control event. Furthermore, it was found that when methoprene is used for mosquito control and breaks down in the environment it does not produce enough retinoic acid, which can cause developmental defects, to harm any species (Office of the Legislative Auditor, State of Minnesota 1999). A USGS report on malformed frogs in Minnesota noted that there is conflicting information on whether methoprene induces malformations in frogs, as a laboratory study by the EPA in 1998 found that there were no malformations to northern leopard frogs but a field study found that methoprene application did result in southern leopard frog malformations (Rosenberry 2015).

The Washington State Department of Ecology monitored methoprene and methoprene acid concentrations in creeks, wasteways, and ponds in Grant County Mosquito Control District No. 1 after the application of the larvicide during the 2005 application season (Johnson and Kinney 2006). Samples were collected downstream of the creeks and wasteways within days of application and repeated samples were taken in the following weeks. Methoprene samples collected rarely exceeded 0.2 μg/L, with methoprene detected in only 4 of 68 samples. Johnson and Kinney cited personal communication with New York's Suffolk County Department of Health Services, which reported that, methoprene had never been detected in surface and well water samples at a detection limit of 0.2 μg/L. However, methoprene had been detected in Suffolk County with a detection limit of 0.01 μg/L immediately after spraying (Johnson and Kinney 2006).

The Massachusetts Department of Public Health and Massachusetts Department of Agricultural Resources aerially applied Anvil 10+10, with sumithrin and PBO, during the summer of 2012 to control for Eastern Equine Encephalitis (EEE). Sumithrin was not applied directly to open water or within 100 feet of lakes, streams, rivers, or bays. However, it was applied to the shores of surface water bodies (MassDEP Water Resources 2012). The application of Anvil 10+10 did not result in significant introduction of sumithrin or PBO into surface waters. No sumithrin was detected in surface waters from 12 hours after spraying or in the days that followed. PBO was detected in low concentrations (0.01 to 0.42 μg/L). The concentration was well below acute drinking water or aquatic life criteria. Non-target fish species and rare or state-listed were determined not to be at significant risk as no risks had been detected during spray events in 1990, 2006, and 2010. As a result, MassDEP did not conduct biological monitoring, and after application no fish kills were reported. Beekeepers reported no impact to their hives

from the mosquito control event. Additionally, testing of cranberries for sumithrin determined no detectable levels of the compound in any sample (State Reclamation and Mosquito Control Board, 2013).

Methoprene has also been implicated in the lobster mortality observed in the Long Island Sound (Antunes-Kenyon and Kennedy, 2001). Prior to the 1999 mosquito control program the lethality of the pesticides had been unknown (Walker et al. 2005). Proposed bills in Suffolk County, NY (September 2013) and in Connecticut (HB-5260) have attempted to ban the use of methoprene near waterbodies, especially the Long Island Sound, for this reason. Walker et al., 2005 found that low levels of methoprene had adverse impacts on aquatic larvae with increased mortality to Stage II larvae and increased frequency of molting in Stage IV larvae. Juvenile lobsters exposed to methoprene experienced decreased protein synthesis in various tissues. They cite studies which indicate an adverse effect to crustaceans from methoprene, including blue crab (*Callinectes sapidus*) (Horst and Walker 1999), mysid (*Mysidopsis bahia*), moina (*Moina macrocopa*) (Cho et al. 1997), daggerblade grass shrimp (*Palaemonetes pugio*) (McKenney and Matthews 1990), and *Daphnia magnia* (Templeton and Laufer 1983). Walker et al. concluded that it is likely that methoprene may be a contributing factor in the reduced lobster population in Western Long Island Sound in addition to other confounding factors (2005).

Paul et al., 2004 examined the effect of synergized pyrethroids, including sumithrin enhanced by PBO, on the toxicity and swimming ability of brook trout (*Salvelinus fontinalis*) and brown trout (*Salmo trutta*). The synergized sumithrin product tested was Anvil 10+10 containing 10% sumithrin and 10% PBO. PBO significantly increased the toxicity of sumithrin after 48 hours and enhanced the intoxicating effect of sumithrin throughout the entire duration of exposure. Brown trout were more sensitive to synergized sumithrin than brook trout. However, exposure to synergized sumithrin did not significantly impair the trout's ability to swim against a current any more than the technical formulation of sumithrin. Paul and Simonin (1995) found that PBO on its own was nontoxic to trout up to 500 μg/L, but PBO in combination with pyrethroids greatly increased the effectiveness of the insecticide.

Phillips et al. (2014, in USEPA 2016) collected sediment samples collected pre- and post-application of mosquito adulticides (permethrin, pyrethrins and d-phenothrin), and found that only four post-application sediment samples were more toxic than their corresponding pre-application sediment samples, however toxicity could not be attributed to spray events. Pre- and post-application (early morning 12-hours post application and evening day after application) water samples indicated toxicity primarily associated with naled applications (organophosphate pesticide). Permethrin, d-phenothrin and pyrethrins were all below toxicity threshold post-application associated with d-phenothrin application indicated concentrations of d-phenothrin and PBO to be below toxicity thresholds.

During the summers of 2002-2004, the Suffolk County Department of Public Works Vector Control (SCVC) sprayed insecticides to control for West Nile Virus. Methoprene and PBO were among the pesticides sprayed during the 2002-2004, and surface water samples were also tested for sumithrin which was previously used in Suffolk County but not during the 2002-2004 sampling season. A total of 72 water samples were collected at 27 sites in Suffolk County in June, July, and August of 2002, 2003, and 2004. None of the compounds, including PBO, sumithrin, and methoprene, were detected in the samples collected before application. Pesticides were most often detected within 30 minutes to 1 hour of application. After spraying, methoprene was detected in 9.7% of samples. PBO was detected in 33.33% of samples. Sumithrin was not sprayed during the sampling season and was not detected in any samples. PBO was detected in 83% of water samples after helicopter application compared to in 33.33% of water samples after truck application. After 4 days of a spraying event, concentrations of the insecticides decreased to below detection limits (Abbene et al. 2005). Monitoring data for prallethrin was not available.

POTENTIAL FOR ADVERSE NATURAL RESOURCES IMPACTS IN REPRESENTATIVE AREAS

As presented in the 2001 FEIS, potential effects to the City's natural resources may result from:

- The action of the adulticides and larvicides evaluated in this technical memorandum on aquatic and terrestrial animals and plant inhabiting the open spaces within the City, as evaluated in the Tier I and Tier II ecological risk assessments; and
- The activities associated with the adulticide and larvicide application methods, or non-pesticide related impacts.

The following sections discuss these two groups of potential effects, taking into account the findings of the 2001 and the results of the evaluations presented in this technical memorandum.

Terrestrial Receptors with Direct Exposure

The 2001 FEIS and the evaluations presented in this technical memorandum indicate very low potential for predicted significant adverse impacts on mammals, birds, or pets through inhalation, preening, or drinking water from puddles contaminated with adulticide. As was identified in the 2001 FEIS, the results of the Tier I and II assessments suggest that non-target terrestrial insects such as bees, moths, butterflies and other insects, may be adversely affected by the application of adulticides, with insects active at night (e.g., moths, crickets, katydid, fireflies, beetles) or those resting on vegetation surfaces having the greatest potential to be affected. As indicated in the 2001 FEIS, potential impacts to non-target insects can be reduced by timing spraying to avoid periods when bees are actively foraging (i.e., two hours after sunrise and two hours before sunset).

As concluded in the 2001 FEIS, the City's parklands that provide the greatest diversity of habitats and vertical complexity such as the wooded areas and wetlands of Van Cortlandt Park, Bergen Beach and other areas of Gateway National Recreational Area associated with Jamaica Bay, and the unmanaged woodlands of Wolfe's Pond Park should have sufficient populations of insects in areas unaffected by the spray to compensate for the loss of some individuals in the sprayed areas. Insects using areas blocked from the spray by trees, as would be the case in Van Cortlandt, and Wolfe's Pond Park, and even some portions of Soundview Park, even though it has large areas of meadow or grass, should be able to move into areas where individuals were lost from the spray. Additionally, woodlands such as those of Van Cortlandt Park, Wolfe's Pond Park, Bergen Beach, and even the low quality woodlands surrounding Paerdegat Basin, the poor quality ruderal meadow of Soundview Park, and the wetlands of Lemon Creek and the former Flushing Airport site, all provide multiple, interlocking layers of vegetation that will shield some individuals from the spray. Any reduction in insect abundance would be expected to be of short duration and would not be expected to result in predicted significant adverse impacts to mammal, bird, reptile, and amphibian species that feed on insects.

Measures identified in the 2001 FEIS to reduce potential impacts to non-target insects such as documenting and then avoiding spraying in the vicinity of butterfly gardens and wildflower meadow areas, and imposing a setback distance of at least 100 feet will continue to be considered as part of the Comprehensive Plan.

Aquatic Receptors in Ponds Exposed to Drift and Larvicides

The results of the Tier II assessment conducted herein, as was the case for the 2001 FEIS for adulticides, suggest the use of ULV adulticides and the application of methoprene should not affect aquatic resources in typical New York City ponds. This is further substantiated by the results of empirical studies, and pre- and post-water quality monitoring conducted by DOHMH since 2000 as part of its mosquito control program, which have found no detectable concentrations of sumithrin, PBO, or prallethrin following adulticide application. Any potential for impact to aquatic biota to City ponds will continue to be minimized through the use of the minimum 300-foot setback during adulticide application.

Aquatic Receptors in Wetlands Exposed To Runoff

As indicated in the 2001 FEIS, the type of land cover over which runoff traverses prior to discharging to wetlands influences the potential for predicted significant adverse impacts to aquatic biota due to the application of adulticides. Where adulticides in runoff have the opportunity to bind with organic material

or soils, wetlands such as those associated with Van Cortlandt Lake, Lemon Creek, Wolfe's Pond and Acme Pond, and Flushing Airport, as well as other freshwater wetlands in the City that receive stormwater runoff, there is little potential for impact to aquatic biota. Similarly, the evaluation of potential impacts to aquatic biota of Jamaica Bay indicated little potential for predicted significant adverse impacts to estuarine or marine organisms from the application of the adulticides evaluated. In the 2001 FEIS malathion was the only adulticide identified as having a potential to result in predicted significant adverse impacts to aquatic biota in Jamaica Bay. This adulticide is not used by DOHMH for the mosquito control plan and was not evaluated in this technical memorandum.

Receptors Exposed through Aquatic-Based Food Chains

Pyrethroids, including prallethrin, deltamethrin, and sumithrin, undergo substantial biotransformation when metabolized in living organisms and do not bioaccumulate. Therefore, risk to terrestrial birds and mammals that eat fish that have bioaccumulated pyrethroids would be unlikely. Methoprene could have the potential to bioaccumulate in aquatic biota but is metabolized quickly in birds Therefore, the ULV application of the adulticides evaluated and the application of the larvicide methoprene are not expected to result in significant predicted adverse impacts to terrestrial wildlife through the aquatic food chain, consistent with the findings of the 2001 FEIS.

Endangered Species

Table 22 presents the updated list of federally and state-listed threatened, endangered, and special concern animal species with the potential to occur within New York City. **Table 23** presents the updated list of federally and state-listed threatened, endangered, and special concern plant species with the potential to occur within New York City.

Birds

Table 22 presents the updated list of federally and state-listed threatened, endangered, and special concern bird species with the potential to occur within New York City. As presented in the ecological risk assessment contained in the previous sections, direct adverse effects to birds through inhalation, preening or consumption of contaminated fish are expected to be minimal. Additionally, the City's no-spray setback from waters and wetlands would reduce the amount of adulticides entering the preferred habitat areas for the shorebirds, wading birds, and waterfowl. Indirect effects caused by a loss of prey species should also be small because of the ability of most of these birds to switch to different prey items should one particular prey item become less abundant. Short-eared owl and northern harrier consume small rodents and other small animals that are not expected to be affected by the application of the proposed adulticide and should not be affected by a loss of prey. Peregrine falcons feed on other birds, which are not expected to be affected by the proposed adulticides and therefore should not experience a loss of prey items. Additionally, the high elevation selected by the peregrine falcon for nesting should minimize potential contact with the adulticides applied by truck. Individuals nesting on bridges should likewise have little contact with adulticides applied aerially because of the City's no-spray setback from waterbodies. No-spray setbacks would be established around peregrine pairs known to be nesting on buildings to further minimize potential effects to this species. As indicated in the 2001 FEIS, DOHMH will continue to maintain a 300-foot buffer between adulticide application and sensitive areas, including nesting habitat for piping plover. Therefore, the results of this evaluation indicate the implementation of the Comprehensive Plan would not have the potential to result in predicted significant adverse impacts to threatened, endangered, or special concern bird species for all evaluated pathways.

Fish

Atlantic sturgeon (*Acipenser oxyrinchus*) and shortnose sturgeon (*Acipenser brevirostrum*) are the only federally- or state-listed fish species with the potential to occur in New York City (**Table 22**). Atlantic sturgeon and shortnose sturgeon are known to frequent the Hudson River estuary, including the East River, Jamaica Bay, and Raritan Bay (Atlantic sturgeon only). However, the Tier II assessment of saltwater fish in Jamaica Bay exposed to pesticides through runoff does not identify risks to endangered marine and estuarine fish. Therefore, no predicted significant adverse impacts to either Atlantic sturgeon

or shortnose sturgeon are expected as a result of the application of ULV adulticides. The results of this evaluation have indicated that the implementation of the Comprehensive Plan would not have the potential to result in predicted significant adverse impacts to threatened, endangered, or special concern marine/estuarine fish species for all evaluated pathways.

Reptiles

Eastern box turtle (*Terrapene carolina*), spiny softshell (*Apalone spinifera*), eastern hog-nosed snake (*Heterodon platirhinos*), and fence lizard (*Sceloporus undulates*) are the only federally- or state-listed reptiles with the potential to occur in New York City (**Table 22**). Due to lack of exposure data, reptiles are represented by birds in this evaluation, as is typical for ecological risk assessments. The results of this evaluation indicate that the implementation of the mosquito control plan would not have the potential to result in predicted significant adverse impacts to threatened, endangered, or special concern bird species for all evaluated pathways.

The 300-foot buffer around sensitive areas, which include wetlands, will continue to protect reptiles in these areas. While the results of conservative evaluation of potential impacts to aquatic receptors in wetlands exposed to runoff indicated a potential for adverse effects to endangered species, the results of the evaluation for Lemon Creek, which took into account partitioning in runoff did not indicate a potential for predicted significant adverse impacts to aquatic biota. The results of the ecological risk assessment indicated no predicted significant adverse impacts to aquatic biota in ponds exposed to drift. In addition, a 2008 EPA ecological risk assessment for California red legged frogs found that use of methoprene may affect, but is not likely to adversely affect California red legged frogs. Therefore, the Comprehensive Plan is not expected to result in predicted significant adverse impacts to reptiles.

Amphibians

Eastern spadefoot (*Scaphiopus holbrooki)* and southern leopard frog (*Lithobates sphenocephalus*) are the only federally- or state-listed amphibian species with the potential to occur in New York City (**Table 22**). Due to lack of exposure data, amphibians are represented by fish in this evaluation, as is typical for ecological risk assessments. The results of this evaluation have indicated that the implementation of the mosquito control plan would not have the potential to result in predicted significant adverse impacts to threatened, endangered, or special concern fish species for all evaluated pathways. Therefore, the Comprehensive Plan is not expected to result in predicted significant adverse impacts to federally- or state-listed amphibians.

Insects

Little bluet (*Enallagma minusculum*) and checkered white (*Pontia protodice*) are the only federally- or state-listed insects with the potential to occur in New York City (**Table 22**). As concluded in the 2001 FEIS, while there may be some adverse effects and losses of non-target insect individuals as a result of the Comprehensive Plan, these potential adverse effects are for the most part not considered to be significant adverse impacts. Little bluet and checkered white fly and are active during the day, and pesticides are applied between dusk and dawn. Therefore, the two protected species would likely have less exposure, other than potential residues on plants, to adulticide applications. In addition, little bluet is a dragonfly whose primary habitat is near ponds and waterbodies, sensitive areas protected by a 300 to 350 foot buffer. Therefore, the potential exposure to little bluet would be limited. While there would be individual losses of non-target insects in the areas near the application of adulticides, the application of adulticides would be limited temporally and spatially, would not occur for the full spring, summer, and fall periods, and large areas would be exposed to far fewer than the 10 applications per year assumed in the technical analysis of effects of multiple applications. Therefore, the Comprehensive Plan would not be expected to result in predicted significant adverse impacts to federally- or state-listed insects.

Plants

Table 23 presents the updated list of federally and state-listed threatened, endangered, and special concern plant species with the potential to occur within New York City. None of these species occur within habitats identified as having groups of organisms with the potential to be adversely affected by the application of adulticides or larvicides. Most of these plants occur within wetland or coastal areas, which

are restricted areas for pesticide application under the Comprehensive Plan and are protected by a 300-350 foot buffer. As indicated in the 2001 FEIS, DOHMH will continue to maintain a 300-foot buffer between adulticide application and sensitive areas, including habitat for seabeach amaranth on Rockaway Beach. Furthermore, published USEPA risk assessments do not identify risks to terrestrial or aquatic vegetation associated with the application of the pesticides evaluated in this document (USEPA 2016, USEPA 2011). Therefore, Comprehensive Plan is not expected to result in predicted significant adverse impacts to threatened, endangered, or special concern plants.

Table 22
Federally and state-listed threatened, endangered, and special concern animal species in New York City

Bronx			
Birds			
Common name	**Scientific name**	**Federal status**	**State status**
Cooper's hawk	*Accipiter cooperii*	No status	Special Concern
Seaside sparrow	*Ammodramus maritimus*	No status	Special Concern
Peregrine falcon	*Falco peregrinus*	No status	Endangered
Piping plover	*Charadrius melodus*	Endangered	Endangered
Common nighthawk	*Chordeiles minor*	No status	Special Concern
Fish			
Common name	**Scientific name**	**Federal status**	**State status**
Atlantic sturgeon	*Acipenser oxyrinchus*	Endangered	Protected
Shortnose sturgeon	*Acipenser brevirostrum*	Endangered	Endangered
Reptiles			
Common name	**Scientific name**	**Federal status**	**State status**
Eastern box turtle	*Terrapene carolina*	No status	Special Concern
Manhattan			
Birds			
Common name	**Scientific name**	**Federal status**	**State status**
Peregrine falcon	*Falco peregrinus*	No status	Endangered
Common tern	*Sterna hirundo*	No status	Threatened
Fish			
Common name	**Scientific name**	**Federal status**	**State status**
Atlantic sturgeon	Acipenser oxyrinchus	Endangered	Protected
Shortnose sturgeon	*Acipenser brevirostrum*	Endangered	Endangered
Queens			
Birds			
Common name	**Scientific name**	**Federal status**	**State status**
Seaside sparrow	*Ammodramus maritimus*	No status	Special Concern
Short-eared owl	*Asio flammeus*	No status	Endangered
Upland sandpiper	*Bartramia longicauda*	No status	Threatened
Red knot	*Calidris canutus rufa*	Threatened	No status
Piping plover	*Charadrius melodus*	Endangered	Endangered
Common nighthawk	*Chordeiles minor*	No status	Special Concern
Northern harrier	*Circus cyaneus*	No status	Threatened
Peregrine falcon	*Falco peregrinus*	No status	Endangered
Least bittern	*Ixobrychus exilis*	No status	Threatened
Osprey	*Pandion haliaetus*	No status	Special Concern
Pied-billed grebe	*Podilymbus podiceps*	No status	Threatened
Black skimmer	*Rynchops niger*	No status	Special Concern
Roseate tern	*Sterna dougallii*	Endangered	Endangered
Common tern	*Sterna hirundo*	No status	Threatened
Least tern	*Sternula antillarum*	No status	Threatened
Queens (cont.)			
Reptiles			
Common name	**Scientific name**	**Federal status**	**State status**
Spiny softshell	*Apalone spinifera*	No status	Special Concern
Eastern box turtle	*Terrapene carolina*	No status	Special Concern
Eastern hog-nosed snake	*Heterodon platirhinos*	No status	Special Concern
Amphibians			
Common name	**Scientific name**	**Federal status**	**State status**
Eastern spadefoot	*Scaphiopus holbrookii*	No status	Special Concern
Insects			

Table 22
Federally and state-listed threatened, endangered, and special concern animal species in New York City

Common name	Scientific name	Federal status	State status
Little bluet	*Enallagma minusculum*	No status	Threatened
Checkered white	*Pontia protodice*	No status	Special Concern
Brooklyn			
Birds			
Common name	**Scientific name**	**Federal status**	**State status**
Seaside sparrow	*Ammodramus maritimus*	No status	Special Concern
Short-eared owl	*Asio flammeus*	No status	Endangered
Red knot	*Calidris canutus rufa*	Threatened	No status
Piping plover	*Charadrius melodus*	Endangered	Endangered
Common nighthawk	*Chordeiles minor*	No status	Special Concern
Northern harrier	*Circus cyaneus*	No status	Threatened
Peregrine falcon	*Falco peregrinus*	No status	Endangered
Least bittern	*Ixobrychus exilis*	No status	Threatened
Pied-billed grebe	*Podilymbus podiceps*	No status	Threatened
Common tern	*Sterna hirundo*	No status	Threatened
Least tern	*Sternula antillarum*	No status	Threatened
Reptiles			
Common name	**Scientific name**	**Federal status**	**State status**
Fence lizard	*Sceloporus undulatus*	No status	Threatened
Eastern box turtle	*Terrapene carolina*	No status	Special Concern
Staten Island			
Birds			
Common name	**Scientific name**	**Federal status**	**State status**
Cooper's hawk	*Accipiter cooperii*	No status	Special Concern
Seaside sparrow	*Ammodramus maritimus*	No status	Special Concern
Whip-poor-will	*Antrostomus vociferus*	No status	Special Concern
Short-eared owl	*Asio flammeus*	No status	Endangered
Upland sandpiper	*Bartramia longicauda*	No status	Threatened
Common nighthawk	*Chordeiles minor*	No status	Special Concern
Northern harrier	*Circus cyaneus*	No status	Threatened
Peregrine falcon	*Falco peregrinus*	No status	Endangered
Bald eagle	*Haliaeetus leucocephalus*	No status	Threatened
Yellow-breasted chat	*Icteria virens*	No status	Special Concern
Staten Island (cont.)			
Birds			
Common name	**Scientific name**	**Federal status**	**State status**
Least bittern	*Ixobrychus exilis*	No status	Threatened
Osprey	*Pandion haliaetus*	No status	Special Concern
Pied-billed grebe	*Podilymbus podiceps*	No status	Threatened
Reptiles			
Common name	**Scientific name**	**Federal status**	**State status**
Spotted turtle	*Clemmys guttata*	No status	Special Concern
Eastern mud turtle	*Kinosternon subrubrum*	No status	Endangered
Fence lizard	*Sceloporus undulatus*	No status	Threatened
Eastern box turtle	*Terrapene carolina*	No status	Special Concern
Amphibians			
Common name	**Scientific name**	**Federal status**	**State status**
Southern leopard frog	*Lithobates sphenocephalus*	No status	Special Concern
Sources: NYNHP Nature Explorer, USFWS Information, Planning, and Consultation System (IPAC System)			

Table 23
Federally and state-listed threatened, endangered, and special concern plant species in New York City

Bronx			
Common name	**Scientific name**	**Federal status**	**State status**
Yellow giant-hyssop	*Agastache nepetoides*	No status	Threatened
Purple milkweed	*Asclepias purpurascens*	No status	Threatened
White milkweed	*Asclepias variegate*	No status	Endangered
Blunt-lobe grape fern	*Botrychium oneidense*	No status	Threatened
Globose flatsedge	*Cyperus echinatus*	No status	Endangered
Yellow flatsedge	*Cyperus flavescens*	No status	Endangered
Persimmon	*Diospyros virginiana*	No status	Threatened
Slender spikerush	*Eleocharis tenuis var. pseudoptera*	No status	Endangered
Golden-seal	*Hydrastis canadensis*	No status	Threatened
Slender blue flag	*Iris prismatica*	No status	Threatened
Large grass-leaved rush	*Juncus biflorus*	No status	Endangered
Short-fruit rush	*Juncus brachycarpus*	No status	Endangered
False lettuce	*Lactuca floridana*	No status	Endangered
Field beadgrass	*Paspalum leave*	No status	Endangered
Wild pink	*Silene caroliniana ssp. pensylvanica*	No status	Threatened
Downy carrion-flower	*Smilax pulverulenta*	No status	Endangered
Northern gama grass	*Tripsacum dactyloides*	No status	Threatened
Queens			
Common name	**Scientific name**	**Federal status**	**State status**
Yellow giant-hyssop	*Agastache nepetoides*	No status	Threatened
Woodland agrimony	*Agrimonia rostellata*	No status	Threatened
Seabeach amaranth	*Amaranthus pumilus*	Threatened	Threatened
Seaside bulrush	*Bolboschoenus maritimus ssp. paludosus*	No status	Threatened
Side-oats grama	*Bouteloua curtipendula var. curtipendula*	No status	Endangered
Cat-tail sedge	*Carex typhina*	No status	Endangered
Dune sandspur	*Cenchrus tribuloides*	No status	Threatened
Smartweed dodder	*Cuscuta polygonorum*	No status	Endangered
Yellow flatsedge	*Cyperus flavescens*	No status	Endangered
Great Plains flatsedge	*Cyperus lupulinus ssp. lupulinus*	No status	Threatened
Coast flatsedge	*Cyperus polystachyos var. texensis*	No status	Endangered
Retrorse flatsedge	*Cyperus retrorsus var. retrorsus*	No status	Endangered
Little bluet	*Enallagma minusculum*	No status	Threatened
Fringed boneset	*Eupatorium torreyanum*	No status	Threatened
Scirpus-like rush	*Juncus scirpoides*	No status	Endangered
Pale duckweed	*Lemna valdiviana*	No status	Endangered
Lowland yellow loosestrife	*Lysimachia hybrid*	No status	Endangered
Cut-leaved evening-primrose	*Oenothera laciniata*	No status	Endangered
Oakes' evening-primrose	*Oenothera oakesiana*	No status	Threatened
Seaside plantain	*Plantago maritima var. juncoides*	No status	Threatened
Pied-billed grebe	*Podilymbus podiceps*	No status	Threatened
Queens (cont.)			
Common name	**Scientific name**	**Federal status**	**State status**
Willow oak	*Quercus phellos*	No status	Endangered
Rough rush-grass	*Sporobolus clandestinus*	No status	Endangered
Narrow-leaf sea-blite	*Suaeda linearis*	No status	Endangered
Roland's sea-blite	*Suaeda rolandii*	No status	Endangered
Saltmarsh aster	*Symphyotrichum subulatum var. subulatum*	No status	Threatened
Northern gama grass	*Tripsacum dactyloides*	No status	Threatened

Table 23
Federally and state-listed threatened, endangered, and special concern plant species in New York City

Winter grape	*Vitis vulpine*	No status	Endangered
Brooklyn			
Common name	**Scientific name**	**Federal status**	**State status**
Dune sandspur	*Cenchrus tribuloides*	No status	Threatened
Red pigweed	*Chenopodium rubrum*	No status	Threatened
Yellow flatsedge	*Cyperus flavescens*	No status	Endangered
Retrorse flatsedge	*Cyperus retrorsus var. retrorsus*	No status	Endangered
Minute duckweed	*Lemna perpusilla*	No status	Endangered
Woodland bluegrass	*Poa sylvestris*	No status	Endangered
Willow oak	*Quercus phellos*	No status	Endangered
Roland's sea-blite	*Suaeda rolandii*	No status	Endangered
Staten Island			
Common name	**Scientific name**	**Federal status**	**State status**
Yellow giant-hyssop	*Agastache nepetoides*	No status	Threatened
Nantucket juneberry	*Amelanchier nantucketensis*	No status	Endangered
Purple milkweed	*Asclepias purpurascens*	No status	Threatened
Green milkweed	*Asclepias viridiflora*	No status	Threatened
Thicket sedge	*Carex abscondita*	No status	Endangered
Dune sandspur	*Cenchrus tribuloides*	No status	Threatened
Dwarf hawthorn	*Crataegus uniflora*	No status	Endangered
Button-bush dodder	*Cuscuta cephalanthi*	No status	Endangered
Southern dodder	*Cuscuta obtusiflora var. glandulosa*	No status	Endangered
Globose flatsedge	*Cyperus echinatus*	No status	Endangered
Great Plains flatsedge	*Cyperus lupulinus ssp. lupulinus*	No status	Threatened
Lowland fragile fern	*Cystopteris protrusa*	No status	Endangered
Velvet panic grass	*Dichanthelium scoparium*	No status	Endangered
Persimmon	*Diospyros virginiana*	No status	Threatened
Angled spikerush	*Eleocharis quadrangulata*	No status	Endangered
American strawberry-bush	*Euonymus americanus*	No status	Endangered
White boneset	*Eupatorium album var. album*	No status	Endangered
Trinerved white boneset	*Eupatorium album var. subvenosum*	No status	Threatened
White-bracted boneset	*Eupatorium leucolepis var. leucolepis*	No status	Endangered
Fringed boneset	*Eupatorium torreyanum*	No status	Threatened
Soapwort gentian	*Gentiana saponaria*	No status	Endangered
Staten Island (cont.)			
Common name	**Scientific name**	**Federal status**	**State status**
Featherfoil	*Hottonia inflata*	No status	Threatened
Whorled-pennywort	*Hydrocotyle verticillata*	No status	Endangered
St. Andrew's cross	*Hypericum hypericoides ssp. multicaule*	No status	Endangered
Wild potato-vine	*Ipomoea pandurata*	No status	Endangered
Slender blue Flag	*Iris prismatica*	No status	Threatened
Least bittern	*Ixobrychus exilis*	No status	Threatened
Large grass-leaved rush	*Juncus biflorus*	No status	Endangered
Scirpus-like rush	*Juncus scirpoides*	No status	Endangered
Minute duckweed	*Lemna perpusilla*	No status	Endangered
Velvety bush-clover	*Lespedeza stuevei*	No status	Threatened
Climbing fern	*Lygodium palmatum*	No status	Endangered
Sweetbay magnolia	*Magnolia virginiana*	No status	Endangered
Oakes' evening-primrose	*Oenothera oakesiana*	No status	Threatened
Shortleaf pine	*Pinus echinata*	No status	Endangered
Virginia pine	*Pinus virginiana*	No status	Endangered
Swamp cottonwood	*Populus heterophylla*	No status	Threatened

Table 23
Federally and state-listed threatened, endangered, and special concern plant species in New York City

Blunt mountain-mint	*Pycnanthemum muticum*	No status	Threatened
Torrey's mountain-mint	*Pycnanthemum torrei*	No status	Endangered
Whorled mountain-mint	*Pycnanthemum verticillatum var. verticillatum*	No status	Endangered
Willow oak	*Quercus phellos*	No status	Endangered
Rose-pink	*Sabatia angularis*	No status	Endangered
Downy carrion-flower	*Smilax pulverulenta*	No status	Endangered
Pink wild bean	*Strophostyles umbellata*	No status	Endangered
Northern gama grass	*Tripsacum dactyloides*	No status	Threatened
Possum-haw	*Viburnum nudum var. nudum*	No status	Endangered
Primrose-leaf violet	*Viola primulifolia*	No status	Threatened
Winter grape	*Vitis vulpina*	No status	Endangered
Sources: NYNHP Nature Explorer, USFWS Information, Planning, and Consultation System (IPAC System)			

Cumulative effects from the Application of Adulticides and Larvicides

As presented in the 2001 FEIS, because of differences in the mode of action between the adulticides evaluated in this EIS and the larvicides that are part of the City's Routine Program, the cumulative effects should be limited. The biological larvicides target primarily mosquitoes although some groups of dipterans are also affected, and therefore subsequent introduction of adulticides will not result in greater effects on natural resources than the adulticides alone would have. The results of the ecological risk assessment did not indicate a potential for predicted significant adverse impacts to aquatic biota from the application of methoprene in ponds or due to drift of ULV adulticides in ponds. Therefore, the potential for adverse cumulative effects from methoprene and drift during adulticide application is limited and would be further minimized through the 300-foot setback used during adulticide application.

Cumulative Effects of Active Ingredients Applied by City with Background

The City's post-spray water sampling from 2003 through 2016, summarized in the proceeding Water Quality section of this technical memorandum did not generally find concentrations of sumithrin, PBO or prallethrin above the LOQ. Therefore, there is little potential for cumulative effects with any background concentrations. Additionally the pre-adulticide sampling conducted prior to adulticide application did not find concentrations of the adulticides above the LOQ.

Potential Related Impacts

The application methods for the adulticides and larvicides evaluated in this technical memorandum would follow the same means and methods described in the FEIS. Therefore, there would be no change in the conclusion presented in the 2001 FEIS that the movement of trucks and aircrafts, and noise from trucks or aircraft, lights from truck or aircraft and other human disturbances associated with implementation of the mosquito control plan would result in significant adverse impacts to natural resources.

INERTS

Because the inerts associated with the additional adulticides evaluated herein, and the larvicides are expected to be similar to those evaluated in the 2001 FEIS, 2001 FEIS finding of no significant adverse impact to natural resources due to inerts would apply to the pesticides evaluated in this technical memorandum. The volume of the inerts (petroleum distillates or white mineral oil) would be very low, and the amount that would make its way into surface waters in and around New York City should not affect water quality or aquatic organisms.

WATER QUALITY

The 2001 FEIS assessed the potential for application of adulticides under the Mosquito-Borne Disease Control Program to affect water quality within the representative study areas and the primary surface water bodies of the City. Of the adulticides evaluated in the FEIS, only malathion has a water quality standard. The FEIS concluded that the application of malathion would have little potential to result in concentrations in surface waters that exceed the standard. Due to the affinity of pyrethroids to bond to soil particles, organic matter, and other particulates in the water column, and to sediment, and taking into account the setback required to protect water bodies during adulticide application, the application of pyrethroids was found to have little potential to adversely affect water quality of surface waters within and surrounding New York City.

This conclusion would still apply to the adulticides evaluated in this technical memorandum, and is supported by the results of pre- and post-spraying water quality and fish observations that have been conducted for the Mosquito-Borne Disease Control Program since 2000. As described in the 2001 FEIS and as required by NYSDEC permits, DOHMH conducts water quality monitoring to detect pesticide residues before and after spray events. As part of the Mosquito-Borne Disease Control Program, water quality samples were collected from water bodies within the spray zone. Data collected from 2003 through 2016 shows that no concentrations of sumithrin, PBO or prallethrin were found above the LOQ, and no fish kills were reported.

PUBLIC HEALTH

SUMMARY OF FINDINGS FROM THE 2001 FEIS

The Public Health impact assessment for the 2001 FEIS was based on the framework of analysis described above, in combination with information and analyses from a Literature Review, a Risk Assessment, Epidemiologic and Attributable Risk Analyses, as well as summary information from reports received by the New York City Poison Control Registry and New York State Department of Health (NYSDOH) Statewide Pesticide Poisoning Registry.

Based on the evaluation of the results of the analyses mentioned above, the 2001 FEIS concluded that no significant adverse public health impacts would be expected from exposure to the adulticides when applied as part of the Comprehensive Plan, and that any effects would likely be less than those of West Nile virus.

To address the proposed modifications to the Comprehensive Plan, this Technical Memorandum includes an updatedreview of scientific literature and government documents published since the 2001 FEIS for sumithrin and PBO. In addition, a new literature review was undertaken for the pyrethroid adulticide prallethrin and the mosquito larvicide methoprene. An abbreviated literature review was also undertaken for the pyrethroid mosquito adulticide deltamethrin and two larvicides, spinosad and pyriproxyfen. The abbreviated reviews are considered sufficient, since EPA/other studies tend to more review pyrethroids as a class versus individual active ingredients, and the spinosad and pyriproxyfen are larvicides that based on the 2000 EAS and 2001 FEIS will have relative exposure levels and pathways to be minimal compared to adulticides. In addition, this Technical Memorandum examines updates to the risk assessment procedures since the 2001 FEIS, the active ingredient application rates and dispersion/fate of such in the environment for the Comprehensive Plan, the toxicity analyses undertaken in the 2001 FEIS (and conclusions from such) and the Epidemiologic and Attributable Risk Analyses from the 2001 FEIS with additional information since the 2001 FEIS to determine if there would be expected changes to the 2001 FEIS public health conclusions with the proposed modifications to the Comprehensive Plan.

LITERATURE REVIEW

The adulticide ingredients sumithrin, PBO and prallethrin, as well as the larvicide methoprene are currently under registration review at USEPA. In November of 2016, Draft Human Health Risk

Assessments for sumithrin and prallethrin were published for public comment. Both assessments address previous data gaps.

Additionally, USEPA human health risk assessments were reviewed and an abbreviated literature review was conducted for three additional chemicals not included in the 2001 FEIS. These include the pyrethroid adulticide active ingredient deltamethrin and two larvicides, spinosad and pyriproxyfen. Detailed descriptions of the findings for each chemical are outlined below.

Sumithrin (phenothrin)

Sumithrin (also known as d-phenothrin or phenothrin) is used for mosquito control in outdoor areas, as well as in shampoo for treatment of head lice (World Health Organization, 1990b). Sumithrin is characterized as having low acute toxicity via oral (Category IV), inhalational (Category IV) and dermal routes (Category III; USEPA 2011, World Health Organization 2009), and not likely to be a human carcinogen (USEPA 2011). The liver is the most sensitive target in toxicity studies (USEPA 2016a). While most pyrethroids are rapidly metabolized in mammals, Kaneko et al., (1981) found that 96 percent of sumithrin absorbed through the skin in rats in a single dose was excreted within 6 days. Residual sumithrin concentrations in fat tissues were slightly higher than in other tissues 7 days after a single oral dose of 10 mg/kg, suggesting that sumithrin may bioaccumulate in animals if they are exposed over a long period of time (Kaneko et al., 1981).

Sumithrin is currently under registration review by USEPA. A draft human health risk assessment was posted for public comment on November 29, 2016 (USEPA 2016a). Data gaps concerning neurotoxicity were satisfied; the requirement of immunotoxicity data was waived (USEPA 2013a). The Health Effects Division (HED) determined that there is sufficient evidence to evaluate toxicity in individuals >6 years of age, but that more data is needed to evaluate risk in infants and younger children. The EPA has requested and anticipates further data regarding juvenile sensitivity (USEPA 2016a). In the interim, conservative uncertainty factors (UF) have been employed to address potentially vulnerable populations. Sumithrin has not yet undergone the Endocrine Disruptor Screening Program (EDSP), now required for all pesticides (USEPA 1998, USEPA 2012a).

A review of the scientific literature was conducted to determine whether additional studies have found associations with the following health outcomes since the 2001 FEIS:

Skin and Eye Irritation:
There are no examples or data supporting an association between sumithrin and skin and eye irritation and no new information related to this outcome was found in this review.

Gastrointestinal:
There are no examples or data supporting an association between sumithrin and gastrointestinal problems and no new information related to this outcome was found in this review.

Respiratory Effects Including Asthma:
There are no examples or data supporting an association between sumithrin and respiratory effects. In a 2009 review, the USEPA found no consistent evidence for an association between pyrethroids as a class and asthma and allergy (USEPA 2009). The review included human pesticide incident reports, animal studies, case reports, and epidemiological studies.

DOHMH examined rates of ED visits for asthma following application of the aerosolized Anvil 10+10 (containing sumithrin 10% and PBO 10%) by truck-based ground spraying to combat West Nile Virus (Karpati et al. 2004). There was no significant difference in the number of ED visits for asthma in the 3 days following spraying (501 visits) compared with the 3 days prior to spraying (510 visits) in analyses by zip code over the course of a 14 month period (Karpati 2004). The analysis also found no significant increase in ED visits in two vulnerable populations; children and COPD patients. At the time that this literature review was conducted (November 2016), this was the only study of its kind to examine potential respiratory affects following city-wide truck-based mosquito spraying. However, it only examined one short term, severe outcome (ED visit for asthma), and does not consider less severe respiratory effects nor

does it account for prenatal exposures that may contribute to later adverse respiratory problems as observed by Liu *et al.* following residential exposures to PBO (Liu et al. 2012).

Immunologic/Allergic:
There are no examples or data supporting an association between sumithrin and immunologic/allergic outcomes and no new information related to this outcome was found in this review. USEPA waived the requirement for immunotoxicity testing for sumithrin reregistration, citing lack of immunotoxicity for pyrethroids as a class (USEPA 2013a).

Multiple Chemical Sensitivity:
There are no examples or data supporting an association between sumithrin and MCS and no new information related to this outcome was found in this review.

Neurological:
There are no examples or data of neurological effects in humans caused by sumithrin and no new information related to this outcome in humans was found in this review. Sumithrin is purportedly less neurotoxic than other Type I pyrethroids, for reasons unknown. No neurotoxicity was seen in an acute (2000mg/kg per day; USEPA 2016 MRID 47593101) or sub-chronic (1456 mg/kg per day for 90 days) exposure studies in the rat (USEPA 2016, MRID 49173604). Three reports referenced in the 2001 FEIS confirm the absence of neurological effects in rats exposed to relatively high levels of sumithrin. A more recent study found spina bifida in rabbit fetuses exposed prenatally to 100mg/kg/day sumithrin, suggestive of potential neurotoxic effects (USEPA 2016, MRID 41230003), however a subsequent study failed to replicate these findings at a higher dose (USEPA MRID 49173605).

Cognitive Developmental Disabilities Including Autism:
There are no examples or data supporting an association between sumithrin and developmental disabilities and no new information related to this outcome was found in this review.

Endocrine Disruption:
Although the EPA has yet to add sumithrin to the EDSP priority list, limited studies have examined its endocrine disrupting properties. Brody et al. identified sumithrin as the likely cause of an apparent epidemic of gynecomastia identified by the CDC in 20/284 Haitian refugees in US detention centers in 1981 and 1982 (Brody 2003). Sumithrin, the active ingredient in a delousing agent applied to bedding and clothing, competed with testosterone for androgen receptor binding in human fibroblast cells. No estrogen receptor binding was observed. Sumithrin treatment led to reduced prostate weight in immature male rats, further evidence of antiandrogenic effects. No changes in plasma hormone levels were observed in affected subjects. Sumithrin has shown inhibitory effects on hormones in human cells (Go et al., 1999, Garey and Wolff, 1998). In these experiments, human breast cancer tissue cells were used to evaluate the effects on hormones associated with sumithrin. Yamada et al. administered sumithrin by oral gavage (100, 300, or 1000 mg/kg body weight per day) to immature female and castrated prepubertal male rats (Yamada 2003). Estrogenic activity was assessed by the 3 day uterotrophic assay in females. Androgenic/anti-androgenic activity was assessed in males by the Herschberger assay. Sumithrin treated females showed no change in uterine weight after 3 days of sumithrin treatment, suggesting lack of estrogenic activity. No changes in male sex organ weights or serum androgen levels were observed in the Herschberger assay after 10 days of sumithrin treatment suggesting lack of androgen or anti-androgenic activity. Liver weight was slightly increased at the 1000mg dose in females and the 300 and 1000 mg dose in males. In vitro studies using human breast cancer cell lines demonstrate no binding of sumithrin to either estrogen or progesterone receptors (Saito 2000, Sumida 2001). In addition, sumithrin had no effect on ERα or PR- dependent gene transcription (Saito 2000, Sumida 2001). These studies are limited in that they utilized an immortalized cell line and concentrations of sumithrin that may not be representative of the spraying of adulticides in New York City.

Sumithrin treatment of MCF-7 cells, a human breast cancer cell line, led to an increased expression of the proto-oncogene WNT10B (Kasat 2002). WNT10B is activated by estrogen, increases mammary cell proliferation, and may be involved in the development of malignant breast tumors. This study suggests a

link between sumithrin exposure and breast cancer or endocrine disruption. However, a major limitation of this study is that the authors did not examine WNT10B expression at the protein level. In addition, they did not explore the mechanism by which sumithrin increases WNT10B expression, e.g. via estrogen receptor activation. Finally, it is not clear whether the concentration of sumithrin utilized in this study (10 and 30μM) is representative of exposures experienced as a result of the spraying of adulticides in New York City.

Developmental/Reproductive Including Birth Defects:

There are no examples or data supporting an association between sumithrin and developmental/reproductive problems or birth defects and no new information related to this outcome was found in this review. Findings from studies conducted in animals since the 2001 FEIS are conflicting, but suggest that effects on fetal development occur following exposure to doses much higher than expected from mosquito applications of sumithrin. Developmental toxicity was found at lower doses than previous studies in the rabbit, with spina bifida and hydrocephalus observed at 100 and 500mg/kg/day, respectively (USEPA 2016 MRID 41230003), but these results are contradicted by a study that found no fetal neurotoxic effects in offspring of rabbits exposed to 750mg/kg/day (USEPA 2016a MRID 49173605). A developmental toxicity study and 2-generation reproductive study in the rat showed adverse maternal (decreased weight gain and food consumption) and fetal (decreased fetal weight and developmental delay) only at a very high dose of 3000mg/kg/day (USEPA 2016a).

Cancer:

There are no examples or data supporting an association between sumithrin and cancer in humans and no new information related to this outcome in humans was found in this review. USEPA classifies sumithrin as not likely to cause cancer in humans. Atmaca et al. observed dose-dependent oxidative DNA damage in the kidney and liver of male rats treated with sumithrin by intraperitoneal injection for 14 days (Atmaca 2015). Effects were seen at relatively high (50-200mg/kg per day) doses and via a route of exposure that may not be representative of the spraying of adulticides in New York City. Nagy et al. found that treatment of cultured human peripheral blood lymphocytes and hepatocytes with sumithrin caused dose-dependent oxidative DNA damage in the absence of overt cytotoxicity (Nagy 2014). Although this is an in vitro study, the use of primary human blood cell cultures is a strength in that human blood cells in circulation may encounter sumithrin following exposures. The use of an immortalized hepatocyte cell line is a weakness of this study. Not surprisingly, peripheral blood cells were more sensitive to the genotoxic effects of sumithrin than the immortalized cell line. The doses used (20μM-1000μM) used in this study may not be representative of the spraying of adulticides in New York City.

Conclusions:

The review of the scientific literature and government documents did not find any new evidence supporting associations between sumithrin and skin and eye irritation; gastrointestinal, respiratory, immunological, neurological, or developmental/reproductive problems; MCS; cognitive developmental disabilities; or cancer. The USEPA draft human health risk assessment and DOHMH finding of no association with asthma ED visits provide additional reassurance of the use of sumithrin for this purpose. Although recent studies suggest the potential for sumithrin to interfere with the endocrine system and to cause changes to peripheral blood cells, these outcomes occurred under scenarios and doses that do not represent exposures that are expected to occur following outdoor ULV application as a mosquito adulticide. Importantly, a 2008 CDC study found no detectable increase in urinary pyrethroid metabolites following ULV spraying of Anvil 10+10 (containing sumithrin 10% and PBO 10%), suggesting that meaningful exposure to these chemicals does not occur following this mode of application (Currier 2005). Finally, two modeling studies of ULV truck application found no increased risk of cancer or noncancer endpoints following acute, sub-chronic, or chronic exposure to sumithrin (Macedo 2007).

Prallethrin

Prallethrin is used in household insecticides to combat mosquitoes, houseflies, and cockroaches (World Health Organization 2002) and in veterinary uses in the treatment of domestic pets. Like other

pyrethroids, prallethrin's primary mode of toxicity in insects and mammals is via modulation of voltage gated sodium channels in nerve axons. It is lipophilic and able to cross as well as insert itself into cell membranes. Prallethrin is characterized as having moderate acute toxicity via oral and inhalational exposures (Category II), and low toxicity via the dermal route (Category IV, USEPA 2003). The most sensitive endpoint in the toxicity database is neurotoxicity (USEPA 2016b). USEPA classifies prallethrin as not likely to be a human carcinogen based on lack of mutagenicity and carcinogenicity in laboratory (USEPA 2003). It is mildly irritating to the eyes, non-irritating to the skin, and not found to be a dermal sensitizer. The World Health Organization International Programme on Chemical Safety (IPCS) Hazard Classification for prallethrin is Moderately Hazardous (World Health Organization 2009).

At the time that this review was conducted (September-December 2016), prallethrin was under registration review by the EPA. A revised human health risk assessment for registration review was posted for public comment on November 29, 2016 (EPA 2016b). The draft states that the guideline toxicology studies for reregistration are considered complete, with the exception of data to assess the potential for enhanced vulnerability of juvenile populations (EPA 2016b). The EPA has requested and anticipates further data regarding juvenile sensitivity (USEPA 2016b). In the interim, conservative uncertainty factors (UF) have been employed to address potentially vulnerable populations. The requirement for immunotoxicity studies has been waived given the lack of immunotoxicity for other pyrethroids (USEPA 2013a). The EPA recommends that the requirement for developmental neurotoxicology (DNT) studies be fulfilled by six existing studies for other pyrethroids given that DNT studies of pyrethroids don't adequately reflect sensitivity during early life (EPA 2016b). Prallethrin has not yet undergone the Endocrine Disruptor Screening Program (EDSP), now required for all pesticides (USEPA 1998, USEPA 2012c).

A review of the scientific literature was to determine whether additional studies have found associations with the following health outcomes since the 2001 FEIS:

Skin and Eye Irritation:

There are no examples or data supporting an association between prallethrin and skin and eye irritation. One case study described necrotic skin lesions in a 68 year old diabetic patient who directly applied an insecticide product containing 1.2% prallethrin to her skin several times a day for two days (Botnariu et al. 2016). Such an exposure is not likely to be representative of exposures experienced as a result of the spraying of adulticides in New York City.

Gastrointestinal:

There are no examples or data supporting an association between prallethrin and gastrointestinal problems.

Respiratory Effects Including Asthma:

There are no examples or data in the scientific literature of respiratory or asthma effects in humans or animals caused by prallethrin. In a 2009 review, the USEPA found no consistent evidence for an association between pyrethroids as a class and asthma and allergy (USEPA 2009). The review included human pesticide incident reports, animal studies, case reports, and epidemiological studies.

Immunologic/Allergic: There is limited evidence that prallethrin alters blood cell number and composition, which may affect immune function. However, USEPA waived the requirement for immunotoxicity testing for prallethrin reregistration, citing lack of immunotoxicity for pyrethroids as a class (USEPA 2013a).

Narendra et al examined changes to red blood cell membranes in 12 adult male volunteers utilizing resulting from inhalational exposure to prallethrin 8-10 hours per day via an electric mosquito repellant mat containing prallethrin 1.6% w/w (Narendra et al. 2007). Significant decreases in red blood cell membrane cholesterol and phospholipid contents and membrane lipid peroxidase activity was observed. Nitrate and nitrate levels in blood plasma and erythrocytes was increased. In a subsequent publication, the same authors found small but significant increases in plasma glucose, phospholipids, nitrite and nitrate, and lipid peroxidases and a decrease in plasma cholesterol in the blood of adult male subjects exposed to

prallethrin 8-10 hours per day via an electric mosquito repellant mat containing prallethrin 1.6% w/w. (Narendra et al. 2008). These studies are limited by the fact that subjects were exposed to additional chemicals contained within the pesticide mixture. In addition, the authors examined chronic, continuous exposure to vaporized prallethrin in an indoor environment, which may not be representative of exposures experienced as a result of the spraying of adulticides in New York City. The hematotoxic and immunotoxic effects of continuous exposure to inhaled prallethrin were explored in a rodent model (Al-Damegh 2013). Adult male rats were exposed to an insecticide containing prallethrin 1.6%w/w by inhalation for up to 72 hours. Rats were exposed via a commercially available Electric Mosquito Repellant Liquid Vaporizer, commonly utilized in homes in Saudi Arabia. The maximum concentration of prallethrin detected in the air was 0.0208ppm. After 24 hours, changes in hematological endpoints were observed including increased numbers of total white blood cell (WBCs), lymphocytes, red blood cells (RBCs), hemoglobin, packed cell volume, platelets, mean corpuscular volume, and mean corpuscular hemoglobin. A reduction in neutrophil number and a transient reduction in monocytes was also observed. Creatine kinase, γ-glutamyltranspeptidase, super oxide dismutase, nitric oxide, MDA, alpha fetoprotein, interleukin-2, and TNF-α. This experiment in which rats were chronically exposed to vaporized prallethrin in an indoor environment may not be representative of exposures experienced as a result of the spraying of adulticides in New York City. Additional chemicals present in the prallethrin containing solution are not identified, making it difficult to attribute the observed effects to prallethrin alone.

Multiple Chemical Sensitivity:
There are no examples or data supporting an association between prallethrin and MCS.

Neurological:
Neurotoxicity is the most sensitive endpoint in the EPA toxicity database for prallethrin, with effects seen across species, sexes, and routes of administration (USEPA 2016b). There are no examples or data of neurological effects in humans caused by prallethrin within the scientific literature reviewed. Acute neurotoxicity studies in the rat show reduced motor activity, tremors, convulsions, and gait and postural abnormalities at high doses (USEPA 2016b MRID 42077005). Sub-chronic exposures led to higher rates of arousal in rats and tremors in dogs, with chronic exposures showing similar effects at lower doses (USEPA 2016b MRID 42030905, 42077002)

Cognitive Developmental Disabilities Including Autism:
There are no examples or data supporting an association between prallethrin and developmental disabilities.

Endocrine Disruption:
Although the EPA has yet to add prallethrin to the EDSP priority list, limited studies find no evidence for endocrine disrupting effects of prallethrin. In vitro studies using human breast cancer cell lines demonstrate no binding of prallethrin to either estrogen or progesterone receptors (Saito 2000, Sumida 2001). In addition, prallethrin had no effect on ER-α or PR- dependent gene transcription (Saito 2000, Sumida 2001). There are no examples or data of endocrine disruption effects in humans caused by prallethrin available within the scientific literature.

Developmental/Reproductive Including Birth Defects: There are no examples or data supporting an association between prallethrin and developmental or reproductive defects. No fetal or offspring toxicity was observed for prallethrin in developmental studies in the rat and rabbit or a 2-generation reproduction study in the rat (EPA 2016b).

Cancer:
Although EPA has previously characterized prallethrin as noncarcinogenic in humans and nonmutagenic (USEPA 2003), a recent study demonstrated chromosomal abnormalities, increased micronucleated erythrocytes, and reduced mitotic index in bone marrow cells of adult male rats orally exposed to 64mg/kg body weight per day prallethrin (1/10 LD50) for 28 days (Mossa 2013a). These findings are indicative of genotoxicity and cytotoxicity. The authors utilized the same treatment paradigm to investigate the effects of prallethrin exposure on liver and kidney function (Mossa 2013b, Refaie 2014).

Decreased body weight gain, increased liver weight, and changes in both blood and liver enzymes were also observed. There are no examples of cancer in humans caused by prallethrin available within the literature.

Conclusions:
The review of the scientific literature and government documents did not find any evidence supporting associations between prallethrin and eye irritation; gastrointestinal, respiratory, endocrine, or developmental/reproductive problems; MCS; cognitive developmental disabilities; or cancer. Neurotoxicity, skin irritation, genotoxicity, and immunotoxicity occurred only at doses greater than would be experienced following outdoor ULV application of prallethrin. In addition, the USEPA draft human health risk assessment for prallethrin posted for comment in November 2016 did not find and cancer or noncancer risks from prallethrin exposure in models of ULV mosquito applications (USEPA 2016b).

Piperonyl Butoxide

The addition of synergistic compounds, such as PBO, improves the insecticidal efficacy of pyrethroids by blocking the enzymes responsible for breaking down pyrethroids in insects (Knowles, 1991). PBO also inhibits these enzymes in mammals, but only at doses much higher than doses that are effective in insects. As reported by Knowles (1991), PBO itself is considered minimally toxic, and is not considered likely to cause significant signs or symptoms of toxicity following short-term oral or skin exposures (Knowles, 1991). USEPA classifies PBO as having low acute toxicity via the oral, inhalational, and dermal routes, and as a possible human carcinogen (Group C). PBO is poorly absorbed from the gastrointestinal tract. Once absorbed, it is excreted rapidly in the urine (Knowles, 1991). Because it is poorly absorbed from the gastrointestinal tract, PBO is largely excreted via the feces (Sarles and Vandegrift, 1952).

At the time of this review (September-December 2016), PBO was under registration review at EPA with a draft for public comment expected in early 2017 and a final decision in mid-2017 (USEPA 2006). The agency anticipates requiring data about the following in order to conduct a complete human health risk assessment: acute and sub-chronic neurotoxicity, immunotoxicity study, field accumulation study in rotational crops. DOHMH will review the findings once the data are available.

Skin and Eye Irritation:
There are no examples or data supporting an association between PBO and skin and eye irritation and no new information related to this outcome was found in this review.

Gastrointestinal:
There are no examples or data supporting an association between PBO and gastrointestinal problems and no new information related to this outcome was found in this review.

Respiratory Effects Including Asthma:
Liu et al reported a significant association between prenatal exposure to PBO measured by personal air monitoring and increased odds of noninfectious cough at age 5-6 years (Liu et al. 2012). There was a small but non-significant positive association between prenatal PBO and asthma and wheeze. PBO was not significantly associated with IgE production or fractional exhaled nitric oxide. PBO exposure at age 5-6 was not associated with increased odds of cough, suggesting that the prenatal period is a time of enhanced vulnerability. It is not possible to determine whether the findings are a direct result of PBO exposure or whether PBO is a proxy for other pesticide active ingredients. There are no examples or data of respiratory or asthma effects in animals caused by the synergist PBO available within the scientific literature.

Immunologic/Allergic:
There are no examples or data supporting an association between PBO and immunologic/allergic effects in humans and no new information related to this outcome in humans was found in this review. However several recent animal studies suggest potential mechanisms by which PBO may alter immune function. 7 week old mice were treated with PBO (0, 3, 30, or 300mg/kg body weight per day; 1/3 LD50 2600 mg/kg per day) by oral gavage for 5 days and inoculated with sheep red blood cells (Fukuyuma 2013, Nishino

2014). Antibody response to the SRBCs and B cell number in the spleen was assessed. PBO led to a nonsignificant trend in decreased production of IgM antibodies to SRBC and decreased expression of B cell surface antigens in the spleen as well as decreased B cells in the germinal center. In vitro experiments utilizing a T cell leukemia cell line demonstrated increased apoptosis in the presence of PBO. Taken together, these data are suggestive of immunosuppressive effects of PBO. Fukuyuma et al. examined allergic airway response in mice pretreated with PBO (100mg/kg body weight per day for 5 days) or PBO in combination with methoxychlor (MXC). Although PBO enhanced the effects of MXC on increased serum IgE, chemokines, and eosinophils following OVA sensitization and inhalation challenge, no effects were seen with PBO treatment alone (Fukuyuma 2014). Vardavas et al. found increased markers of oxidative stress and inflammation in the liver and kidney of rabbits treated with oral PBO at 22.5 or 45 mg/kg body weight per day for 4 months (Vardavas 2016a and 2016b). Emerson et al. found that preadministration of PBO in experimental allergic encephalomyelitis (EAE), a mouse model of multiple sclerosis attenuated symptom severity by inhibition of T-cell response (Emerson 2001). While these studies suggest interaction of PBO with the immune system, the doses and route of exposure do not reflect exposure that would be experienced ollowing mosquito adulticide spraying in New York City. In cell-based laboratory studies, PBO (55μM) induced program cell death in cultured mouse splenocytes (Battaglia 2010). PBO (50μM) inhibited histamine release from isolated rat mast cells and inhibited Ca2+-ATPase activity in isolated rat brain synaptosomal membranes and leukocyte membranes (Grosman et al. 2007, Grosman et al. 2005). Again, these experimental paradigms likely do not reflect human exposures resulting from mosquito spray applications.

Multiple Chemical Sensitivity:

There are no examples or data supporting an association between PBO and MCS and no new information related to this outcome was found in this review.

Neurological:

There are no examples or data of neurological effects in humans or animals caused by the synergist PBO available within the literature. However the potential for PBO to interact with the central nervous system is indicated by studies showing binding to and inhibition of cannabinoid receptors (CB1) on isolated mouse brain membrane preparations (Dhopeshkawar 2011, Dhopeshkawar 2014).

Cognitive Developmental Disabilities Including Autism:

Since the publication of the 2001 FEIS, epidemiological and laboratory based studies have found evidence for PBO effects on cognitive development and behavior. Horton et al found an association between PBO in maternal personal air monitors and cognitive development at 36 months in a cohort of low income families residing in New York City (Horton 2011). Specifically, children exposed to higher levels of PBO, but not permethrin, had poorer performance on the Bayley Scales of Infant Development Mental Development Index (MDI). This study suggests that the developing fetus may be particularly sensitive to PBO exposures and that inhalation may be an important route of exposure, however no internal measures of PBO were obtained. It is not possible to determine whether the findings are a direct result of PBO exposure or whether PBO is a proxy for other pesticide active ingredients. Rodent studies suggest the potential for PBO effects on behavior. Tanaka administered PBO (.01, .03, .09%) in the diet of female mice beginning at 5 weeks of age (F0 generation), through pregnancy and 9 weeks of age in offspring (F1 generation) (Tanaka 2003). Dose-dependent effects on behavior were observed in male offspring, including delayed surface righting at postnatal day 7 and depressed olfactory orientation at postnatal day 14. Increased movement activity of exploratory behavior was observed in the adult male F1 generation. In follow up studies, dietary exposure to PBO during the gestational and postnatal periods resulted in dose dependent decreased body weight in male and female neonates, delayed surface righting on PND 7 in males and females, delayed swimming direction in males on PND7 and in high dose females, delayed swimming head angle in males, and increased rearing in males (Tanaka and Inomata 2015). PBO levels administered in these studies are much higher than estimated dietary intake in humans. 0.03% PBO is the equivalent of 40-160mg/kg body weight per day, 200 times the ADI of 0-0.2 mg/kg body weight per day. Using a high throughput screen, Wang et al. demonstrated that PBO can inhibit

sonic hedgehog (shh) signaling and disrupt zebrafish development (Wang 2012). Shh signaling plays a critical role in cancer as well as nervous system development and stem cell proliferation. Finally, PBO (50μM) inhibited Ca2+-ATPase activity in isolated rat brain synaptosomal membranes and leukocyte membranes (Grosman 2005).

Endocrine Disruption:

There are no examples or data supporting an association between PBO and endocrine disruption in humans and no new information related to this outcome in humans was found in this review. PBO was prioritized for screening by the USEPA EDSP. Tier 1 screening indicated no interaction with the estrogen, androgen, or thyroid hormone pathways, and Tier 2 screening was deemed unnecessary (USEPA 2015a and 2015b). Hayashi et al. administered PBO to female rats in the diet at 5000, 10000, or 20000ppm for 28 days and examined effects on the female reproductive tract (Hayashi 2013). They observed decreased uterine and ovarian weight at the highest dose, prolonged diestrous, uterine atrophy, hepatic enlargement, and reduced serum estrogen at 10000 and 20000 ppm. There were no effects on corticosterone levels. In vitro assays found PBO to be a weak ER antagonist. Taken together these data suggest that PBO may be anti-estrogenic, however the doses administered are much higher than typical human exposures and not likely to be relevant to those experienced following adulticide spraying for mosquito control.

Developmental/Reproductive Including Birth Defects:

There are no examples or data of developmental or reproductive effects in humans caused by PBO available within the literature and no new information related to this outcome in humans was found in this review. The 2001 FEIS described animal studies in which developmental and reproductive effects were seen at doses much higher than anticipated following adulticide spraying for mosquito control. No additional evidence of an association between PBO and these effects was found in this review.

Cancer:

PBO is classified by the International Agency for Research on Cancer as a Group 3 carcinogen, indicating it is not classifiable as to its carcinogenic potential in humans, due to inadequate evidence in either animals or humans (IARC, 1983). USEPA has classified piperonyl butoxide as to its carcinogenic potential as a Group C - possible human carcinogen based on statistically significant increases in liver tumors in mice. There are no examples of cancer in humans caused by PBO available within the literature. Since the publication of the 2001 FEIS, a large number of laboratory studies have investigated the mechanism by which PBO is genotoxic and carcinogenic to the liver (Fujimoto 2012, Henderson 2015, Kawai 2009, Kawai 2010, Kossler 2015, Morita 2013, Muguruma 2006, Muguruma 2007, Muguruma 2008, Muguruma 2009, Nemeto 2011, Sakamoto 2013, Sakamoto 2015, Suzuki 2010, Tasaki 2010, Tasaki 2013, Tasaki 2014, Yafune 2013, Yasuno 2008). Most of these studies administer PBO orally by adding it to the diet at high doses (20,000 ppm) and provide supporting evidence for the nongenotoxic effects of PBO on liver hypertrophy and carcinogenesis. Vardavas 2016 observed genotoxicity in the liver and kidney of rabbits treated with PBO at 22.5 and 45 mg/kg body weight per day for 4 months (Vardavas 2016). Using a high throughput screen, Wang et al. demonstrated that PBO can inhibit sonic hedgehog (shh) signaling and disrupted zebrafish development (Wang 2012). Shh signaling plays a critical role in cancer as well as nervous system development and stem cell proliferation.

Conclusions:

The review of the scientific literature and government documents did not find any new evidence supporting associations between PBO and skin and eye irritation, gastrointestinal or developmental/reproductive problems, or MCS. Limited evidence from recent laboratory studies suggests that PBO may interact with receptors in the brain and alter immune system function, but exposure routes and doses do not reflect those expected to occur following ULV application of adulticides containing PBO. Numerous recent studies provide additional mechanistic information about the carcinogenic potential of PBO in rodents but effects are seen primarily at very high doses. Since the publication of the 2001 FEIS, pregnancy cohort studies have found associations between maternal PBO exposure and cognitive and respiratory outcomes in children (Horton 2011, Liu 2012). However, it is difficult to

account for the source of PBO and concomitant exposure to other chemicals in this study. Two modeling studies of ULV truck application found no increased risk of cancer or noncancer endpoints following acute, sub-chronic, or chronic exposure to PBO, further evidence exposure to PBO from this method of application are unlikely to have adverse health effects (Macedo 2007, Schleier 2009).

Deltamethrin

Deltamethrin is a pyrethroid adulticide that has been under USEPA Registration Review since 2010. Like other pyrethroids, the primary target organ is the nervous system. Deltamethrin has moderate acute toxicity via the oral (category II) and inhalation (II/III) routes of exposure and minimal toxicity via the dermal (category III) route of exposure. It is minimally irritating to the eye (category III) and non-irritating to the skin (category IV). USEPA classifies deltamethrin as not likely to be a human carcinogen and there is no evidence of mutagenicity. It is not a skin sensitizer. The most recent human health risk assessment was conducted in 2007 and potential risks from ULV mosquito application were not specifically addressed. Because deltamethrin is a metabolite of the pyrethroid tralomethrin, USEPA considers them to have equivalent toxicity in mammals and cumulative exposures should be considered.

Skin and Eye Irritation:
There are no examples or data supporting an association between deltamethrin and skin and eye irritation.

Gastrointestinal:
There are no examples or data supporting an association between deltamethrin and gastrointestinal problems.

Respiratory Effects Including Asthma:
There are no examples or data supporting an association between deltamethrin and respiratory effects.

Immunologic/Allergic:
There are no examples or data supporting an association between deltamethrin and immunologic/allergic effects.

Multiple Chemical Sensitivity:
There are no examples or data supporting an association between deltamethrin and MCS.

Neurological:
Like other Type II pyrethroids, deltamethrin is toxic to the nervous system of insects. Acute, high dose exposures to deltamethrin cause neurological effects in humans, including ataxia and convulsions. There are no examples or data of neurological effects in humans caused by chronic deltamethrin available within the literature. Laboratory studies have shown evidence for deltamethrin induced neuronal apoptosis and degeneration in the rat brain and cultured neurons (Wu 2000, Wu 2003).

Cognitive Developmental Disabilities Including Autism:
There are no examples or data supporting an association between deltamethrin and cognitive developmental disabilities.

Endocrine Disruption:
There are no examples or data supporting an association between deltamethrin and endocrine disruption. Deltamethrin has not yet undergone the USEPA Endocrine Disruptor Screening Program (EDSP), now required for all pesticides.

Developmental/Reproductive Including Birth Defects:
There are no examples or data supporting an association between deltamethrin and developmental/reproductive problems.

Cancer:
There are no examples or data supporting an association between deltamethrin and cancer. USEPA classifies deltamethrin as not likely to be a human carcinogen. Laboratory studies have suggested genotoxic effects of deltamethrin. (Villarini 1998) Ortiz-Perez found no evidence of DNA damage in

African children using the comet assay following application of deltamethrin inside their homes. In this study, deltamethrin was applied to the indoor walls of the home as a wettable powder (25mg/m2) and was detectable in the child's urine and indoor soil floor (Ortiz-Perez 2005). Although it is difficult to compare exposure pathways in this study with those that occur following ULV application for mosquito control, this study suggests that deltamethrin is not genotoxic.

Conclusion:

The review of the scientific literature and government documents did not find any evidence supporting associations between deltamethrin and adverse health outcomes. Although studies are limited and the human health risk assessment for deltamethrin is not as current as for prallethrin and sumithrin, EPA considers the mode of action to be highly similar to other pyrethroids. Thus the risk profile for other pyrethroids is accepted as a proxy when data is lacking.

Pyrethroids as a Class

A review of the epidemiologic literature on effects of chronic low level exposure to pyrethroids as a class is not included. In part this is because it is difficult to separate out the proportion of exposure that might occur through sporadic, single spray events conducted by DOHMH versus what New Yorkers may be exposed to from a variety of sources (e.g. food, home use, lawn/garden use, etc.). In 2016, in response to both West Nile Virus and potential Zika virus, DOHMH applied approximately 406 gallons of pyrethroids Citywide. To put this into context, in 2009, NYSDEC's report on New York State Pesticide Sales and Usage showed a total of approximately 45,000 pounds and 27,000 gallons of pyrethroids applied Citywide by commercial applicators.

Methoprene

Methoprene is an insect growth regulator (IGR) that mimics juvenile hormone, thereby blocking progression from larval to adult stages. Methoprene is effective against many insect species including mosquitos, beetles, fire ants, and others. Because it interferes with life cycle progression and does not exert direct toxicity, it is classified as a biochemical pesticide. Methoprene may be applied in briquette, granular, or liquid form, and is approved for use as a cattle feed additive to combat hornflies. Methoprene rapidly biodegrades in the environment and its main byproduct is carbon dioxide. The aerobic soil metabolism half-life of methoprene is 10-14 days. The aqueous photolysis half-life is less than one day. The half-life of methoprene on the surfaces of plants is 1 to 2 days (Csondes 2004, Siemering 2003). Depending on the formulation, methoprene briquettes can release active methoprene into a body of water continuously for 30-150 days, while granules remain active for 21-30 days (Siemering 2003). Methoprene is categorized as having very low acute toxicity via the oral, inhalational, and dermal routes (USEPA 2013b). Because there is no mammalian juvenile hormone analog, human toxicity is thought likely to be very low. Studies of methoprene metabolism in mammals show low absorption in the intestine and excretion in feces and rapid metabolism by liver esterases (Chamberlain 1975, Morello et al. 1980). At the time that this review was conducted (September – December 2016), methoprene was under registration review with the USEPA (USEPA 2013b).

Skin and Eye Irritation:

There are no examples or data supporting an association between methoprene and skin and eye irritation.

Gastrointestinal:

There are no examples or data supporting an association between methoprene and gastrointestinal problems.

Respiratory Effects Including Asthma:

There are no examples or data supporting an association between methoprene and respiratory effects.

Immunologic/Allergic:

There are no examples or data supporting an association between methoprene and immunologic/allergic effects.

Multiple Chemical Sensitivity:
There are no examples or data supporting an association between methoprene and MCS.

Neurological:
There are no examples or data of neurological effects in humans or animals caused by methoprene available within the literature. However, the potential for methoprene to interact with the central nervous system is indicated by studies showing binding to and inhibition of cannabinoid receptors (CB1) on isolated mouse brain membrane preparations (Dhopeshkawar 2011, Dhopeshkawar 2014). This is one of very few documented examples of methoprene interaction with mammalian receptors of any kind (see also Developmental/Reproductive Including Birth Defects below).

Cognitive Developmental Disabilities Including Autism:
There are no examples or data supporting an association between methoprene and cognitive developmental disabilities.

Endocrine Disruption:
There are no examples or data supporting an association between methoprene and endocrine disruption.

Developmental/Reproductive Including Birth Defects:
There were no data available in the scientific literature on reproductive or developmental toxicity effects caused by methoprene in humans. Although the main target of methoprene in insects, juvenile hormone, is not expressed in mammals, several studies have found evidence that methoprene interacts with the vertebrate retinoid signaling pathway which plays a critical role in early development. RXRs play a critical role in development via regulation of gene transcription in response to diverse ligands including thyroid hormone, Vitamin D, and peroxisome proliferators (Rowe 1997, Szanto 2004). Unsworth et al. found increased risk of morphological abnormalities in offspring of pregnant mice injected with high dose methoprene (1mg/g body weight per day for 3 days) (Unsworth 1974). The dose and route of exposure in this study do not mimic human exposure following methoprene application for mosquito control. No teratogenic effects were observed in offspring of methoprene treated swine, sheep, hamsters, rats, or rabbits (Wright 1975). Studies conducted by EPA show no developmental toxicity in rabbits or mice at high doses (USEPA 2001 MRID 00029250, 00029251). Cell-based studies further suggest mechanism by which methoprene bay interact with vertebrate systems. Harmon et al. demonstrated binding and activation of the methoprene metabolite methoprene acid to retinoid X receptor (RXR) (Harmon 1995). Methoprene has also been shown to interfere with retinoid signaling in a mouse cell line by blocking the conversion of retinol to the active RXR ligand, retinoic acid (Schoff 2004). Interaction with the RXR pathway may explain earlier observations of teratogenicity in mice treated with methoprene during pregnancy (Unsworth 1974). The ability of methoprene to disrupt RXR signaling is further evidenced by findings that methoprene photolytic products disrupt zebrafish development (Smith 2003). Finally, a 1980 study found that methoprene suppressed proliferation of mouse embryonic fibroblasts, but no mechanism was identified (Zielinska 1980). However, no teratogenic effects were observed in offspring of methoprene treated swine, sheep, hamsters, rats or rabbits (Wright 1975, USEPA 2001)

Cancer:
There are no examples or data supporting an association between methoprene and cancer. USEPA classifies methoprene as not likely to be a human carcinogen. Lifetime carcinogenic studies show no evidence of carcinogenicity in mice (USEPA 2001). Weak mutagenic activity has been described for methoprene in the drosophila spot wing test (Marec 1987). However, this study used doses much higher than seen in the field, and other studies fail to show mutagenic activity of methoprene (Hsia 1979, USEPA 2001).

Conclusions:
The review of the scientific literature and government documents did not find any evidence supporting associations between methoprene and skin and eye irritation; gastrointestinal, respiratory, immune, endocrine, or developmental/reproductive problems; MCS; cognitive developmental disabilities; or cancer. Although limited laboratory studies suggest that methoprene may interact with mammalian

pathways that may impact neurological and developmental/reproductive systems, effects were seen only at high doses. Importantly, significant exposures are unlikely to occur when applied according to manufacturer's specifications.

Spinosad

Spinosad is a mosquito larvicide comprised of a mixture of two fermentation products of the soil bacterium *Saccharopolyspora spinosa*, spinosyn A and D. Spinosad is categorized as having low acute toxicity via the oral, dermal, and inhalational routes (Category III or IV). It acts as a neurotoxin, mimicking the neurotransmitter acetylcholine as well as binding GABA receptors. A draft human health risk assessment for Spinosad was published in 2016 (USEPA 2016). The primary toxic effect of spinosad was histopathological changes such as vacuolization in numerous organ types (Yano 2002, USEPA 2016). There was no evidence of skin or eye irritation or developmental, reproductive, immunotoxic, neurotoxic, or carcinogenic effects. Spinosad is classified as not likely to be carcinogenic in humans by USEPA.

Some spinosad formulations are certified for use in organic agriculture by the Organic Materials Review Institute (OMRI). Spinosad is considered safe for use as an oral systemic insecticide in dogs for flea control (Robertson-Plouch 2008).

Skin and Eye Irritation:
There are no examples or data supporting an association between spinosad and skin and eye irritation.

Gastrointestinal:
There are no examples or data supporting an association between spinosad and gastrointestinal problems.

Respiratory Effects Including Asthma:
There are no examples or data supporting an association between spinosad and respiratory effects.

Immunologic/Allergic:
There are no examples or data supporting an association between spinosad and immunologic/allergic effects. The USEPA draft human health risk assessment for spinosad finds no evidence of immunotoxicity.

Multiple Chemical Sensitivity:
There are no examples or data supporting an association between spinosad and MCS.

Neurological:
There are no examples or data of neurological effects in humans or animals caused by spinosad available within the literature. The USEPA draft human health risk assessment for spinosad finds no evidence of neurotoxicity.

Cognitive Developmental Disabilities Including Autism:
There are no examples or data supporting an association between spinosad and cognitive developmental disabilities.

Endocrine Disruption:
There are no examples or data supporting an association between spinosad and endocrine disruption.

Developmental/Reproductive Including Birth Defects:
There are no examples or data supporting an association between spinosad and developmental/reproductive problems. Reproductive toxicity was seen only at high doses that also induced maternal toxicity (USEPA 2016). Developmental toxicity was not observed at doses that induced maternal toxicity in rats or rabbits (Breslin 2000).

Cancer:
There are no examples or data supporting an association between spinosad and cancer. USEPA classifies spinosad as not likely to be a human carcinogen. A recent study found no genotoxicity in mice orally exposed to spinosad at doses up to 50mg/kg per day for 5 days (Saxena 2016).

Conclusion:
The review of the scientific literature and government documents did not find any evidence supporting associations between spinosad and adverse health outcomes. Spinosad's accepted use in organic agriculture and as a systemic flea repellant in domestic animals provide further support for its use as a mosquito larvicide.

Pyriproxyfen

Pyriproxyfen is a broad spectrum pyridine-based insecticide. Its primary mode of action is to suppress insect embryogenesis, inhibit metamorphosis, and block adult emergence. It is categorized as having low acute toxicity via the oral, dermal, and inhalational routes (Category III or IV). It is not a skin or eye irritant or sensitizer and is classified as not likely to be a human carcinogen (USEPA 2015a). Target organs for toxicity in mammals are the liver and kidney. Insecticide formulations containing pyriproxyfen are approved for use in cat and dog collars and as a topical treatment for flea, tick, and mosquito control (Varloud 2015). Pyriproxyfen is under registration review at USEPA (USEPA 2011). The most recent human health risk assessment was published in 2015 and the toxicology database is complete (USEPA 2015a).

Skin and Eye Irritation:
There are no examples or data supporting an association between pyriproxyfen and skin and eye irritation.

Gastrointestinal:
There are no examples or data supporting an association between pyriproxyfen and gastrointestinal problems.

Respiratory Effects Including Asthma:
There are no examples or data supporting an association between pyriproxyfen and respiratory effects.

Immunologic/Allergic:
There are no examples or data supporting an association between pyriproxyfen and immunologic/allergic effects. At very high doses (9mM or 15mM), pyriproxyfen enhanced the immune response to ovalbumin in mice; however, this is much higher than the exposure level that would be expected following larvicide application in New York City (Sharmin 2013).

Multiple Chemical Sensitivity:
There are no examples or data supporting an association between pyriproxyfen and MCS.

Neurological:
There are no examples or data of neurological effects in humans or animals caused by pyriproxyfen available within the literature.

Cognitive Developmental Disabilities Including Autism:
There are no examples or data supporting an association between pyriproxyfen and cognitive developmental disabilities.

Endocrine Disruption:
There are no examples or data supporting an association between pyriproxyfen and endocrine disruption. The USEPA Tier 1 Endocrine Disruptor Screening Program (EDSP) is complete for pyriproxyfen. In mammals, there was limited evidence of potential interaction with the androgen and thyroid pathways. However, these effects were considered to be secondary to liver enzyme induction, increased liver weights and hepatocellular hypertrophy. Tier 2 testing was not required (USEPA 2015b).

Developmental/Reproductive Including Birth Defects:
There are no examples or data supporting an association between pyriproxyfen and developmental/reproductive problems. Pyriproxyfen was added to drinking water tanks in Brazil to control *Aedes aegypti* during the 2016 Zika outbreak. Although there was some concern that there was a causal link between exposure to pyriproxyfen and microcephaly, studies have shown there to be no association (Albequerque 2016, Dzieciolowska 2017)

Cancer:

There are no examples or data supporting an association between pyriproxyfen and cancer. USEPA classifies pyriproxyfen as not likely to be a human carcinogen.

Conclusion:

The review of the scientific literature and government documents did not find any evidence supporting associations between pyriproxyfen and adverse health outcomes. Toxicity is seen only at very high doses not likely to be experienced following application as a mosquito larvicide. Veterinary use as a topical treatment for flea and tick prevention further supports the use of pyriproxyfen as a larvicide.

RISK ASSESSMENT

The objective of the public health risk assessment in the 2001 FEIS was to determine whether the application of adulticides to control the transmission of mosquito-borne pathogens in New York City may pose a significant human health risk. As disclosed in the 2001 FEIS, in the public health risk assessment, there were four steps, each of which is briefly described below:

- Hazard Identification identifies the chemicals of concern to be analyzed.
- Exposure Analysis determines how much of an adulticide people might be exposed to under various conditions during applications.
- Toxicity Analysis determines how much of an adulticide is required to cause a toxic effect, and predicts exposure levels at which risk is likely to be negligible or nonexistent.
- Risk Characterization integrates the relevant information from the preceding two steps to characterize the risks to the exposed population (i.e., the likelihood that there will be an increase in a particular health effect in the population exposed to a particular adulticide). The risk characterization also includes a description of the assumptions and uncertainties that go into the risk assessment, and an assessment of the overall confidence in the results of the analysis.

Hazard Identification

In this risk assessment for the 2001 FEIS, the chemicals of concern were the active ingredients in the adulticide products that could be applied as part of the Proposed Action. For this Technical Memorandum, the chemicals of concern are the active ingredients in the additional products under consideration as part of the proposed modifications for the Comprehensive Plan.

Exposure Analysis

The 2001 FEIS analyses used the following guidance documents to develop a range of exposure parameters for the different groups of people identified in each geographical area:

- Risk Assessment Guidance for Superfund, Human Health Evaluation Manual (USEPA, 1989a). This contains the general exposure equations used to estimate the amount of adulticide taken in by people. This document, published in 1989, remains the standard guidance document for risk assessment for human health.
- Calculating the Concentration Term, Supplemental Guidance (USEPA, 1992b). This supplemental guidance was developed specifically to provide a standardized approach to calculate chemical concentrations to which people may be exposed in various media, (e.g., soil, water, food, etc.).
- Exposure Factors Handbook - Volume 1. General Factors; Volume 2. Food Ingestion Factors; Volume 3. Activity Factors (USEPA, 1997c, d, e). This three-volume set is a compilation of exposure data under a variety of exposure conditions. This information was used to determine the range of potential exposures for people in each of the geographical areas.
- Risk Assessment Guidance for Superfund, Volume 1: Human Health Evaluation Manual, Supplemental Guidance, Dermal Risk Assessment, Interim Guidance (USEPA, 1999a). This

guidance was developed specifically for skin exposures and provides recommended values to estimate skin exposures.

A review of the documents cited in the 2001 FEIS was undertaken for this Technical Memorandum to determine if there were material changes in EPA guidance. Such review indicated there were minimal changes (e.g., dermal contact factors in water), and the methodology employed for the 2001 FEIS has not materially changed, and can be relied upon for the comparative analysis undertaken for this Technical Memorandum.

In addition, since the 2001 FEIS was completed, EPA has undertaken risk analyses as part of the re-registration process, and the general procedures followed in the re-registration were very similar to those undertaken for the 2001 FEIS, although they included additional pathways (e.g. treatment of horses in barns, crop treatments) that were not material exposure pathways analyzed in the 2001 FEIS.

Based on the described framework of analysis conducted for the 2001 FEIS, which is applicable to the proposed amendments for the control of Zika virus, plus the relatively minor changes associated with dispersion modeling and application rates of pyrethroids/new products, there were no significant changes in predicted exposure pathways with the new ingredients/potential for exposure.

Toxicity Analysis

Much of the discussion in this section is based on the information presented in the 2001 FEIS. As noted, USEPA has made some changes on determining the end factors for comparison, but none of these changes have resulted in significant changes in comparative thresholds for the analysis.

The purpose of the toxicity analysis is to determine how much of an adulticide is required to cause an adverse health effect, and to predict exposure levels at which those health effects are likely to be negligible or nonexistent. Those exposure levels are also called “toxicity criteria.” It should be noted that, where applicable, the toxicity effects of the breakdown products of the active ingredients are inherently accounted for in the toxicity tests performed for the active ingredient (i.e., the derivation of the toxicity test accounts for the presence of the active ingredient and the breakdown product). In this step, two general types of toxicity criteria are developed: the non-carcinogenic (or non-cancer) reference dose and concentration; and the carcinogenic slope factor and unit risk.

Before defining these terms, it should be noted that risks of harm are evaluated differently for cancer than for all other illnesses. For health effects other than cancer, scientists attempt to determine the maximum dose that is considered to have negligible health effects if a person is exposed on a daily basis. For cancer, however, risk is evaluated according to probability; specifically, the increased probability that an individual will, during his or her lifetime, develop cancer following a specific exposure to a chemical.

First, the toxicity criteria for health effects other than cancer will be discussed. For the analyses conducted in the 2001 FEIS, EPA suggested comparing to a reference dose (RfD) or reference concentration (RfC) as defined by USEPA as a chemical-specific dose or concentration to which people, including sensitive individuals, can be exposed on a daily basis without adverse health effects (Barnes and Dourson, 1988; Dourson et al., 1989; USEPA, 1989a). “Chemical-specific” refers to the fact that RfDs and RfCs are unique to a particular chemical; each chemical has its own RfD and RfC. The difference between a reference “dose” and a reference “concentration” is that a reference “dose” refers to what individuals take into their bodies (e.g., through ingestion or through the skin), measured as a ratio of chemical ingested or absorbed to an individual’s body weight per day, whereas a reference “concentration” is the amount of a chemical that an individual is exposed to through breathing. Acute (short-term) and sub-chronic RfDs and RfCs are similar to chronic (long-term) RfDs or RfCs, except that the acute and sub-chronic RfDs and RfCs represent a daily exposure that is not likely to cause adverse health effects for exposures occurring during a shorter period of time (sub-chronic exposure) or a single day (acute exposure).

The second type of criteria is the cancer slope factor (CSF) and unit risk (UR). Like the cancer slope factor, the UR is the increased probability that an individual will develop cancer following a specific exposure to a chemical. This increased probability is in addition to everyone's probability of developing

cancer from everyday exposures to a multitude of chemicals. The CSF parallels the RfD (it is used for ingestion exposures), while the UR parallels the RfC (it refers to concentrations in the air). It should be noted that not all chemicals can cause cancer.

The toxicity criteria used in the 2001 FEIS were provided by the following sources:

- USEPA's Hazard Identification Assessment Review Committee (HIARC) documents,
- USEPA's Integrated Risk Information System (IRIS) files,
- USEPA's Office of Pesticide Programs (OPP), and
- USEPA's "Tox 1-Liners," which contain summaries of toxicology studies submitted to the Health Effects Division of USEPA's Office of Pesticide Programs.

While there have been some changes in how USEPA has identified toxicity analysis thresholds, there have been no significant changes in threshold levels for the products/active ingredients of concern.

Risk Characterization

As noted in the 2001 FEIS, the information developed in the "Exposure Analysis" and "Toxicity Analysis" was combined to describe the likelihood and nature of potential health effects that human populations may experience following exposures to adulticides associated with New York City's control of adult mosquitoes.

Table 3.C-14 of the FEIS characterized the non-cancer risks, cancer risks and acute exposure risks for all evaluated population groups (see Attachment A). Non-cancer risks adverse health effects were not expected for any evaluated human population group, through any exposure pathway (i.e., inhalation, dermal, ingestion). Cancer risks were within USEPA acceptable ranges (at the time, characterized as less than 0.000001 to 0.0001, or from 1 in 1million to 1 in 10,000), or would be low enough to be of no concern for all chemicals with the exception of PBO. However, it was determined that when considering the various conservative assumptions used both within the exposure analyses and toxicity analysis, the cancer risk for PBO was most likely over estimated and there should be no concern for excess cancer risk. Acute adverse health effects were determined to be unlikely to occur with exposures to the active ingredients in the pyrethroid products including PBO. Therefore, no significant adverse public health impact would be expected.

As described above, there have been no significant changes since the 2001 FEIS that would affect the Exposure Analysis and Toxicity Analysis presented in the 2001 FEIS. Given that pyrethroids are generally aggregated by recent USEPA studies for the registration of such products, and the reasonable worst case application assumptions used in the 2001 FEIS remain in place and would not be affected by the proposed modifications, the Risk Characterization would also not significantly change as a result of the proposed modifications to the Comprehensive Plan.

EPIDEMIOLOGIC AND ATTRIBUTABLE RISK ANALYSES

Epidemiologic and Attributable Risk Analyses

As noted in the 2001 FEIS, to examine the possible impact of adulticiding on asthma exacerbations in New York City, DOHMH collaborated with NYSDOH and the CDC to develop analytic plans that would use existing data on emergency department/urgent care visits and hospitalizations and that would make best use of data available on adulticiding. The analyses were designed to determine whether the relative change in rates of asthma (i.e., emergency department/urgent care visits and hospitalizations for asthma) before (Pre-period) and after (Post-period) adulticiding occurred in 1999 was different from the change in the same time period in prior years, when no adulticiding occurred. While these analyses were designed to reduce some of the potential biases or confounding factors in the data, there were inherent limitations of the exposure and outcome data.

As presented above under "Literature Review," DOHMH examined rates of ED visits for asthma following application of the aerosolized Anvil 10+10 (containing sumithrin 10% and PBO 10%) by truck-based ground spraying to combat West Nile Virus (Karpati et al. 2004). There was no significant

difference in the number of ED visits for asthma in the 3 days following spraying (501 visits) compared with the 3 days prior to spraying (510 visits) in analyses by zip code over the course of a 14 month period. The Karpati study found that spraying pyrethroids for WNV control in New York City was not followed by population-level increases in public hospital ED visit rates for asthma (Karpati 2004).

Calls to the New York City Poison Control Center (NYC PCC) are monitored by DOHMH during the mosquito control season and relevant pesticide exposures are forwarded to the New York State Pesticide Poisoning Registry (NYS PPR) for review and possible inclusion in the registry. Beginning in 2002, syndromic surveillance was adopted as a tool to identify possible respiratory symptom related clusters in areas in which a spray action occurred. Further investigations of clusters entailing review of emergency department (ED) data have not conclusively linked clusters to spray events. DOHMH uses syndromic surveillance to identify unusual increases of ED asthma and respiratory vists. When potential clusters have been found, further investigation has not identified common exposures or causes for visits.

CONCLUSION

Levels of exposure due to community mosquito control efforts are orders of magnitude lower than the exposures assessed in toxicity studies. Community mosquito-control applications occur occasionally versus regularly in areas as needed. Over a long time period with continuous exposure, health effects might occur, but available data do not suggest potential health effects from low-level, infrequent or one-time exposures such as occur during community mosquito control efforts. Based on the three analysis components presented above (Literature Review, Risk Assessment and Epidemiologic and Attributable Risk Analyses) there would be no additional potential predicted significant adverse impacts expected beyond those disclosed in the 2001 FEIS with the proposed modifications to the Comprehensive Plan.

WATER SUPPLY

The term “water supply” comprises the physical systems that support the City’s population and one million upstate consumers with drinking water. Most of the City’s water supply is provided by three upstate watersheds, which collect rainwater via streams and pipes from large land coverage areas, and divert such rainwater to upstate reservoirs.

At the time the 2001 FEIS was prepared, only a very small portion of the City in Queens could be supplied with water from groundwater. Currently, the City’s groundwater program is not active and future plans are only to use such groundwater as needed for droughts or emergencies. No additional analyses were performed for the potential impacts on groundwater supply, given the extremely low exposure levels calculated for the 2001 FEIS and the rarity of expected future uses of the groundwater supply in New York City.

The 2001 FEIS examined the potential infiltration of adulticides into the surface-water supply and assessed the potential impacts on the water supply from the application of adulticides under the Comprehensive Plan. In addition, the 2001 FEIS addressed the potential cumulative impacts on the surface-water supply should Westchester County perform similar concurrent adulticiding operations at the time such actions are undertaken in New York City. Since the 2001 FEIS predicted that there would be no significant cumulative impacts on the water supply should Westchester County perform similar control actions, no changes to such conclusions are expected with the proposed modifications to the Comprehensive Plan.

Impacts on the water supply from applications in New York City would likely only occur from the exposure of the Jerome Park Reservoir to airborne drift of adulticides, since the surface of the Jerome Park Reservoir is at the highest local grade elevation in the immediate area and there is no runoff from the surrounding region into the reservoir.

For this Technical Memorandum, no additional analyses were required for pyriproxyfen, spinosad, and methoprene because with the proposed application methods and practices under the modifications to the Comprehensive Plan, and the physical attributes of these larvicides, they will likely not be introduced in any material quantities to the surface or groundwater supplies.

Under the proposed modifications to the Comprehensive Plan, DOHMH is considering the use of two additional pyrethroid adulticide active ingredients that were not analyzed in the 2001 FEIS: prallethrin and deltamethrin. In addition, the Comprehensive Plan will continue the use of sumithrin and PBO at levels in the products discussed earlier in this Technical Memorandum. For this Technical Memorandum the assessment of potential impacts on surface water supply from the Comprehensive Plan was based on an examination of modeling assumptions and analyses employed in the 2001 FEIS for active ingredient application rates, dispersion/fate of such in the environment, previously modeled results to comparative water supply standards and previous 2001 FEIS conclusions to determine if there would be expected changes to the 2001 water supply impact conclusions with the Comprehensive Plan.

IMPACTS ON SURFACE WATER SUPPLY

Compared to the values employed in the 2001 FEIS analyses for pyrethroids, there are no significant changes in short term maximum pyrethroid active ingredient rates with the additional pyrethroid active ingredients addressed under this Technical Memorandum. In addition, as noted in the Framework of Analysis above, while drift/deposition models have been updated since the FEIS was completed, the maximum predicted concentrations would be expected to be similar and within the same order of magnitude of the conservatively predicted concentrations presented in the FEIS. In addition, the key reasonable worst case application assumptions employed in the 2001 FEIS would still apply for the proposed modifications to the Comprehensive Plan.

The assessment for this Technical Memorandum also considered that a 100 foot buffer was assumed for the 2001 FEIS modeling of drift deposition; however, DOHMH actually implements a 300-350 feet buffer around waterways when applying pesticides. The 2001 FEIS noted that the results of the air-drift modeling indicated that there is significantly less deposition of products from trucks beyond 300 feet from point of application. The resultant deposition of the airborne adulticides onto the ground at distances greater than 300 feet from point of application comprises a relatively small percentage of the product applied, because deposition concentration decreases as distance increases from the point of application. Therefore, for comparable application rates of pyrethroids assessed in the 2001 FEIS, the expected drift and deposition onto surface water bodies under the proposed modifications to the Comprehensive Plan with the larger buffer around waterways, would be expected to result in smaller concentrations than those calculated for the 2001 FEIS, and are not expected to be measurable, on the basis of the post-spray water quality sampling conducted by DOHMH.

There are no compound specific drinking water standards from NYSDEC or USEPA for the active ingredients in the pyrethroids under considerations[7]. However, the active ingredients in pyrethroids can be considered as Unspecified Organic Contaminants, (UOCs), and the maximum predicted active ingredient levels in the Jerome Park Reservoir reported in the 2001 FEIS were well below the UOC standard of 0.050 mg/L.

Based on the analysis above and the 2001 FEIS conclusions, the concentrations of active ingredients from pyrethroids in adulticides into the Jerome Park Reservoir under the Comprehensive Plan would not result in any significant adverse human health impacts.

CONCLUSIONS

The 2000 EAS concluded that the application of the larvicides to be used as part of the Comprehensive Plan would not result in any significant adverse environmental impacts. The 2001 FEIS identified potential significant adverse impacts in the areas of natural resources, water quality and noise. The potential predicted significant adverse natural resources impact was related to the application of malathion (an organophosphate adulticide), to crustaceans from runoff after application over large land areas that drain to Jamaica Bay and other inlet bays. The predicted significant adverse water quality

[7] 6 NYSCRR Part X Section 703.5, Current through April 30, 2017; USEPA National Recommended Water Quality Criteria – Aquatic Life Criteria Table

impact was also related to the use of malathion, resulting in exceedances of the water quality standard from runoff. Potential significant adverse noise impacts were predicted from aircraft and police escort/truck operations. Based on the anlyses presented in this Technical Memorandum, there are no additional potential predicted significant adverse impacts expected beyond those disclosed in the 2000 EAS and 2001 FEIS for the proposed modifications to the Comprehensive Plan.

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ATTACHMENT A

Table 3.C-14
Risk Assessment Summary

Active Ingredient	Products Selected for Detailed Technical Analysis	Non-Cancer Risk (Based on All Human Population Groups)				Cancer Risk (Based on Resident Children)		Acute Exposure Risk (Based on Resident Children)
		Sub-Chronic		Chronic				
		Average Exposure	Reasonable Max Exposure	Average Exposure	Reasonable Max Exposure	Average Exposure	Reasonable Max Exposure	
Malathion	Fyfanon ULV Concentrate Insecticide	X	X	X	X	X	X	Y*
Naled	Dibrom Concentrate Insecticide	X	X	X	X	NC		Y*
Permethrin	Permethrin 57% OS	X	X	X	X	X	X	X
Resmethrin	Scourge Insecticide	X	X	X	X	X**		X
Sumithrin	Anvil 10+10 ULV	X	X	X	X	X**		X
PBO	Scourge Insecticide	X	X	X	X	Y**		X

Notes:

* Results are based on exposures to a one-time exposure to resident children, the most sensitive population group, assuming exposure to one spray event.

** Results are based on exposures to resident children, the most sensitive population group, and resident adults, assuming the same individual is exposed to ten spray events in one season.

x (Non-Cancer Risk) – no expected potential risk from exposure

x (Cancer Risk for Malathion and Permethrin) – risk within USEPA acceptable range based on CSF calculation.

x (Cancer Risk for Resmethrin and Sumithrin) – exposure low enough not to be of concern based on MOE calculation

x (Acute Exposure) – no expected adverse health effects

Y (Cancer Risk for PBO) – exposure may not be low enough to ensure adequate protection for human health

Y (Aute Exposure) – potential adverse health effects

NC – no evidence of carcinogenicity