A Three-Year Assessment of Vector Production in Structural Best Management Practices in Southern California

CALIFORNIA DEPARTMENT OF HEALTH SERVICES

VECTOR-BORNE DISEASE SECTION

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Summary

In 1998, the California Department of Health Services, Vector-Borne Disease Section (VBDS) entered into a Memorandum of Understanding (MOU) with the California Department of Transportation (Caltrans) to provide technical expertise regarding vector production and vector-borne diseases related to its stormwater Best Management Practice (BMP) Retrofit Pilot Study. The purpose of the Caltrans BMP Retrofit Pilot Study was to evaluate the water quality benefits and cost effectiveness of various structural designs retrofitted into existing locations including freeways, interchanges, park and rides, and maintenance stations. A negative consequence of these efforts might include impacts on the operations of vector control agencies and potentially affect public health by increasing habitat availability for aquatic stages of disease vectors, and by creating harborage, food, and moisture for reservoir and nuisance species.

It was the intent of the Caltrans / VBDS MOU to protect public health by documenting and, where possible, mitigating vector production and harborage at the BMP study sites. The agreement required VBDS to establish a comprehensive vector surveillance and monitoring study, develop vector abatement protocols, recommend appropriate engineering modifications to Caltrans BMPs that would reduce the potential of these structures to produce or harbor vectors, and conduct focused studies to identify which designs were least conducive to vector production. In 2001, Caltrans extended the VBDS contract through June 2003 based on their need for further monitoring and evaluation of water quality and vector production.

VBDS, in collaboration with four local mosquito and vector control agencies, monitored 37 structural BMPs at 31 sites in San Diego and Los Angeles Counties for mosquito abundance, vegetative cover, aquatic predators, physical and chemical properties of water, and evidence of rodent and other vector populations between May 1999 and April 2001. This information was used to make an initial assessment of what factors within BMPs are most conducive to vector production and which species utilize these structures. Since mosquitoes are the most abundant vectors associated with aquatic habitats, this study emphasized mosquito production within BMP structures.

Eight mosquito species were collected from Caltrans BMP structures during this two-year study, four of which are known vectors of human disease. Of the nine different BMP technologies implemented by Caltrans, those that maintained permanent sources of standing water (i.e., Multi-Chambered Treatment Trains (MCTT), Continuous Deflective Separators (CDS™), and the wet basin) provided excellent habitat for immature mosquitoes, and frequently supported large populations relative to other structural designs. In contrast, BMPs designed to drain rapidly (i.e., biofiltration swales and strips, sand media filters, infiltration basins and trenches, drain inlet inserts, extended detention basins and the oil/water separator) provided less suitable habitats for vectors.

Between May 2001 and April 2002, VBDS and three local mosquito and vector control agencies continued to monitor those BMPs that had been most problematic during the 1999-2001 mosquito production study. This purpose of continued monitoring was to evaluate: 1) previously problematic designs for further mosquito breeding, 2) the efficacy and field-longevity of mosquito-proofing modifications made to MCTT and CDS™ devices, and 3) the vegetation management plan at the San Diego wet basin. A total of 12 BMPs were monitored; 6 in San Diego and 6 in Los Angeles County.

Despite an extremely dry year with rain events alarmingly below average, standing water was detected and mosquitoes were collected from 7 of the 12 devices, including one CDS™ device previously modified in November 2000 in an attempt to exclude mosquitoes. Six mosquito species were collected during this one-year period, four of which are known vectors of human disease.

This three-year report provides an initial assessment of the potential public health risks involved with the construction of structures such as the Caltrans BMPs and addresses some problems that encourage vector production within these structures from data collected between early May 1999 and the end of April 2002. Results provide evidence that continued collaboration between Caltrans, public health, and vector control is needed to improve mosquito and vector management in stormwater management structures.

Introduction

The importance of managing stormwater runoff is well known among transportation and stormwater management agencies and municipalities across the country. Federal and state laws regulating stormwater runoff have several purposes such as flood control, erosion control, improvement of water quality, and re-charge of underground aquifers. In recent years, stormwater management strategies have fallen under increasingly stringent regulations requiring the implementation of what have been termed Best Management Practices (BMPs). Best Management Practices for stormwater management may include modifying activity schedules, prohibitions or modifications of practices, maintenance procedures, etc. Best Management Practices may also involve the use of structures such as retention and detention ponds, swales, ditches, channels, vaults, infiltration basins, filtration systems and others.

The California Department of Transportation (Caltrans) is the agency responsible for managing California's state highway system. Its Storm Water Program has two primary goals: to comply with requirements of the federal Clean Water Act and resulting National Pollution Discharge Elimination System (NPDES) permit and other state requirements, and to provide the most cost-effective solutions for mitigating the harmful effects of stormwater runoff. In 1997, Caltrans began an extensive program plan to retrofit 33 selected facilities with 39 structural BMPs for water quality in Los Angeles County (Caltrans District 7) and San Diego County (Caltrans District 11). These BMPs include biofiltration strips and swales, various filtration technologies, extended detention basins, infiltration basins and trenches, continuous deflective separators, an oil/water separator, drain inlet inserts and a wet basin. Construction began in September 1998 and was almost entirely completed during the following six months. A total 37 operational BMPs were monitored (Table 1). These include 24 in Caltrans District 7 at 19 sites (Table 2), and 13 in Caltrans District 11 at 12 sites (Table 3). In 1998, the California Department of Health Services, Vector-Borne Disease Section (VBDS) entered into a Memorandum of Understanding (MOU) with Caltrans to provide technical expertise regarding vector[1] production and the potential of vector-borne diseases within its stormwater BMP Retrofit Pilot Study.

The purpose of the Caltrans BMP Retrofit Pilot Study was to evaluate the water quality benefits and cost effectiveness of various structural designs retrofitted into existing locations including freeways, interchanges, park and ride facilities, and maintenance stations. Potential negative consequences of these efforts may include direct impacts on the operations of vector control agencies and public health by increasing habitat availability for aquatic stages of disease vectors, and by creating harborage, food, and moisture for reservoir and nuisance species. It was the intent of the Caltrans / VBDS MOU to protect public health by documenting and, where possible, mitigating vector production and harborage at the BMP study sites. The agreement required VBDS to establish a comprehensive vector surveillance and monitoring study, develop vector abatement protocols, and recommend appropriate engineering modifications to Caltrans BMPs that would reduce the potential of these structures to produce or harbor vectors. In addition to reviewing BMP design criteria and monitoring maintenance and operations, the role of VBDS was to conduct studies to identify which of these designs were least conducive to vector production.

In accordance with the MOU, VBDS staff established comprehensive vector surveillance and monitoring plans for the 37 operational BMP devices. The plans outlined various activities to be conducted in collaboration with Greater Los Angeles County Vector Control District (GLACVCD), San Gabriel Valley Mosquito and Vector Control District (SGVMVCD), Los Angeles County West Vector Control District (LACWVCD), and San Diego County Vector Surveillance and Control (SDCVSC) in their respective jurisdictions between May 1999 and April 2001. The primary tasks of the local vector control agencies were weekly monitoring of all BMP Pilot Project study sites for immature stages of mosquitoes, midges, and sand flies in their area. At the same time, VBDS staff maintained an overall independent surveillance schedule to

[1] California Health & Safety Code, Section 2200. “Vector" means any animal capable of transmitting the causative agent of human disease or capable of producing human discomfort or injury, including, but not limited to, mosquitoes, flies, other insects, ticks, mites, and rodents.

monitor vegetative cover, predators of mosquito immatures, certain physical and chemical properties of water, and evidence of rodent and other vector populations.

A single vector abatement regimen was prepared by VBDS and implemented by the collaborating vector control agencies. After evaluation of various mosquito larvicides, a liquid formulation of the Insect Growth Regulator methoprene (Altosid EC®: a juvenile hormone mimic that inhibits successful emergence of adult mosquitoes and a variety of midges) was recommended because of its short residual activity, extremely low environmental toxicity, and negligible effects on larval population dynamics. The local vector control agencies implemented this mosquito abatement procedure as needed.

In 2001, Caltrans agreed to extend the VBDS contract through June 2003 based on their need for further monitoring and evaluation of water quality and vectors. Between May 2001 and April 2002, VBDS, GLACVCD, SGVMVCD, and SDCVSC continued to monitor those BMPs that had been most problematic during 1999-2001. This continued monitoring was used to evaluate: 1) previously problematic designs for further mosquito breeding, 2) the efficacy and field-longevity of mosquito-proofing modifications made to MCTT and CDS™ devices, and 3) the vegetation management plan at the San Diego wet basin. A total of 12 BMPs were monitored; 6 in San Diego and 6 in Los Angeles County.

Purpose and Objectives

The primary purpose of this study was to develop a better understanding of vectors associated with different structural BMPs implemented by Caltrans as part of their BMP Retrofit Pilot Study. Three years of larval mosquito data obtained through weekly monitoring beginning in early May 1999 and running through April 2002 are summarized. The data were used to identify vector sources within BMP types or within individual designs and were used to evaluate the success of efforts to mitigate these problem areas. This study provides an initial assessment of the potential public health risks involved with the construction of structures such as the Caltrans BMPs and addresses several factors that encouraged vector production within these structures.

Table 1. Structural Best Management Practice (BMP) technologies used in the Caltrans BMP Retrofit Pilot Study designed for treating non-point source pollution in stormwater runoff.

BMP Technology-Type	Site Name	Water Quality Site Number
Wet Basin	I-5/La Costa Ave. (east)	111104*
Extended Detention Basins (EDB)	I-5/I-605	74101
	I-605/SR 91 interchange	74102
	I-5/SR 56	111101*
	I-15/SR 78	111102
	I-5/Manchester Ave. (east)	111105
Drain Inlet Inserts (DII) - (Two per site)	Foothill Maintenance Station	73216
	Rosemead Maintenance Station	73218
	Las Flores Maintenance Station	73217
Infiltration Basins and Trenches	Altadena Maintenance Station[a]	73211a,b
	Carlsbad Maintenance Station (east) [a]	112207a,b
	I-605/SR 91[b]	73101
	I-5/La Costa Ave. (west)[b]	111103
Oil/Water Separators	Alameda Maintenance Station	74201
Media Filters	Eastern Regional Maintenance Station[c]	74202*
	Foothill Maintenance Station[c]	74203
	Termination Park and Ride[c]	74204*
	SR 78/I-5 Park and Ride[c]	112204*
	La Costa Park and Ride[c]	112203*
	Escondido Maintenance Station[d]	112202*
	Kearny Mesa Maintenance Station[e]	112201*
Multi-Chambered Treatment Trains (MCTT)	Via Verde Park and Ride	74206*
	Lakewood Park and Ride	74208*
Continuous Deflective Separators (CDS™**)**	I-210 east of Orcas Ave.	73102*
	I-210 east of Filmore Ave.	73103*
Biofiltration Swales and Strips	I-5/Palomar Airport Rd. [f]	112206
	SR 78/Melrose Dr. [f]	112205
	I-605 Del Amo Ave.[f]	73225
	I-5/I-605[f]	73224
	Cerritos Maintenance Station[f]	73223
	I-605/SR 91[f]	73222a,b
	I-605/SR 91[g]	73222a,b
	Altadena Maintenance Station[g]	73211a,b
	Carlsbad Maintenance Station (west)[g]	112207a,b

[a]Infiltration Trench; [b]Infiltration Basin; [c]Austin-Type; [d]Delaware-Type; [e]Canister-Type (StormFilter™); [f]Biofiltration Swales; [g]Biofiltration Strips
*Continued vector monitoring through April 2002
Source: California Department of Health Services

Table 2. BMP structures constructed in Los Angeles County, Caltrans District 7, for the Caltrans BMP Retrofit Pilot Study.

BMP Technology-Type	Site Name	Water Quality Site Number
Extended Detention Basins (EDB)	I-5/I-605	74101
	I-605/SR 91 interchange	74102
Drain Inlet Inserts (DII)	Foothill Maintenance Station	73216
	Rosemead Maintenance Station	73218
	Las Flores Maintenance Station	73217
Infiltration Basins and Trenches	Altadena Maintenance Station[a]	73211a,b
	I-605/SR 91[b]	73101
Oil/Water Separators	Alameda Maintenance Station	74201
Media Filters	Eastern Regional Maintenance Station[c]	74202*
	Foothill Maintenance Station[c]	74203
	Termination Park and Ride[c]	74204*
Multi-Chambered Treatment Trains (MCTT)	Via Verde Park and Ride	74206*
	Lakewood Park and Ride	74208*
Continuous Deflective Separators (CDS™**)**	I-210 east of Orcas Ave.	73102*
	I-210 east of Filmore Ave.	73103*
Biofiltration Swales and Strips	I-605 Del Amo Ave.[d]	73225
	I-5/I-605[d]	73224
	Cerritos Maintenance Station[d]	73223
	I-605/SR 91[d]	73222a,b
	I-605/SR 91[e]	73222a,b
	Altadena Maintenance Station[e]	73211a,b

[a]Infiltration Trench; [b]Infiltration Basin; [c]Austin-Type Media Filter; [d]Biofiltration Swales; [e]Biofiltration Strips
*Continued vector monitoring through April 2002
Source: California Department of Health Services

Table 3. BMP structures constructed in San Diego County, Caltrans District 11, for the Caltrans BMP Retrofit Pilot Study.

BMP Technology-Type	Site Name	Water Quality Site Number
Wet Basin	I-5/La Costa Ave. (east)	111104*
Extended Detention Basins (EDB)	I-5/SR 56	111101*
	I-15/SR 78	111102
	I-5 Manchester Ave. (east)	111105
Infiltration Basins and Trenches	Carlsbad Maintenance Station (east) [a]	112207a,b
	I-5/La Costa Ave. (west)[b]	111103
Media Filters	SR 78/I-5 Park and Ride[c]	112204*
	La Costa Park and Ride[c]	112203*
	Escondido Maintenance Station[d]	112202*
	Kearny Mesa Maintenance Station[e]	112201*
Biofiltration Swales and Strips	I-5/Palomar Airport Rd. [f]	112206
	SR 78/Melrose Dr. [f]	112205
	Carlsbad Maintenance Station (west)[g]	112207a,b

[a]Infiltration Trench; [b]Infiltration Basin; [c]Austin-Type; [d]Delaware-Type; [e]Canister-Type (StormFilter™); [f]Biofiltration Swales; [g]Biofiltration Strips
*Continued vector monitoring through April 2002
Source: California Department of Health Services

Overview of Vector Issues

Structural BMP technologies used in the Caltrans BMP Retrofit Pilot Study can be divided into 9 categories based on their intended operation (Table 1). Each category provided unique challenges in preventing vector production. Structures such as the Caltrans BMPs have the potential to create suitable habitat for a variety of organisms including those classified as vectors. Mosquitoes in particular are highly opportunistic insect vectors that will colonize any source of standing water provided that there is some organic content from which larvae can derive sustenance. This is supported by the fact that all nine BMP categories were found to harbor mosquito larvae at some point during the two-year study.

Of the nine different BMP technologies implemented by Caltrans, those that maintained permanent sources of standing water (i.e., Multi-Chambered Treatment

Trains (MCTT), Continuous Deflective Separators (CDS™), the StormFilter™, and the wet basin) provided excellent habitat for immature mosquitoes, and frequently supported large populations relative to other structural designs. In contrast, BMPs designed to drain rapidly (i.e., biofiltration swales and strips, sand media filters, infiltration basins and trenches, drain inlet inserts, extended detention basins and the oil/water separator) provided less suitable habitats for vectors.

Eight different species of larval mosquitoes, in four different genera, were collected during the course of this study and identified by VBDS and the four collaborating vector control districts (Table 4). The genus *Culex* was represented by three species (*Cx. quinquefasciatus*, *Cx. tarsalis*, and *Cx. stigmatosoma*), the genus *Culiseta* by two species (*Cs. incidens* and *Cs. inornata*), the genus *Anopheles* by two species (*An. hermsi* and *An. franciscanus*), and the genus *Ochlerotatus* (formerly *Aedes*) by a single species (*Oc. squamiger*). Four of these mosquito species are involved with disease cycles that can be transmitted to humans. *Culex* mosquitoes are commonly vectors of viruses. For example, *Cx. pipiens*, a very close relative of *Cx. quinquefasciatus*, is considered to be the primary vector of West Nile Virus in the eastern United States. In California, *Cx. tarsalis* is the primary vector of St. Louis encephalitis (SLE) and western equine encephalomyelitis (WEE) whereas *Cx. quinquefasciatus* plays a secondary role in the transmission of SLE, particularly in urban areas. *Cx. stigmatosoma* is a competent vector of both SLE and WEE to wild animals, thus maintaining the disease in nature through the enzootic cycle. In contrast, *Anopheles* mosquitoes are the primary vectors of malaria parasites throughout the world. *An. hermsi* has been associated with sporadic outbreaks of malaria in southern California and was responsible for an outbreak in San Diego in the mid 1980's.

Table 4. Species of mosquito larvae collected and identified from BMP structures used in the Caltrans BMP Retrofit Pilot Study.

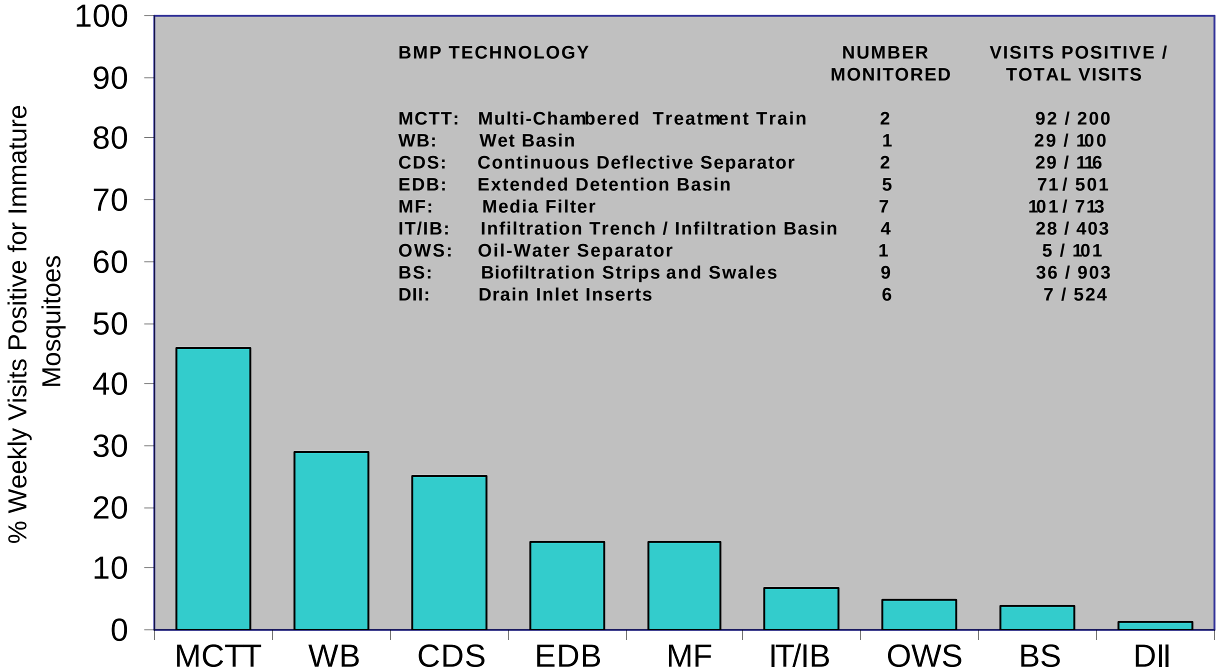
Genus	species
Culex	(*pipiens*) *quinquefasciatus*[a] *tarsalis*[a] *stigmatosoma*[a]
Culiseta	*incidens* *inornata*[c]
Anopheles	*hermsi* [b,c] *franciscanus* [c]
Ochlerotatus	*squamiger*[c]

[a]Vector of encephalitis viruses including St. Louis encephalitis (SLE) and western equine encephalomyelitis (WEE).
[b]Vector of human malaria parasites.
[c]Only collected in San Diego County, Caltrans District 11.
Source: California Department of Health Services

Sites were monitored for immature mosquitoes on a weekly basis by local vector control agencies, and weekly or bi-weekly (depending on season) by VBDS. The larval mosquito collection data presented in this study as "immature mosquitoes per dip" is in reference to the standardized collection technique, which can be used as an indicator of habitat suitability and larval density. To obtain a "dip sample", a one-pint cup attached to a long handle is used to collect a standard volume of source water that may or may not contain immature mosquitoes. If immature mosquitoes are discovered in the sample, they can be 1) identified to species, 2) examined for developmental stages, and 3) counted. Depending on the habitat or mosquito species present, alternative and more specialized means of collecting mosquitoes may be more appropriate.

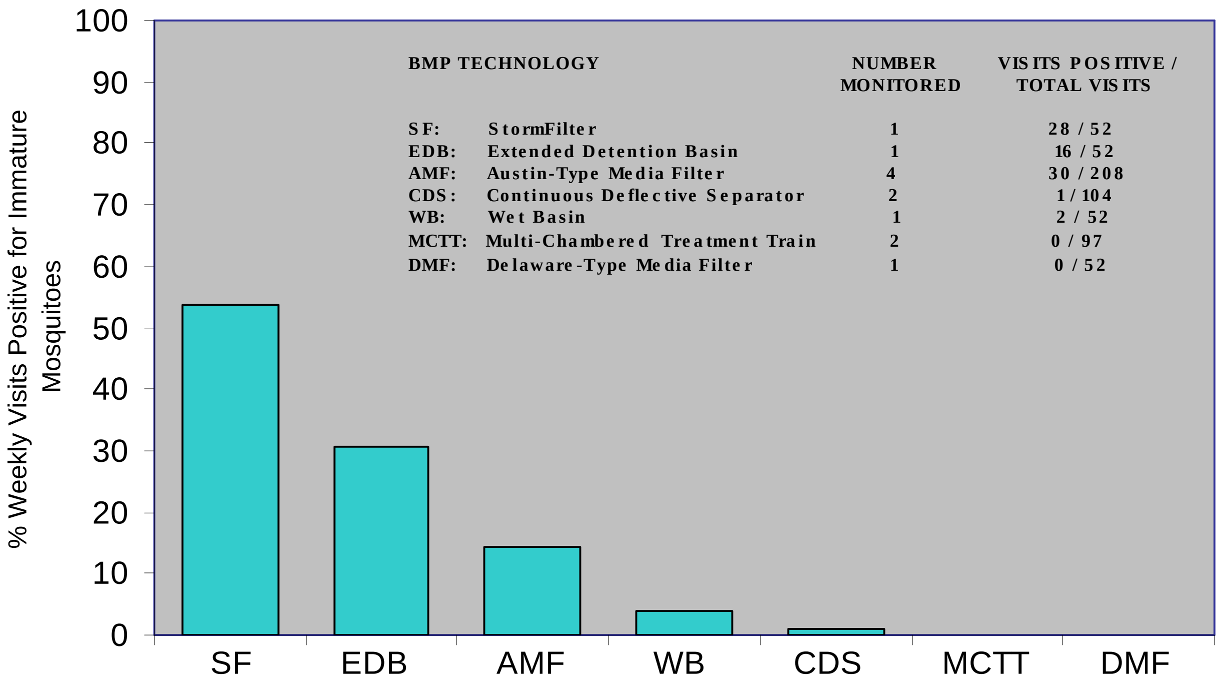
Data shown in bar graphs is presented in two ways: 1) percent of the total number of weekly visits positive for immature mosquitoes versus BMP type or individual structure and 2) the mean monthly number of larval mosquitoes collected per dip from individual sites. The percent of weekly site visits positive for mosquito larvae compared to the total number of visits indicated the frequency of mosquito breeding in particular sites and/or BMP types, and generally reflected how often standing water was present in these structures. For example, MCTT settling basins held permanent pools of water and not surprisingly contained larval mosquitoes most often. The mean monthly number of larval mosquitoes collected per dip from individual sites was a useful indicator of larval mosquito density, seasonal use, and the success of "vector proofing" attempts on habitat availability / suitability. An overall summary of immature mosquitoes detected from different BMP technology types is presented in Figures 1 and 2, and site-specific information is provided in Tables 5 and 6.

Figure 1. Weekly vector monitoring of BMP technology types in Caltrans District 7 and 11, May 1999 to April 2001.



Source: California Department of Health Services

Figure 2. Weekly vector monitoring of selected BMP technology types in Caltrans District 7 and 11, May 2001 to April 2002.



Source: California Department of Health Services

Table 5. Weekly monitoring of BMPs for immature mosquitoes between May 1999 and April 2001.

BMP Type	Site Name	WQ Site #	Monitoring Period	Weekly Mosquito Monitoring Total Visits	+ Visits	% Pos.
Wet Basin	I-5/La Costa Ave.	111104	6/15/99 - 4/30/01	100	29	29.0%
Extended Detention Basins (EDB)	I-5/I-605	74101	6/2/99 - 4/24/01	103	21	20.4%
	I-605/SR 91	74102	6/2/99 - 4/24/01	103	0	0.0%
	I-5/SR 56	111101	5/5/99 - 4/30/01	103	50	48.5%
	I-15/SR 78	111102	5/5/99 - 4/30/01	93	0	0.0%
	I-5/Manchester Ave.	111105	5/5/99 - 4/30/01	99	0	0.0%
Drain Inlet Inserts (DII) (*Two per site*)	Foothill MS	73216	5/7/99 - 4/26/01	184	0	0.0%
	Rosemead MS	73218	5/7/99 - 4/26/01	198	8	4.0%
	Las Flores MS	73217	12/8/99 - 4/24/01	142	0	0.0%
Infiltration Basins and Trenches	Altadena MS[a]	73211a,b	6/1/99 - 4/24/01	103	0	0.0%
	Carlsbad MS [a]	112207a,b	5/5/99 - 4/30/01	98	0	0.0%
	I-605/SR 91[b]	73101	6/2/99 - 4/24/01	101	0	0.0%
	I-5/La Costa Ave.[b]	111103	5/5/99 - 4/30/01	101	28	27.7%
Oil/Water Separators	Alameda MS	74201	6/1/99 - 4/24/01	101	5	5.0%
Media Filters	Eastern Regional MS[c]	74202	6/1/99 - 4/24/01	103	7	6.8%
	Foothill MS[c]	74203	5/7/99 - 4/26/01	92	3	3.3%
	Termination P&R[c]	74204	5/20/99 - 4/24/01	106	14	13.2%
	SR 78/I-5 P&R[c]	112204	5/5/99 - 4/30/01	103	24	23.3%
	La Costa P&R[c]	112203	5/5/99 - 4/30/01	103	29	28.2%
	Escondido MS[d]	112202	5/5/99 - 4/30/01	102	6	5.9%
	Kearny Mesa MS[e]	112201	5/5/99 - 4/30/01	104	18	17.3%
Multi-Chambered Treatment Trains (MCTT)	Via Verde P&R	74206	5/7/99 - 4/26/01	98	28	28.6%
	Lakewood P&R	74208	5/20/99 - 4/24/01	102	64	62.7%
Continuous Deflective Separators (CDS™**)**	I-210 (Orcas Ave.)	73102	3/16/00 - 4/24/01	59	22	37.3
	I-210 (Filmore Ave)	73103	3/16/00 - 4/24/01	57	7	12.3%
Biofiltration Swales and Strips	I-5/Palomar Airport [f]	112206	5/5/99 - 4/30/01	97	0	0.0%
	SR 78/Melrose Dr. [f]	112205	5/5/99 - 4/30/01	96	0	0.0%
	I-605/Del Amo Ave.[f]	73225	6/2/99 - 4/24/01	101	4	4.0%
	I-5/I-605[f]	73224	6/2/99 - 4/24/01	102	15	14.7%
	Cerritos MS[f]	73223	6/2/99 - 4/24/01	102	3	2.9%
	I-605/SR 91[f]	73222a,b	6/2/99 - 4/24/01	102	4	3.9%
	I-605/SR 91[g]	73222a,b	6/2/99 - 4/24/01	102	0	0.0%
	Altadena MS[g]	73211a,b	6/1/99 - 4/24/01	103	10	9.7%
	Carlsbad MS[g]	112207a,b	5/5/99 - 4/30/01	98	0	0.0%

[a]Infiltration Trench; [b]Infiltration Basin; [c]Austin-Type Media Filter; [d]Delaware-Type Media Filter; [e]Canister-Type Media Filter; [f]Biofiltration Swales; [g]Biofiltration Strips

Source: California Department of Health Services

Table 6. Weekly monitoring of BMPs for immature mosquitoes between May 1, 2001 and April 30, 2002.

BMP Type	Site Name	WQ Site #	Weekly Mosquito Monitoring Total Visits	 + Visits	 % Pos.
Wet Basin	I-5/La Costa Ave.	111104	52	2	4%
Extended Detention Basin (EDB)	I-5/SR 56	111101	52	16	31%
Media Filters	Eastern Regional MS[a]	74202	52	0	0%
	Termination P&R[a]	74204	52	3	6%
	SR 78/I-5 P&R[a]	112204	52	16	31%
	La Costa P&R[a]	112203	52	11	21%
	Escondido MS[b]	112202	52	0	0%
	Kearny Mesa MS[c]	112201	52	28	54%
Multi-Chambered Treatment Trains (MCTT)	Via Verde P&R	74206	45	0	0%
	Lakewood P&R	74208	52	0	0%
Continuous Deflective Separators (CDS™)	I-210 (Orcas Ave.)	73102	52	1	2%
	I-210 (Filmore Ave)	73103	52	0	0%

[a]Austin-Type Media Filter; [b]Delaware-Type Media Filter; [c]StormFilter™

Source: California Department of Health Services

Multi-Chambered Treatment Trains (MCTT)

The Multi-Chambered Treatment Trains (MCTT) supported the greatest number of mosquitoes over the longest period of time compared to other BMP designs in the Caltrans BMP Retrofit Pilot Study during 1999 and 2000. The data presented in Figure 3 demonstrates that the current MCTT design and operation supports dense populations of mosquitoes year-round in the southern California climate. These complex BMPs have several components that created optimal habitats for mosquito larvae. The primary factor was the standing water that remained within the settling basin and the settling basin pump-sump. The water in the settling basin was necessary for the unit to function properly during a storm event. However, during dry periods, this water, rich in organic debris, stagnated and became very attractive to egg laying mosquitoes. In addition, the plastic settling tubes that covered the bottom of the settling chamber created hundreds of sheltered microhabitats that increased the suitability of this environment to the larval mosquitoes.

During much of 1999, water remained below the top of the settling tubes creating difficulty in obtaining representative vector samples. A request was made to maintain water in these units at a level several inches above the settling tubes in order for vector control personnel to accurately monitor the water for vectors and abate them when necessary. In early 2000, this was agreed upon. However, an unidentified leak in the settling basin at the Via Verde Park and Ride site frequently caused the water level to drop below the settling tubes. As a result, many samples from this site were taken from the settling basin pump sump only. Repairs to the settling basin were done in early 2001.

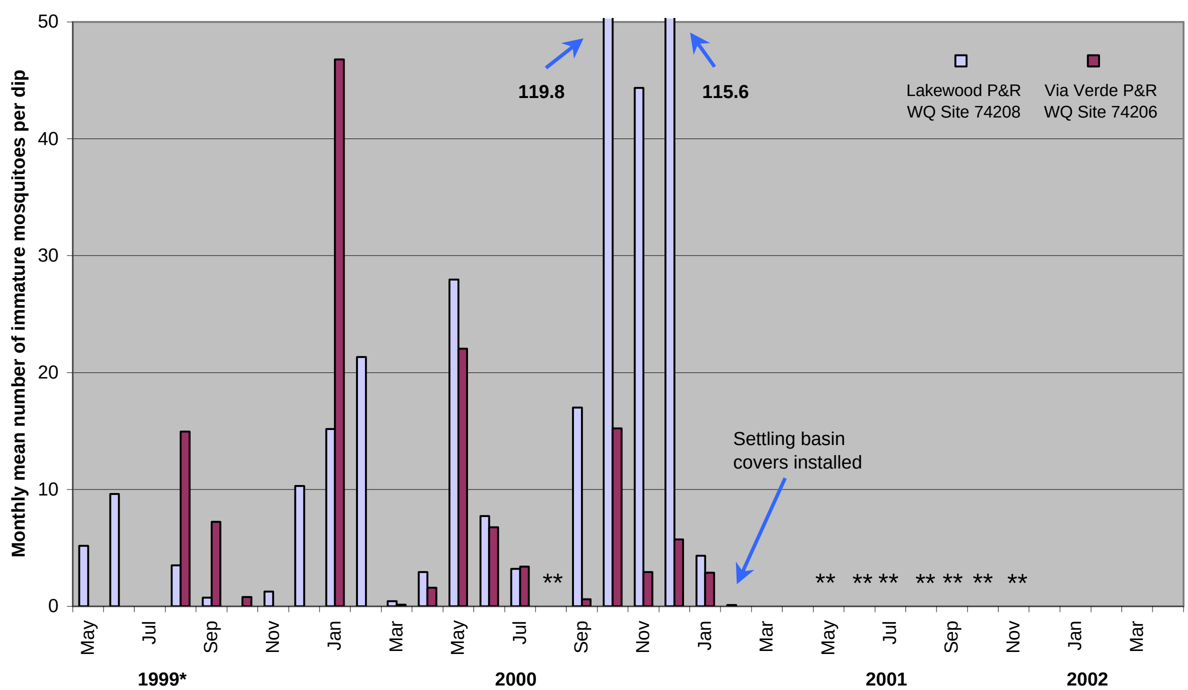
The MCTT structures had two additional sources of permanent standing water, one in the catch basin that fed incoming stormwater into the settling basin and the other in the pump sump of the sand media chamber. The catch basin was suspected of being a suitable habitat for mosquitoes. This water was located in a deep concrete vault, below a fiberglass grate that was covered by large bags of plastic aeration balls. The water was impossible to access for sampling during the first year and a half of operation by vector control personnel. In October 2000, the aeration bags were removed from the catch basin and hinges were added to the grate to allow for weekly vector monitoring. (No mosquito larvae were detected in the catch basins following the modification). The sand media chamber pump sumps were covered with a fine-mesh mosquito net in September 1999 shortly after mosquito larvae were detected at the Lakewood Park and Ride site. These screens were damaged on several occasions and were replaced.

Species of mosquito detected from MCTTs included *Cx. quinquefasciatus*, *Cx. stigmatosoma*, *Cx. tarsalis*, and *Cs. incidens.* Of 98 visits by SGVMVCD to the Via Verde Park and Ride site between May 7, 1999 and April 26, 2001, larvae were detected on 28 (29%) occasions and of 102 visits by GLACVCD to the Lakewood Park and Ride site between May 20, 1999 and April 24, 2001, larvae were detected on 64 (63%) occasions (Figures 3 and 6, Table 5). Together, these two sites were positive for mosquito larvae on 46% of the visits by vector control personnel (Figure 1).

Because of the frequency and density of mosquito breeding in the MCTT settling basins, VBDS and GLACVCD recommended that Caltrans cover and seal the basins. After some background research, positive-seal aluminum covers commonly used in wastewater treatment facilities were recommended in an attempt to prevent vector production. MCTT settling basins were drained and covered in late February 2001 and early March 2001, at the Via Verde and Lakewood Park & Ride sites, respectively.

Monitoring continued through April 2002 to determine the long-term efficacy and longevity of the covers under field conditions. In addition, mosquitoes could still access permanent standing water present in the catch basin. Between May 1, 2001 and April 30, 2002, GLACVCD monitored Lakewood P&R 52 times, and SGVMVCD monitored Via Verde P&R 45 times. No mosquitoes were detected breeding in the settling basins or the catch basins at either MCTT device during this time (Figure 2, Table 6). Unfortunately, vector monitoring was not possible for a significant portion of the 2001-2002 monitoring period. The settling basin at Lakewood P&R was pumped dry on May 21, 2001 and remained empty until November 13, 2001. Similarly, the settling basin at Via Verde P&R remained below the level of the settling tubes (preventing sampling) between July 12, 2001 and November 15, 2001.

Figure 3. Monthly collection of immature mosquitoes from Multi-Chambered Treatment Trains (MCTT) in Caltrans District 7.



*The water level in the settling basins was frequently below the top of the settling tubes during 1999, making vector monitoring difficult.
**Settling basins pumped dry.
Source: California Department of Health Services

Continuous Deflective Separators (CDSÔ)

The CDS™ units were installed in March 2000. They rapidly established themselves as excellent breeding sources for mosquitoes since standing water was retained in the cylindrical vortex sump. These units, like the MCTT units discussed previously, required standing water in the sump in order to function properly during a storm event. The result of this was a source of water rich in organic debris and excellent for the development of mosquito larvae. In addition, the influent / effluent weir box contained a depression several centimeters deep that provided additional usable habitat for vectors. Although the CDS™ sumps and weir boxes were covered, there were numerous means by which egg-laying female mosquitoes could access the sump including gaps between the lid and the sump, holes in the side of the sump (~ 3/4 inch diameter, used to support hoist-chain for the debris net bag), and the main influent and effluent pipes leading into and out of the CDS™ sump.

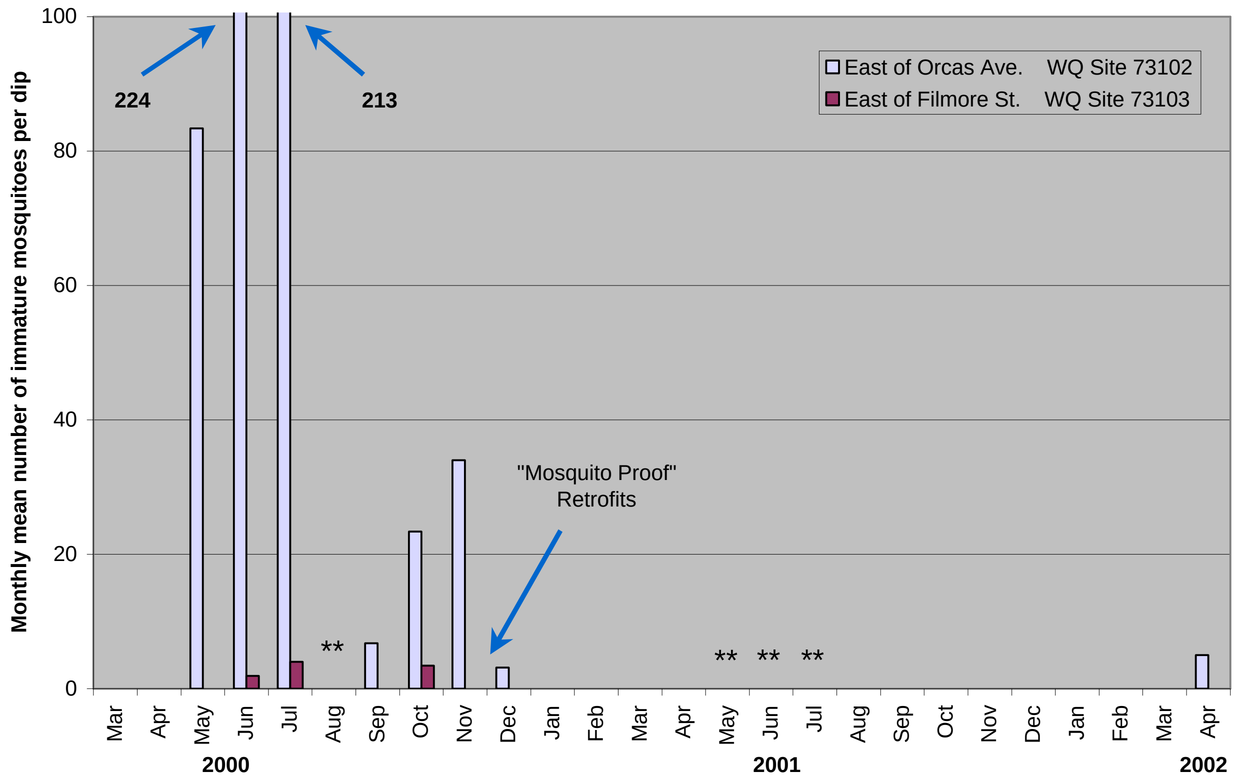
The East of Orcas Ave. CDS™ site produced the highest number of larvae in a dip sample of all the BMPs in the study. The average number of larvae per dip in June 2000 was 224 (Figure 4), but 1,680 larvae were collected from 4 dips (420 larvae per dip) during one weekly visit in the same month. Species of mosquito detected from CDS™ structures were almost exclusively *Cx. quinquefasciatus*, with a few *Cx. tarsalis* collected from the East of Orcas Ave. site in May 2000. Of 59 visits by GLACVCD to the East of Orcas Ave. site between March 16, 2000 and April 24, 2001, larvae were detected on 22 (37%) occasions and of 57 visits to the East of Filmore St. site between March 16, 2000 and April 24, 2001, larvae were detected on 7 (12%) occasions (Figures 4 and 6, Table 5). Together, these two sites were positive for mosquito larvae on 25% of the visits by vector control personnel (Figure 1).

In response to the intense mosquito breeding at the CDS™ sites, Caltrans grouted the weir box depressions in early August 2000. Since then, only small puddles of standing water were occasionally detected on the floor of the weir box, and no mosquitoes were detected utilizing this source. In November 2000, foam was added to the sump and weir box covers, the holes in the side of the sump were caulked, and a "mosquito proof" bag was placed around the CDS™ effluent pipe. The number of mosquito larvae decreased over the remaining weeks in November and into December.

No larvae were detected in the CDS™ sump after December 20, 2000. In February and March, 2001, Caltrans experimented with different designs of the effluent pipe mosquito-proof bag. The current design, implemented in March 2001, utilizes a heavy steel chain sewn into the bag. The influent pipe leading into the CDS™ unit remained unchanged and left a potential access point to vectors.

Monitoring continued through April 2002 to determine the long-term efficacy and longevity of the retrofits under field conditions. Between May 1, 2001 and April 30, 2002, GLACVCD monitored each site 52 times. The CDS™ sumps were drained on May 8, 2001, preventing GLACVCD from evaluating the mosquito-proofing modifications during this critical part of "mosquito season". On July 25, 2001, the CDS™ sumps were refilled to allow the vector monitoring study to continue. On April 25, 2002, VBDS noted that sand flies (Psychodidae) had become extremely abundant in the Orcas Ave. CDS™ device, with hundreds of adults taking flight from the sump and weir box upon removal of the lids for inspection. In addition, hundreds of sand fly larvae were observed in the putrid sump water. Several days later, on April 30, 2002 GLACVCD collected second-instar *Culex quinquefasciatus* mosquito larvae from the sump water. Evidently, female mosquitoes had either found an unrecognized flaw in the mosquito-proofing retrofits, or they may have traveled down the long inlet pipe from the inlet grate located along the north edge of I-210. The Filmore Ave. CDS™ device was not found to harbor mosquitoes during this 1-year addendum study (Figure 4).

Figure 4. Monthly collection of immature mosquitoes from individual Continuous Deflective Separators in Caltrans District 7.



**Settling basins pumped dry.
Source: California Department of Health Services

Wet Basin

Wet basins are designed to treat incoming runoff water by acting as a biological filter and sedimentation basin. However, permanent pools of water quickly become very complex biological systems of plants and animals, which in turn create mosquito habitats that may become severe under certain conditions. The best conditions for mosquito survival and development in southern California's permanent pools occur when annual aquatic plants (e.g., cattails) perish, fall, and clog shoreline habitats. Mosquito larval predators such as the mosquitofish, *Gambusia affinis*, become excluded by dense vegetation in these habitats. In addition, the decaying vegetation creates a rich organic media perfect for the nutrition of mosquito larvae. Similarly, suitable habitats for mosquito larvae are created when live plants become dense and create pockets of water that are inaccessible to predators.

During its first year of operation, the wet basin experienced dramatic changes typical of permanent pools of water in southern California. Mosquitofish were introduced into the pond soon after it was completed (June 17 and 18, 1999) by SDCVSC in an attempt to control immature mosquitoes that were already present only a few weeks after its completion. Invasive cattail plants grew rapidly and covered over 50% of the original surface area of the pool within approximately 6 months, and effectively out-competed all other emergent vegetation by spring of 2000. By May 2000, the cattail plants averaged over 2 meters in height and extended 2 meters or more in width from the shoreline.

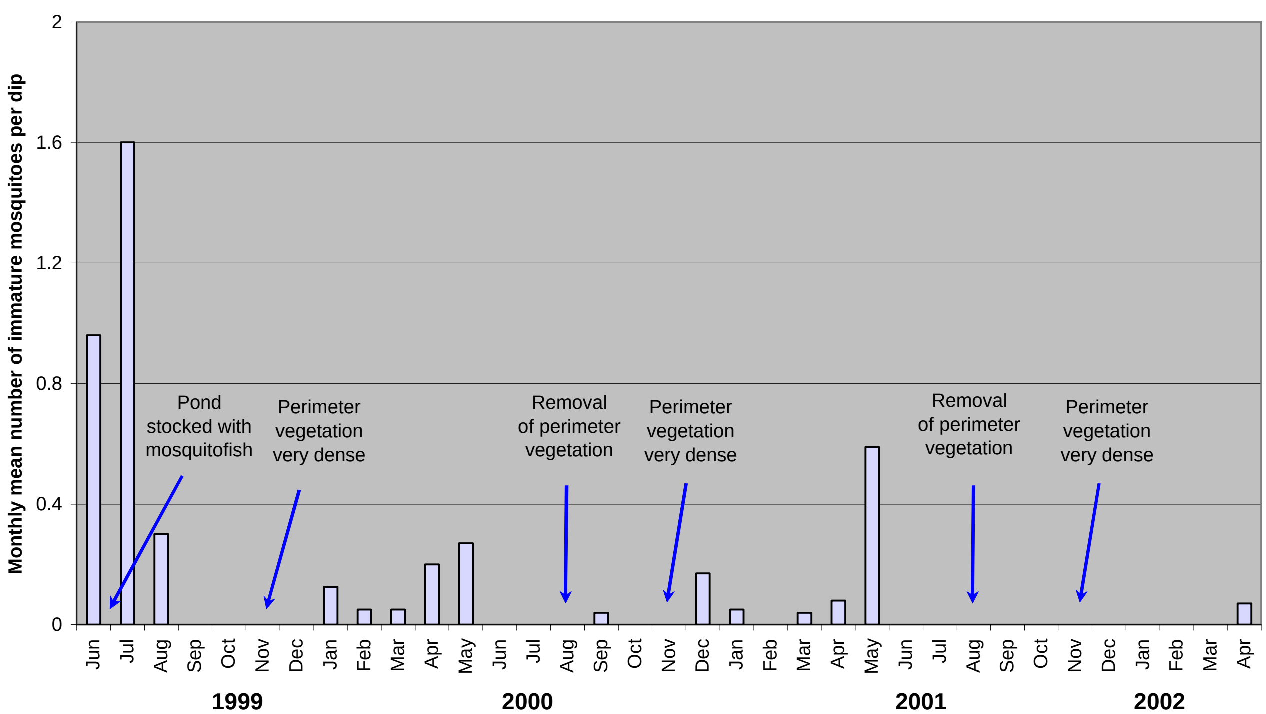
In June 2000, cattails were beginning to fall and formed a dense thatch on the water surface. Cattails were mechanically removed by maintenance crews in August 2000 to allow for continued vector monitoring and to prevent the entire pond from becoming clogged with vegetation. Within 3 months, the cattails re-colonized the pond perimeter and forebay, returning the pond to conditions similar to that prior to vegetation removal. By June 2001, cattails had spread inwards from the shorelines covering over 75% of the original open water surface. The density of the cattails made shoreline access and subsequent vector monitoring by SDCVSC practically impossible.

Caltrans again authorized the removal of cattails in August 2001. As seen before, re-colonization occurred within only a few months, especially along the shorelines and throughout the forebay. By March 2002, SDCVSC noted that shoreline access for vector monitoring was becoming increasingly difficult. In late April 2002, SDCVSC further noted that vegetation growth in the vicinity of the inlet pipe had created a dam effect that effectively blocked sediment and subsequently reduced water flow into the basin by approximately 50%. This in turn allowed the water level throughout the basin to drop and reportedly created many shallow water habitats along the shorelines ideal for mosquito breeding.

Five species of mosquito were collected from this site. Three of these, *Cx. tarsalis, An. hermsi*, and *An. franciscanus*, are typical species associated with permanent ponds. The other species, *Cx. stigmatosoma* and *Cs. incidens*, were only found on one occasion. Despite the presence of large numbers of mosquitofish in the pond, mosquito larvae were found in small, isolated shoreline pockets of water among fallen cattails, accumulations of vegetation and plant debris, and/or algal mats. Out of 100 site visits by SDCVSC between June 15, 1999 and April 30, 2001, mosquito larvae were detected on 29 (29%) occasions (Figure 6). Between May 2001 and April 2002, SDCVSC monitored this site an additional 52 times. Surprisingly, mosquito larvae were only detected on May 14, 2001 and on April 8, 2002 (4%) during this time period.

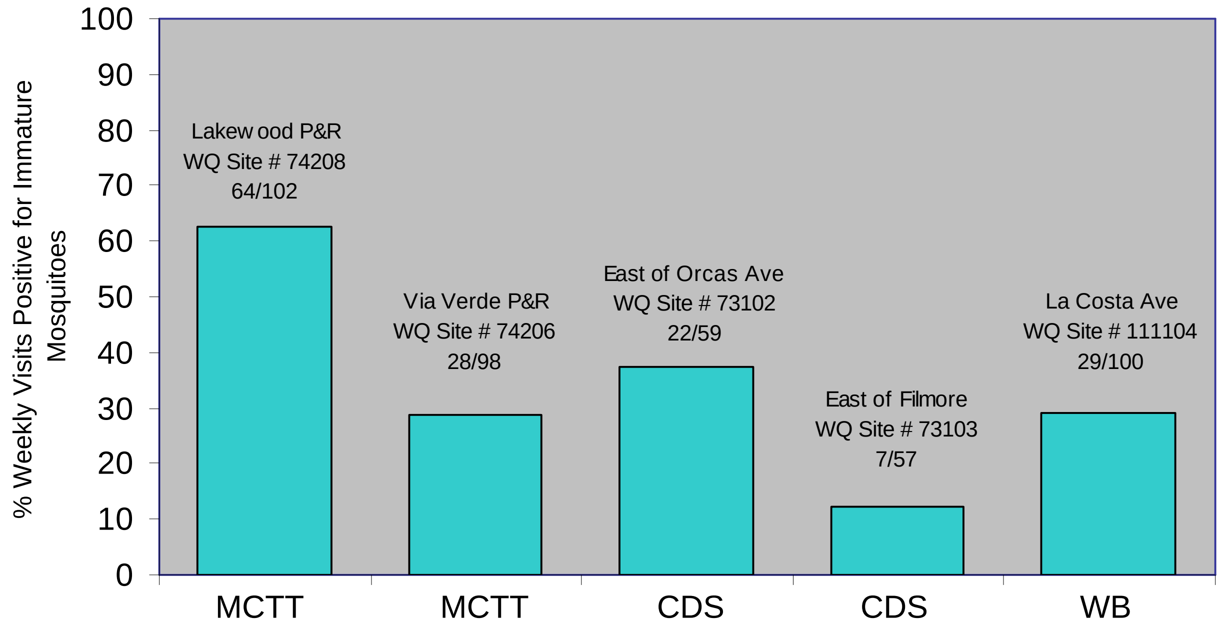
In general, the number of larvae collected per dip from the wet basin was small compared to other Caltrans BMPs included in this study (Figure 5), but these findings were significant given the large surface area of the BMP (approx. 1,371 m^2) and the difficulty in obtaining dip samples among the dense shoreline vegetation.

Figure 5. Monthly collection of immature mosquitoes from La Costa Ave. (east) Wet Basin in Caltrans District 11 (WQ Site No. 111104).



Source: California Department of Health Services

Figure 6. Weekly vector monitoring of individual Multi-Chambered Treatment Trains, Continuous Deflector separators, and the Wet Basin, May 1999 to April 2001.



Extended Detention Basins (EDB)

The five EDBs are all unique in size, shape, and overall design, thus rendering different habitats potentially suitable for immature mosquitoes. In general, EDBs drained at prescribed rates; therefore, pools of standing water did not remain for more than a few days.

The I-605 & SR 91 EDB site in Caltrans District 7 retained a significant amount of standing water among the large rock rip rap placed at the mouth of the influent pipe. Water up to approximately 20 cm deep remained in this area for several days following storm events before infiltrating and/or evaporating. As a result, grasses and other vegetation became dense in this area, providing a potentially attractive habitat for larval mosquitoes. Of 103 site visits by GLACVCD between June 2, 1999 and April 24, 2001, no vectors were detected (Figure 9).

The EDB at the I-5 and I-605 interchange in Caltrans District 7 was built with a concrete-lined bottom that helped water to drain-down rapidly following a storm event. However, the design of the effluent area required that the stormwater exit the EDB through a flow-restriction pipe approximately 56 cm below the level of the effluent pipe. The two were connected via the use of a small sump, approximately 1 m^2 and 56 cm deep. As a result, this sump retained water for weeks or months following a storm event, providing a sheltered habitat for mosquito larvae.

Larval mosquitoes identified from this location were primarily *Cx. quinquefasciatus*, but *Cx. tarsalis* and *Cs. incidens* were also identified on a few occasions. Of 103 visits by GLACVCD between June 2, 1999 and April 24, 2001, mosquito larvae were detected on 21 (20%) occasions (Figures 8 and 9). Because of the frequency and density of mosquito breeding in the effluent sump, VBDS and GLACVCD recommended that it be modified to prevent accumulation of standing water. In February, 2001, the sump was filled and modified to function without retaining water. No significant sources of standing water or mosquito larvae were detected at this site following the modification, through April 2001.

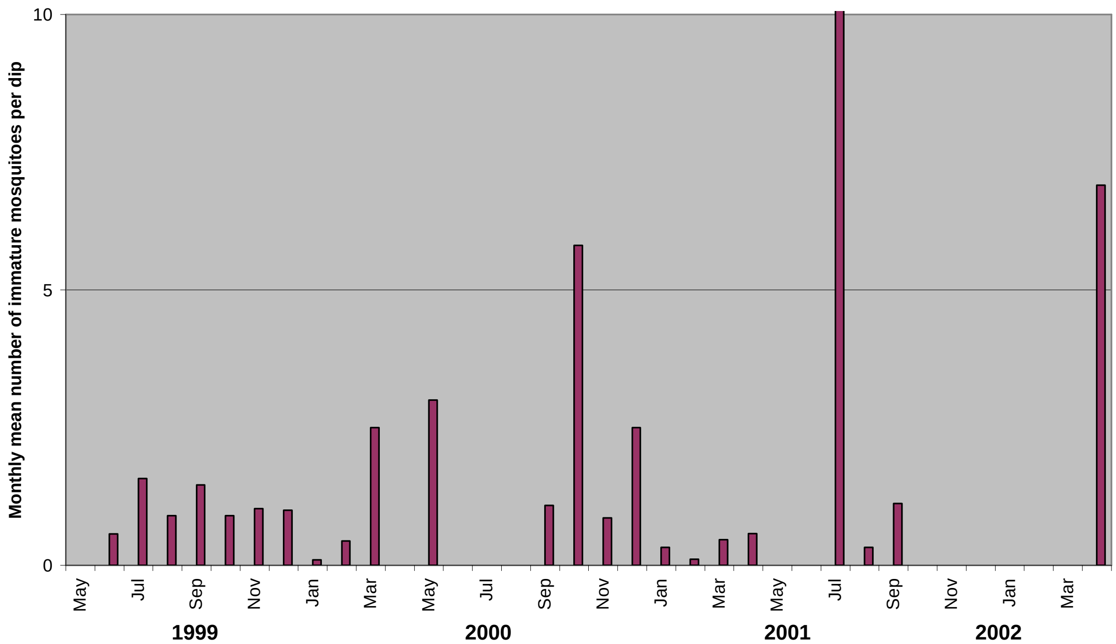
Two of the three EDB sites in Caltrans District 11 (I-15 & SR 78 interchange and I-5 & Manchester Ave.) retained only minor amounts of shallow standing water following storm events, generally on and around the influent and effluent concrete pads. However, VBDS noted potential areas for standing water: 1) in the large rock "rip rap" depressions on either side of the influent pipe at the I-15 & SR 78 site, and 2) on the influent concrete pad of the I-5 & Manchester Ave. site where a debris and vegetation barrier was beginning to form in 2001. Of 192 total visits to both sites by SDCVSC between May 5, 1999 and April 30, 2001, no vectors were detected (Figure 9).

The I-5 & SR 56 interchange EDB site in Caltrans District 11 had an unintended physical feature that was very attractive to mosquitoes. Two areas of large rock rip rap within the EDB created depressions in the basin floor. Following each storm event, water (up to 30 cm deep) remained trapped in these depressions for weeks (with little to no infiltration), creating protected microhabitats for mosquitoes among the rocks. This habitat not only protected larvae from potential predators and sunlight, but also effectively hid them from vector control inspectors and made effective abatement difficult or impossible. In addition, VBDS noted that irrigation water runoff from a nearby hillside contributed to the water source present in the rip rap depression closest to the mouth of the influent pipe.

The I-5 & SR 56 interchange EDB site harbored immature mosquitoes more often than the other four EDBs and was also one of three BMP structures in this study (the others were the I-5 & SR 78 P&R Austin-type sand media filter and the La Costa Ave. infiltration basin) from which the greatest number of mosquito species were identified. Possibly due to its location adjacent to a wetland mitigation site, six of the eight mosquito species identified during this study (Table 4) were collected from standing water at this site. Only *Oc. squamiger* and *An. franciscanus* remained undetected at this site. Of 103 visits by SDCVSC between May 5, 1999 and April 30, 2001, larvae were detected on 50 (49%) occasions (Figure 9). The number of larvae collected per dip sample was relatively small compared to other BMPs in this study (Figure 7); however, these findings were significant given the large surface area of the rip rap depressions at this site (approx. 160 m^2) and the difficulty in accessing water between the rocks for sampling.

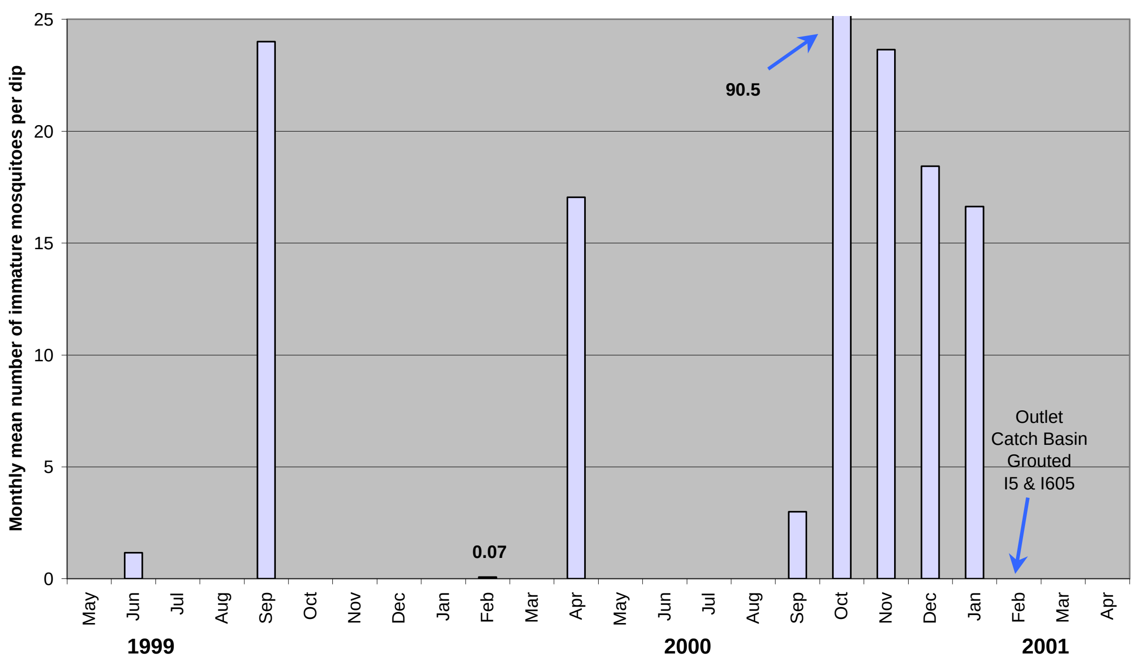
The standing water situation at this site worsened between May 1, 2001 and April 30, 2002, possibly due to decreased infiltration or by undetected sources of urban runoff (i.e., the hillside irrigation system noted previously). In fact, this site was only dry for a combined period of approximately 5 weeks, thus remaining a potential mosquito breeding habitat for most of the year. SDCVSC monitored this site 52 times between May 1, 2001 and April 30, 2002. Mosquito larvae were detected on 16 occasions (31%) during this time period. Five species, *Culex stigmatosoma, Cx. tarsalis*, *Cx. quinquefasciatus*, *Culiseta incidens*, and *Anopheles hermsi* were collected and identified.

Figure 7. Monthly collection of immature mosquitoes from the Extended Detention Basin at the I-5 & SR-56 interchange (Sorrento Valley) in Caltrans District 11 (WQ Site No. 111101) May 1999 to April 2002.



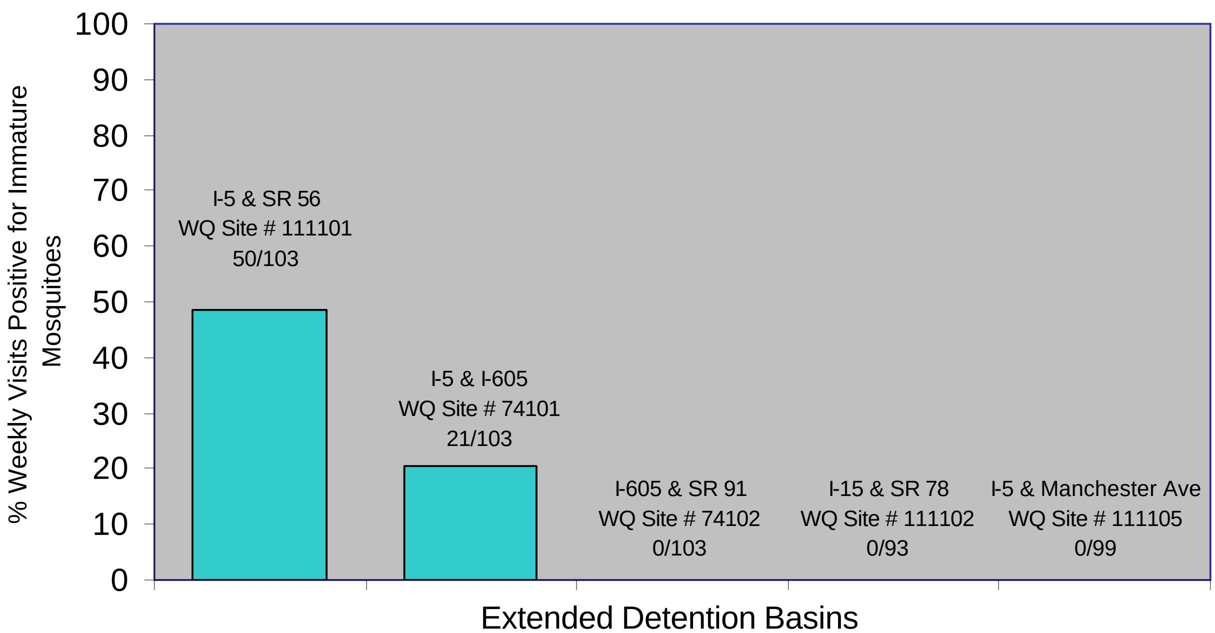
Source: California Department of Health Services

Figure 8. Monthly collection of immature mosquitoes from the concrete-lined Extended Detention Basin at the I-5 & I-605 interchange in Caltrans District 7 (WQ Site No. 74101), May 1999-April 2001.



Source: California Department of Health Services

Figure 9. Weekly monitoring of individual Extended Detention Basins May 1999 to April 2001.



Source: California Department of Health Services

Media Filters

Caltrans implemented three types of media filters for this study; Austin, Delaware, and a proprietary canister filter device called StormFilter™. Each type benefits water quality by filtering water runoff through a substrate; however, differences in design and construction required that each be evaluated separately with regards to vector production.

Austin-Type. In general, the Austin-type sand media filters drained at prescribed rates when functioning properly (i.e., no clogging and functional effluent pumps). However, mosquitoes utilized features within individual structures that held standing water for relatively long periods of time. In addition, the settling basins at both sites were found to also provide significant mosquito breeding habitats due to construction flaws, clogging, and/or pump failure. These are listed below:

- the effluent pump sumps in Caltrans District 7 media filters held permanent standing water. Mosquito breeding was detected at Eastern Regional MS and Termination P&R sites. These pump sumps were tightly covered with fine-mesh "mosquito-proof" screen shortly thereafter.
- the spreader troughs located on the sand-media side of all five structures had a tendency to hold standing water and occasionally harbored immature mosquitoes. In particular, the two media filters in Caltrans District 11 were modified shortly after construction to include three depressions in the spreader troughs that allowed effluent pipes to flow unobstructed from the settling basin. These depressions, although only about 100 cm^2 and up to about 10 cm deep, retained water for weeks to months following storm events and were consistent sources of mosquito larvae.
- the pipe transporting effluent from settling basins to sand media basins was provisioned with discharge orifices that were prone to clogging due to their small diameter. The settling basin effluent pipes at La Costa Ave. P&R site in Caltrans District 11 and the Eastern Regional MS site in Caltrans District 7 both clogged on several occasions, creating significant vector habitats.
- in the settling basin at the Termination Park and Ride site in Caltrans District 7, a faulty grade resulted in a large pool of standing water following every storm event that provided a large habitat for mosquito larvae.
- At the I-5 & SR 78 P&R site in Caltrans District 11, VBDS discovered an intermittent underground irrigation leak that allowed small pools of standing water to persist for months in the settling basin.

Due to the presence of standing water, mosquitoes were detected at all of the Austin-type units. The majority of larval mosquitoes identified from structures in Caltrans District 7 were *Cx. quinquefasciatus*, but significant numbers of *Cx. tarsalis*, *Cx. stigmatosoma*, and *Cs. incidens* were also identified. In Caltrans District 11, six of the eight mosquito species identified during this study (Table 4) were collected from standing water at the I-5 & SR 78 P&R site. Only *Cs. incidens* and *An. franciscanus* remained undetected at this site. Five species, *Cx. tarsalis*, *Cx. quinquefasciatus*, *Cx.*

stigmatosoma, *Cs. inornata*, and *An. hermsi* were collected from standing water at the La. Costa Ave. P&R site. The presence of *Oc. squamiger* (normally a tidal saltmash species) and *An. hermsi* (a species that prefers vegetated ponds) in these two Austin-type sand media filters beginning in December 2000, may indicate that biological changes within structures (site maturation) occur over time, creating favorable conditions for previously excluded vector species.

Between late September and early November 2000 in Caltrans District 7, clogged orifices in the effluent transition pipe (between the settling and sand-media basins) resulted in standing water in the settling basin at Eastern Regional MS. This in turn resulted in very dense populations of mosquitoes. Bags filled with sand were placed around the effluent transition pipe to prevent further clogging in November 2000. At Termination P&R, a faulty grade in the settling basin resulted in a large permanent pool of standing water following every storm event. The standing water was approximately 30 m^2 and several cm deep and provided a large habitat for mosquito larvae. In January 2002, Caltrans authorized re-sloping the settling basin with concrete, which eliminated this persistent source of standing water.

Of 507 visits to the five sites between May 5, 1999 and April 30, 2001 (92 at Foothill MS by SGVMVCD; 209 at Eastern Regional MS and Termination P&R by GLACVCD; 206 at La Costa Ave. P&R and I-5/SR 78 P&R by SDCVSC), mosquitoes were detected on 77 (15%) occasions. Visits to individual sites are summarized in Figure 15. The number of larvae per dip sample collected during visits by vector control personnel are summarized cumulatively for all five structures in Figure 10, and individually in Figures 11 and 12.

In Caltrans District 7, between May 1, 2001 and April 30, 2002, GLACVCD continued monitoring Eastern Regional MS and Termination P&R. Each site was monitored 52 times. No breeding was detected at Eastern Regional MS during this time period. *Culex quinquefasciatus* mosquitoes were detected breeding in the Termination P&R settling basin in late December 2001 and early January 2002. However, no standing water or mosquitoes were detected at this site following the modifications to the settling basin.

GLACVCD noted deterioration of the mosquito-nets and tape seal covering the effluent pump sumps. These were repaired and/or replaced several weeks after Caltrans was notified. However, a crow was observed pecking and damaging the screen on April 23, 2002, an unprecedented means of mosquito net failure. The use of mosquito nets can be very effective in eliminating access to potential vector breeding sites but, as noted above, many factors can lead to their failure. These are by no means permanent solutions, and will require regular and frequent inspection and replacement.

In Caltrans District 11, SDCVSC continued monitoring La Costa Ave. P&R and I-5 & SR 78 P&R these sites between May 1, 2001 and April 30, 2002. Each site was inspected 52 times. Water remained in the spreader trough depressions for most of this monitoring period. The settling basins at both sites became potential sources of mosquito production on several occasions during the 1999-2001 mosquito production study, and again during this one-year addendum study. The effluent transition pipe at La Costa Ave. P&R clogged with debris several times, resulting in standing water in the settling basin. At the I-5 & SR 78 P&R site, VBDS discovered a hidden irrigation break in late December 2000 that fed the pools of standing water in the settling basin and likely was the cause of these persisting for months. This source was repaired shortly thereafter. In July 2001, SDCVSC reported another irrigation leak at the I-5 & SR-78 P&R site that flowed into the settling basin. It was repaired the following week.

Mosquito larvae were detected on 11 occasions (21%) at La Costa P&R and 16 occasions (31%) at the I-5 & SR-78 P&R during this time period. Five species, *Culex stigmatosoma, Cx. tarsalis*, *Cx. quinquefasciatus*, *Culiseta incidens*, and *Cs. inornata* were collected and identified.

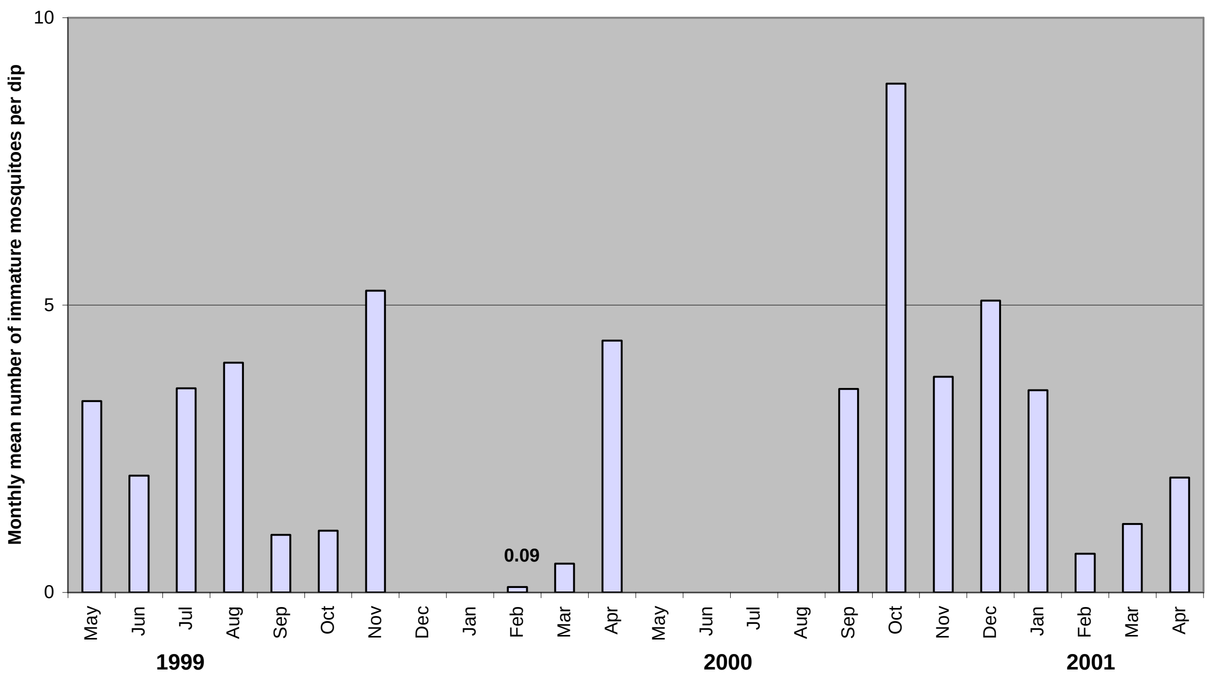
Delaware-Type. The Delaware-type sand media filter was located underground, covered by heavy steel doors. The unit was designed with two chambers, a settling chamber and a sand media filter chamber, similar to the Austin-type media filters; however, the settling chamber was approximately 36 cm deeper than the sand media chamber, resulting in a large body of standing water following storm events. Small gaps between the individual door covers allowed adult mosquitoes to enter and utilize the water in the settling chamber. A slow leak past the settling chamber clean-out valve drained water in the settling chamber over the course of several weeks, until only shallow (2-4 cm deep), stagnant water remained. Mosquito larvae were detected in the settling basin water on several occasions, despite its relatively cryptic location below ground (Figure 13). Of 102 visits by SDCVSC between May 5, 1999 and April 30, 2001, larvae were detected on six (6%) occasions. Between May 1, 2001 and April 30, 2002, SDCVSC visited this site an additional 52 times. Surprisingly, no mosquitoes were detected breeding in the standing water during this time period. (Figure 15).

StormFilter™. The canister-type media filter is located below ground similar to the Delaware-type unit. This structure was covered by spring-loaded aluminum doors, which did not create perfect seals. Small holes and gaps around the covers allowed adult mosquitoes to access the water below. The canister-type unit had unique features not found in other media filter designs; these included an initial catch basin vault chamber that led to 3 separate filter chambers designed to fill sequentially, depending on the amount of water produced by a storm event. Each of the three filter chambers was equipped with a spreader trough and energy dissipater serving to slow the incoming water flow at the mouth of the influent pipe.

The catch basin and the spreader trough of the first filter chamber held water permanently between May 1999 and April 2001 and were the primary sources of mosquitoes. The smaller spreader troughs located in the second and third filter chambers held only a few centimeters of water until it evaporated weeks or months later. Mosquito larvae were only found in the two shallow spreader troughs on a few occasions. Of 104 visits by SDCVSC between May 5, 1999 and April 30, 2001, mosquito larvae were detected on 18 (17%) occasions (Figures 14 and 15). VBDS noted dense populations of copepods in the permanent water at this site during certain times of the year, which may have limited the number of mosquito larvae found at this site.

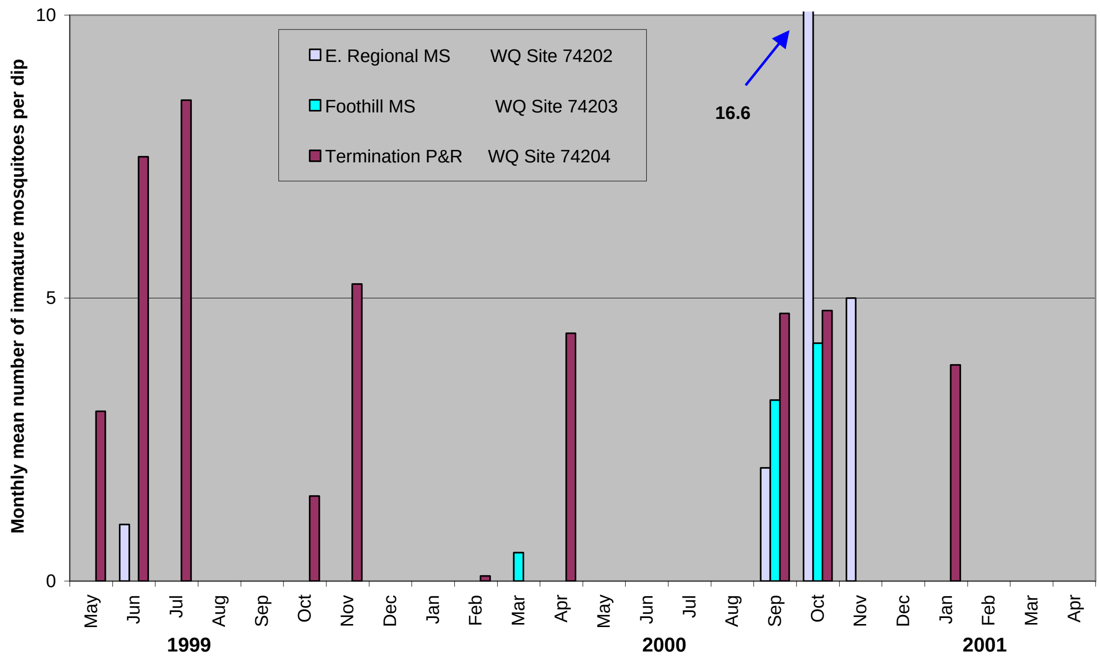
Between May 1, 2001 and April 30, 2002, SDCVSC visited this site an additional 52 times and mosquito larvae were detected on 28 (54%) of these visits; the most of any BMP during this one year follow-up study. Water was present in the catch basin and each spreader trough for the entire year. Breeding occurred in each of the four separate chambers, demonstrating the accessibility of the chambers to these vectors. Adult mosquitoes were also seen flying in the underground chambers during 5 different weekly visits.

Figure 10. Cumulative monthly collection of immature mosquitoes from five Austin-Type Sand Media Filters in Caltrans District 7 and 11, May 1999 to April 2001.



Source: California Department of Health Services

Figure 11. Monthly collection of immature mosquitoes from individual Austin-Type Sand Media Filters in Caltrans District 7, May 1999 to April 2001.



Note: Eastern Regional MS. Mosquito larvae were detected in effluent pump sump in early June 1999 prior to it being covered with mosquito screen. The effluent pipe from the settling basin to the sand media basin was clogged between late September and early November 2000.

Source: California Department of Health Services

Figure 12. Monthly collection of immature mosquitoes from individual Austin-Type Sand Media Filters in Caltrans District 11, May 1999 to April 2002.

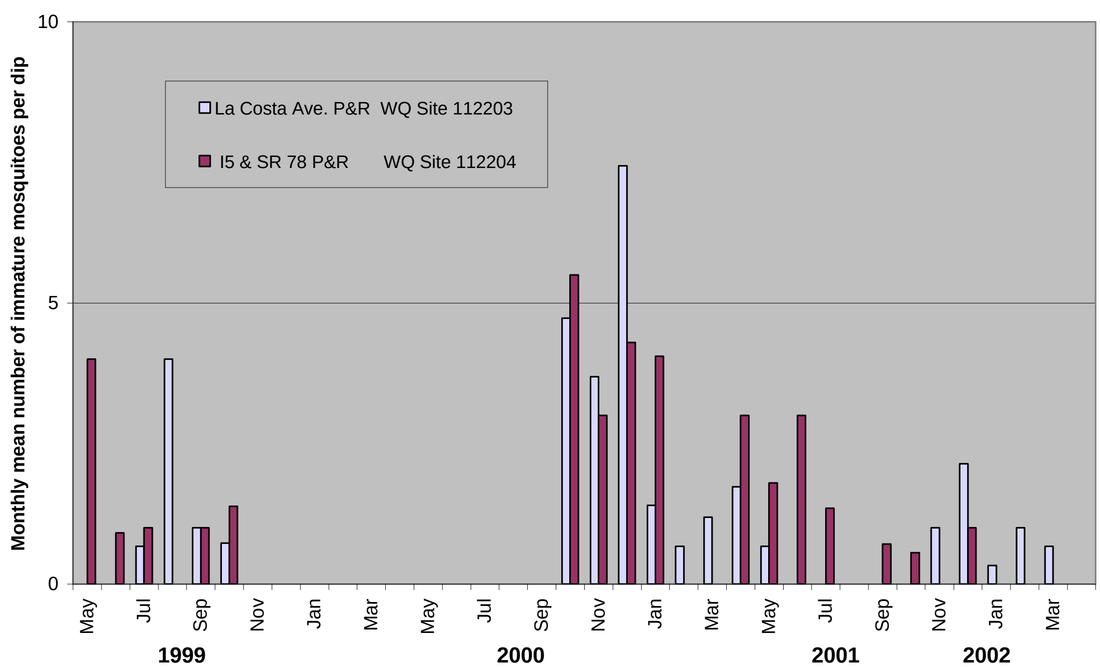
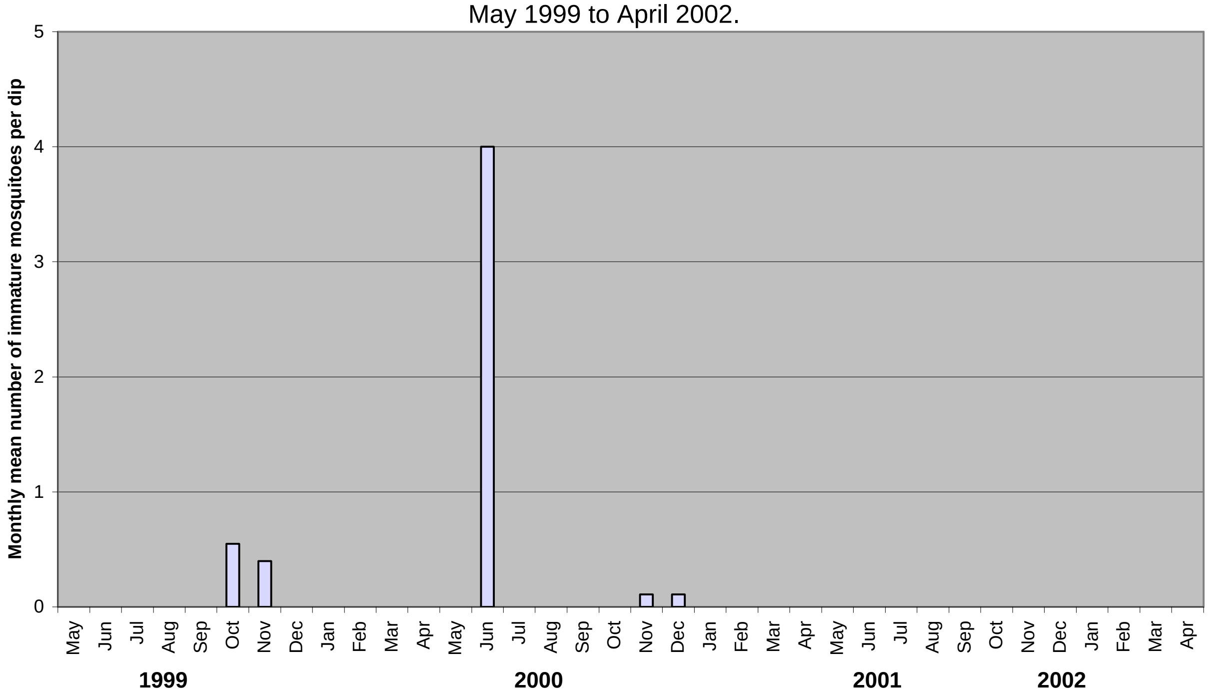


Figure 13. Monthly collection of immature mosquitoes from Escondido Maintenance Station Delaware-Type Sand Media Filter in Caltrans District 11 (WQ Site No. 112202)
May 1999 to April 2002.



Source: California Department of Health Services

Figure 14. Monthly collection of immature mosquitoes from Kearny Mesa Maintenance Station StormFilter (Canister-Type Media Filter - pearlite/zeolite) in Caltrans District 11 (WQ Site No. 112201), May 1999 to April 2002.

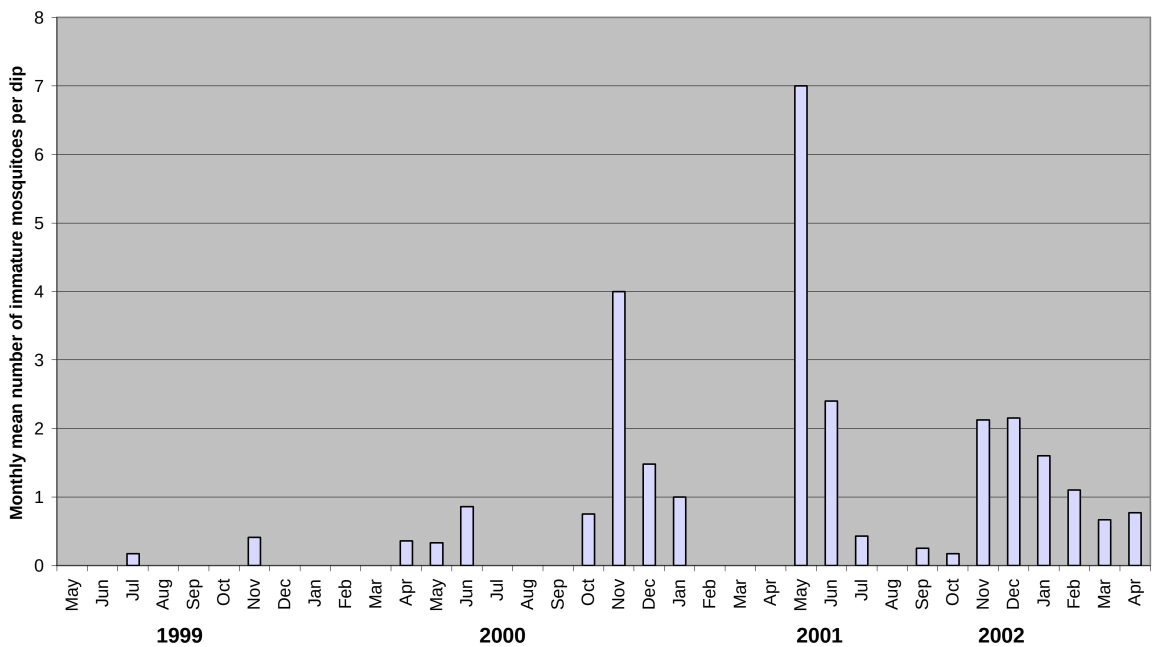
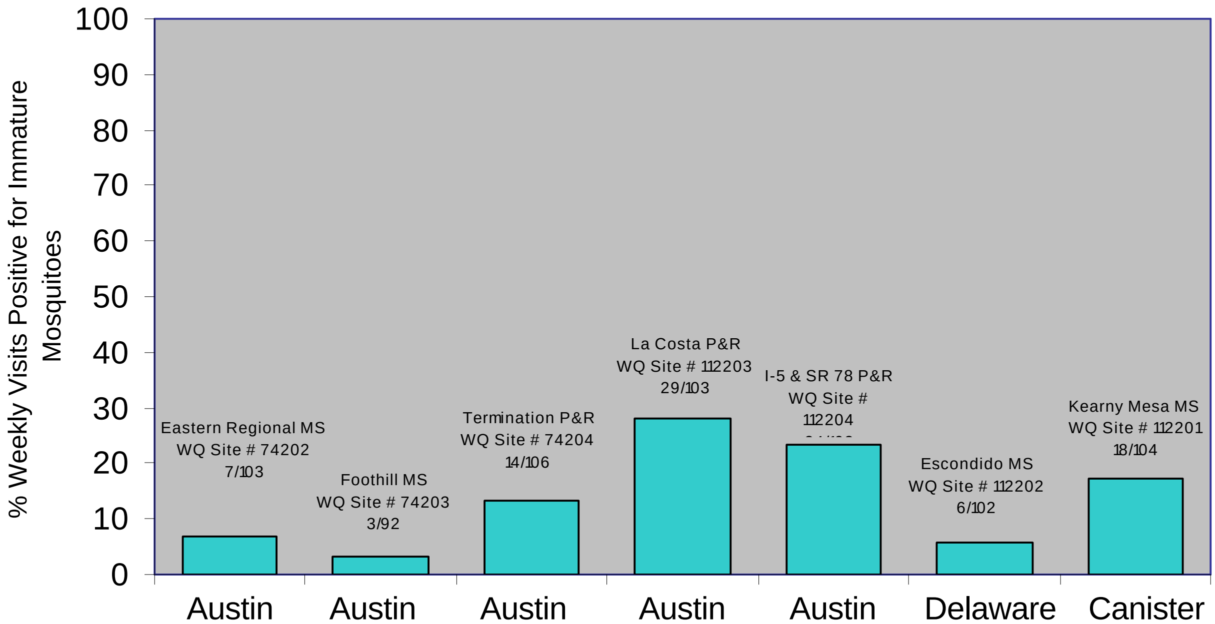


Figure 15. Weekly vector monitoring of individual Media Filters, including Austin-Type, Delaware-Type, and Canister-Type, May 1999 to April 2001.

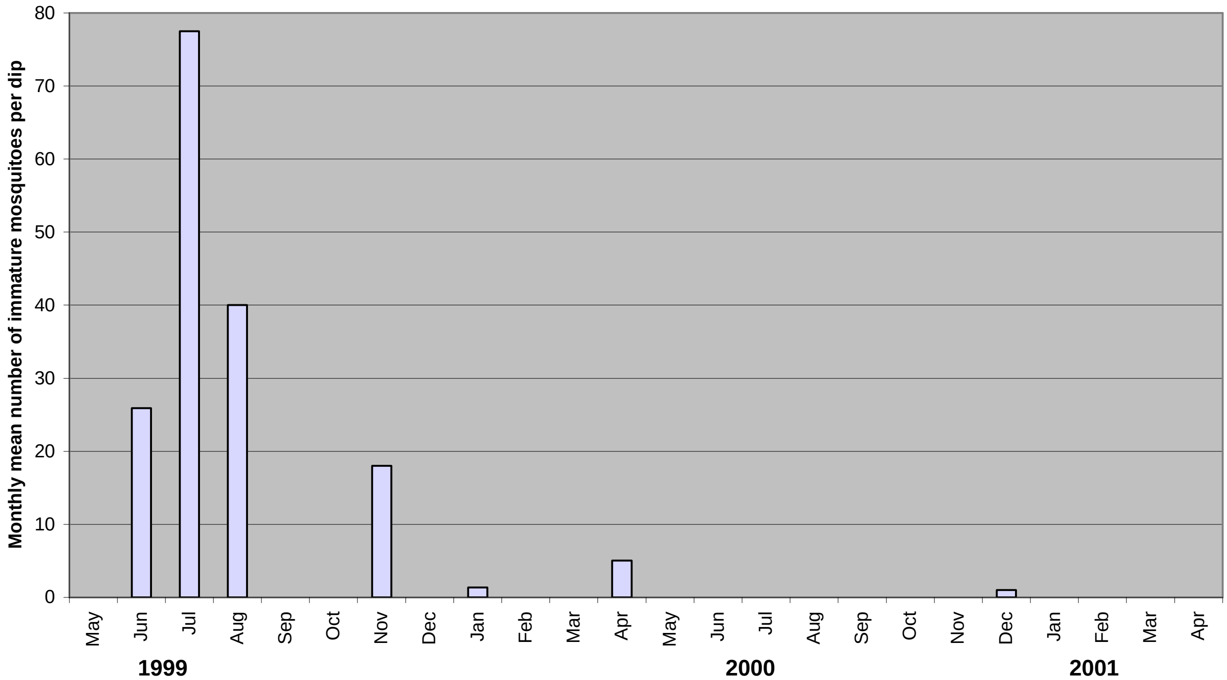


Source: California Department of Health Services

Drain Inlet Inserts (DII)

Stormwater that passes through DII units flows directly into the storm drain system. Although storm drains can and do produce mosquito larvae in pools of underground standing water, the DII units in this study did not appear to create habitat suitable for mosquito larvae. The only mosquito habitat noted was in the plastic flumes used to house the effluent measuring devices. These effluent flumes retained about 0.25 m^2 of standing water, approximately up to 6 cm deep until it evaporated weeks or months following a storm event. *Cx. tarsalis*, *Cx. stigmatosoma*, and *Cx. quinquefasciatus* were collected from the effluent flume of the Fossil Filter® DII at the Rosemead Maintenance Station in Caltrans District 7. Of 99 visits by SGVMVCD to this site between May 7, 1999 and April 26, 2001, mosquito larvae were detected on eight (8%) occasions (Figures 16 and 18). Even though the underground effluent flumes would not be incorporated into future DII units, these data demonstrate the persistence and ability of mosquitoes to utilize even the most remote sources of water. Vectors were not been detected by LACWVCD in association with DIIs installed at the Las Flores Maintenance Station or by SGVMVCD at the Foothill Maintenance Station sites n Caltrans District 7 (Figure 18).

Figure 16. Monthly collection of immature mosquitoes from Rosemead Maintenance Station Drain Inlet Insert (Fossil Filter) in Caltrans District 7 (WQ Site No. 73218)[1]. May 1999 to April 2001.

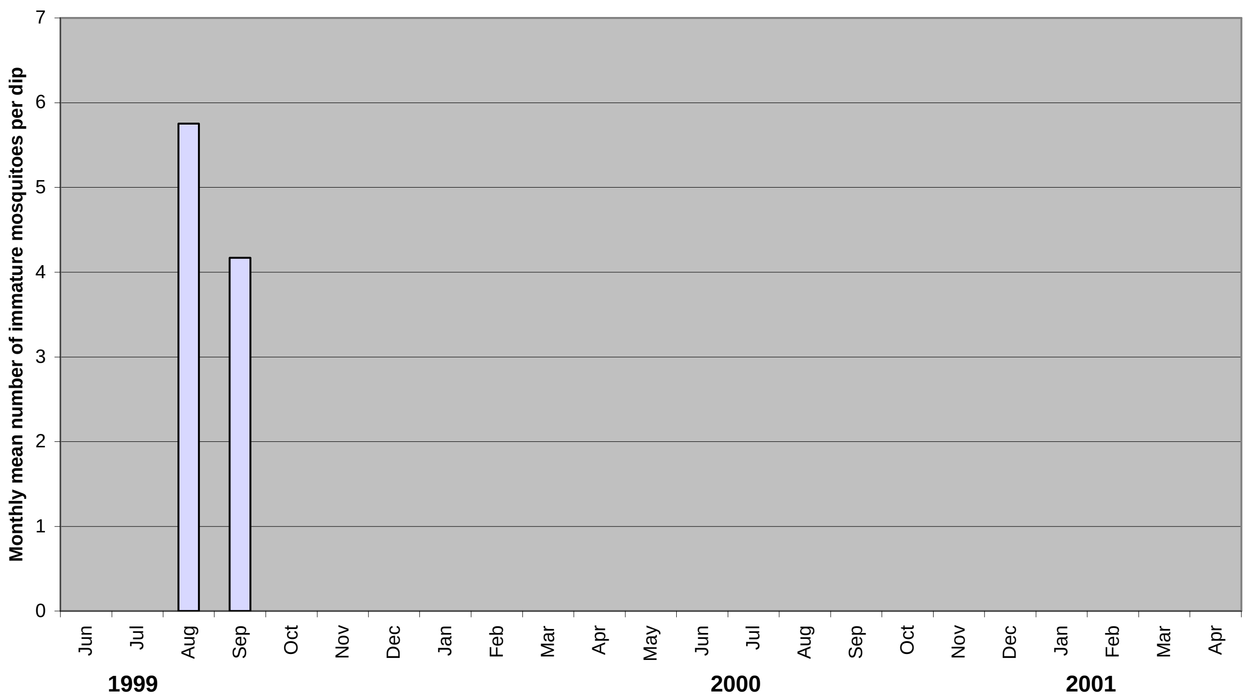


[1]Immature mosquitoes at this site were only collected from water standing in the plastic effluent flume of the Fossil Filter® DII. Immature mosquitoes were not detected in association with the Stream Guard® DII at this site.
Source: California Department of Health Services

Oil/ Water Separator

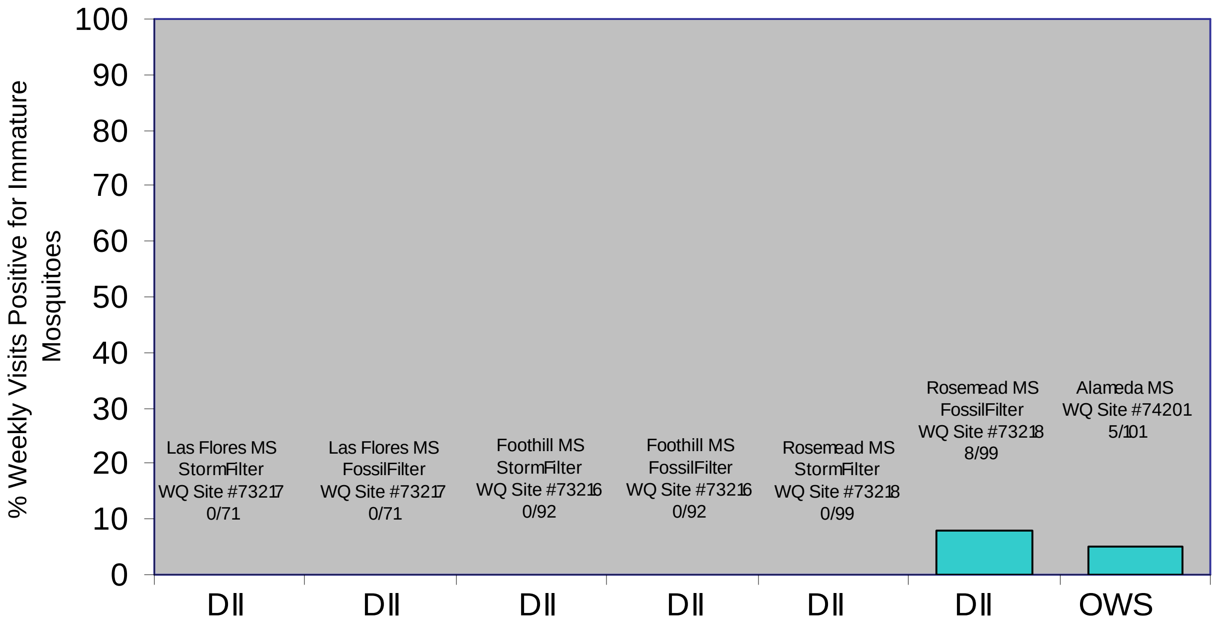
The oil/water separator in Caltrans District 7 may not provide suitable habitat for mosquito larvae. The sealed construction and the oils that the unit was designed to trap should preclude mosquitoes. However, the channel leading into and out of the unit could provide habitat for mosquito larvae if standing water were to accumulate. The only mosquito habitat detected by VBDS and GLACVCD at this site was created by the plastic flume used to house the effluent measuring devices (similar to the DII units discussed previously), located below a wooden cover. Both *Cx. tarsalis* and *Cx. quinquefasciatus* were collected from standing water in this plastic flume. Of 101 visits by GLACVCD to this site between June 1, 1999 and April 24, 2001, mosquito larvae were detected on five (5%) occasions during August and September of 1999 (Figures 17-18). As mentioned for the DII units, plastic effluent flumes would not be incorporated into future oil/water separator installations, but these data again demonstrate the persistence of mosquitoes.

Figure 17. Monthly collection of immature mosquitoes from Alameda Maintenance Station Oil-Water Separator in Caltrans District 7 (WQ Site No. 74201)[1]. May 1999 to April 2001.



[1]Immature mosquitoes at this site were only collected from water standing in the plastic effluent flume used to take water samples.
Source: California Department of Health Services

Figure 18. Weekly vector monitoring of individual Drain Inlet Inserts and the Oil/Water Separator, May 1999 to April 2001.



Source: California Department of Health Services

Infiltration Basins and Trenches

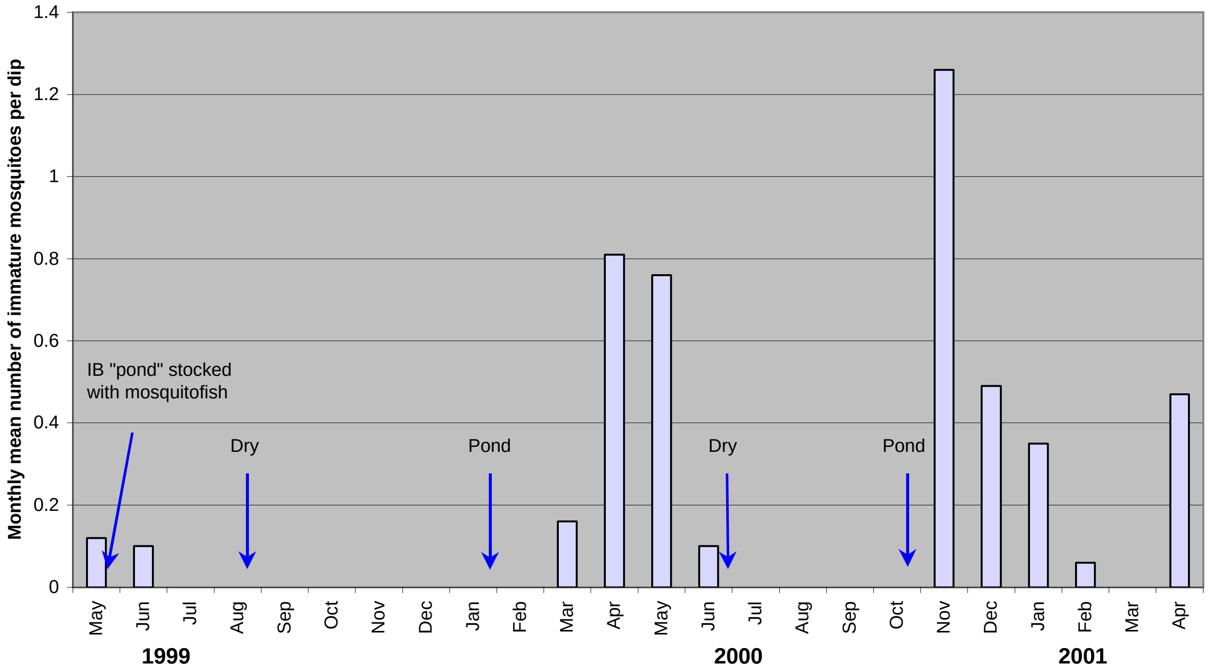
Infiltration basins and trenches were designed to allow water to percolate back into the soil. Both infiltration trench pilots in this study were covered by a thick layer of gravel or aggregate matrix. Due to the depth of this matrix layer in combination with rapid percolation rates, standing water was rarely noted above ground. At the Altadena Maintenance Station in Caltrans District 7, GLACVCD placed adult mosquito emergence traps randomly above the aggregate matrix to determine if vectors were able to move down between the rocks and reproduce in pockets of standing water that might be hidden from view. No vectors were detected at either site (98 visits to Carlsbad MS by SDCVSC between May 5, 1999 and April 30, 2001; 103 visits to Altadena MS by GLACVCD between June 1, 1999 and April 24, 2001; Figure 20).

Infiltration basins have the potential to create mosquito habitat if water entering these structures remains above ground before it percolates into the soil. Water that entered the infiltration basin located at the I-605 and SR 91 interchange in Caltrans District 7 percolated rapidly during this study. Of 101 site visits by GLACVCD between June 2, 1999 and April 24, 2001, vectors were not detected in the infiltration basin; however, *Cx. quinquefasciatus* larvae were detected in a nearby influent pipe catch basin that held standing water between June 29th and August 24th, 1999. This catch basin was subsequently filled in with concrete on September 29, 1999 and no mosquito larvae were detected in or around this infiltration basin site since (Figure 20).

The infiltration basin located at La Costa Avenue in Caltrans District 11 was built close to a brackish water lagoon near the coast. The water table at this site fluctuated, but generally remained very high. Because of this, percolation rates were extremely slow, resulting in a semi-permanent pool of water. Mosquitofish were stocked into this pool of water by SDCVSC on May 19, 1999 to control mosquito larvae; however the fish perished when the pool dried out in mid-August, 1999. For the purpose of this study, Caltrans decided against re-stocking this pool with mosquitofish in the future. In the absence of mosquitofish, other predators such as dragonfly larvae, water beetles, and backswimmers flourished at this site when water was present, and may have preyed on some mosquito larvae; however, mosquito larvae were detected at this site on a regular basis when water was present (Figures 19 and 20).

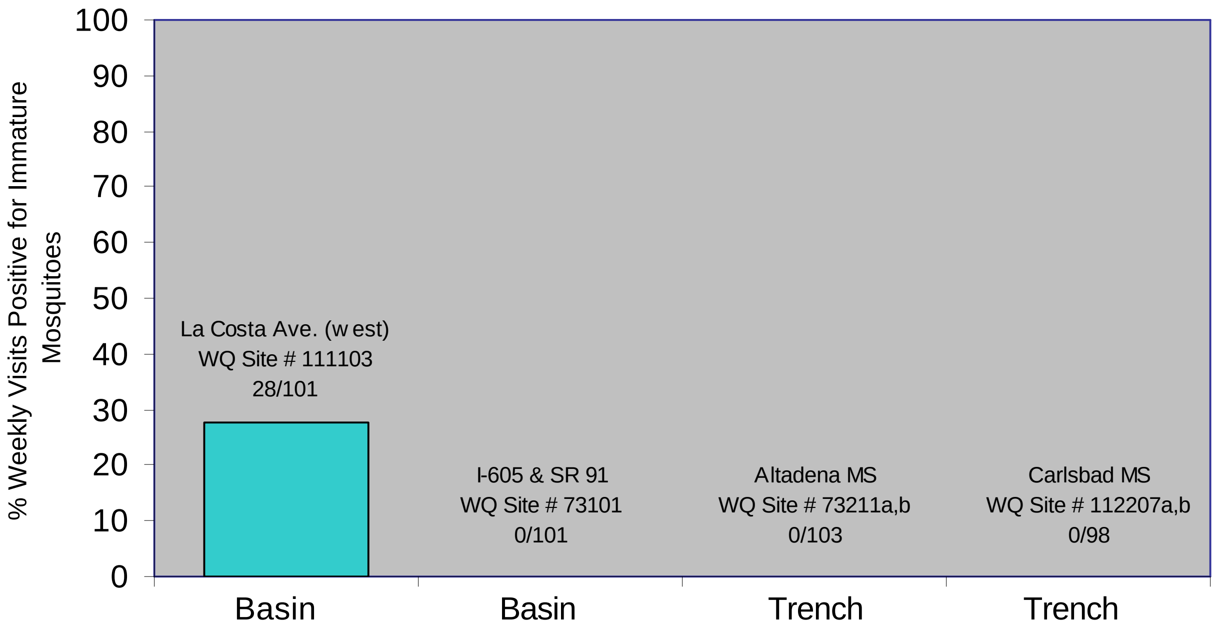
Six of the eight mosquito species identified during this study (Table 4) were collected from the pool of water at this site. Only *Oc. squamiger* and *Cs. incidens* remained undetected at this site. Of 101 visits by SDCVSC between May 5, 1999 and April 30, 2001, larvae were detected on 28 (28%) occasions (Figure 20). The number of larvae collected per dip sample was relatively small compared to other BMPs in this study (Figure 19); however, these findings were significant given the large surface area of the pond (approx. 316 m^2).

Figure 19. Monthly collection of immature mosquitoes from I-5 & La Costa Ave. (west) Infiltration Basin in Caltrans District 11 (WQ Site number 111103). May 1999 to April 2001.



ource: California Department of Health Services

Figure 20. Weekly vector monitoring of individual Infiltration Basins and Trenches May 1999 to April 2001



Source: California Department of Health Services

Biofiltration Swales and Strips

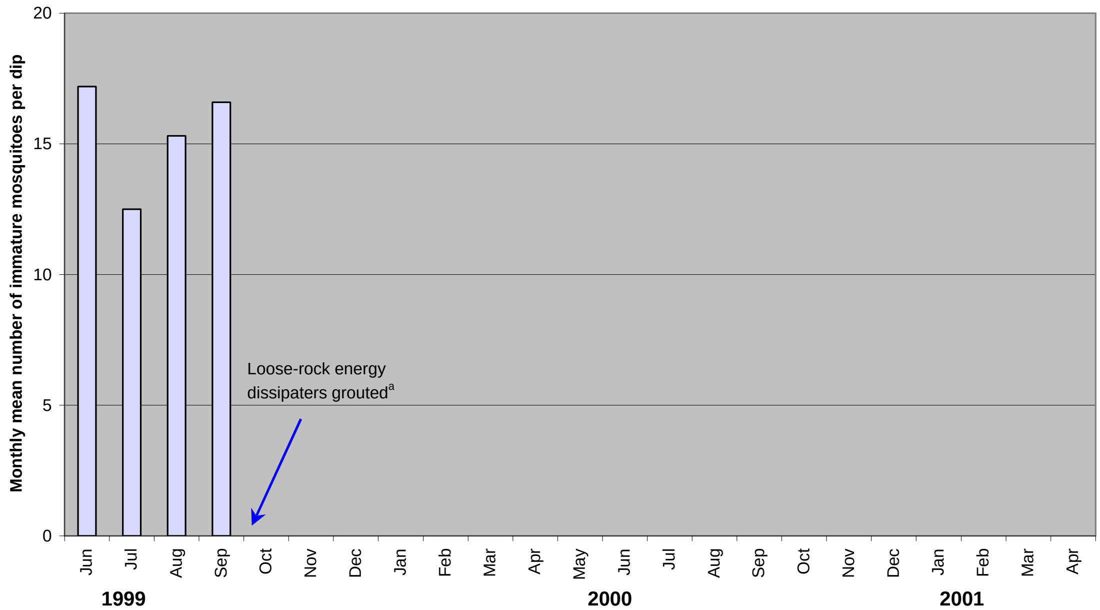
Caltrans implemented 6 biofiltration swales and 3 biofiltration strips into their BMP Retrofit Pilot Study. These units functioned by filtering incoming water through dense vegetation (i.e., saltgrass). Biofiltration strips at the Altadena and Carlsbad Maintenance Stations served as "pre-filters" to infiltration trenches. The remaining 7 swales and strips were designed to work alone.

During the first few months of operation, the four biofiltration swales in Caltrans District 7 incorporated energy dissipaters containing small rock rip rap. Concrete depressions built to contain the rip rap retained water following storm events (or from irrigation) and became sources of mosquito larvae. In late September and early October of 1999, these energy dissipaters were modified by removing the rip rap, filling the depressions with concrete, and imbedding rocks into it. This allowed them to continue their intended function, but prevented the accumulation of standing water.

Prior to October 1999, GLACVCD regularly detected mosquitoes associated with rip rap depressions at the four Caltrans District 7 sites (I-605 / SR 91 interchange, Cerritos Maintenance Station, I-5 / I-605 interchange, and I-605 Del Amo Ave.) (Figures 21, 22 and 24). Species identified from these sites included *Cx. quinquefasciatus*, *Cx. tarsalis*, *Cx. stigmatosoma*, and *Cs. incidens*. No mosquito larvae were detected at these sites after October 1999. In Caltrans District 11, SDCVSC did not detect any vectors associated with the two biofiltration swales (Figure 24).

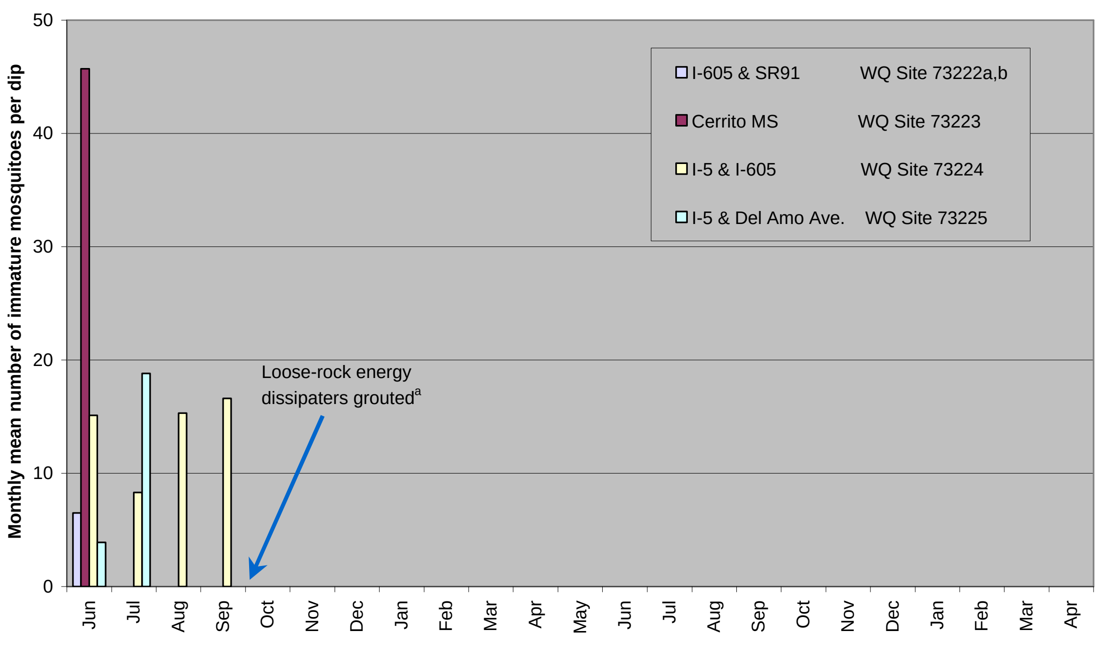
The biofiltration strips were not directly associated with vector production during this study; however, the spreader trough that fed the biofiltration strip at the Altadena Maintenance Station retained approximately 15 cm deep water along its entire length following a storm event. This water could be drained from the spreader trough manually by unscrewing an end-cap. Several species of mosquito larvae were detected in the spreader trough including *Cx. quinquefasciatus*, *Cx. tarsalis*, and *Cx. stigmatosoma*. Of 103 visits by GLACVCD between June 1, 1999 and April 24, 2001, larvae were detected on 10 (9.7%) occasions (Figure 24). Because vectors were utilizing this source of water for breeding, Caltrans began draining the spreader trough shortly after every storm event, beginning in January 2000. Larvae were detected only once following this change in maintenance procedure when the water remained stagnant for several days.

Figure 21. Monthly collection of immature mosquitoes from Biofiltration Swales in Caltrans District 7, May 1999 to April 2001.



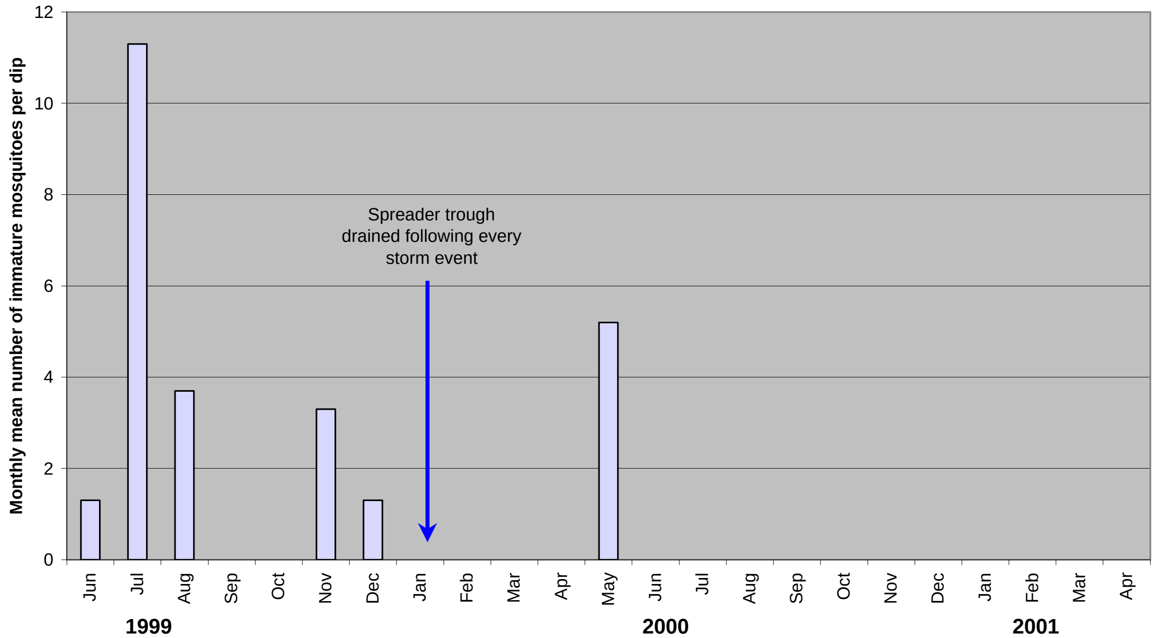
Source: California Department of Health Services

Figure 22. Monthly collection of immature mosquitoes from individual Biofiltration Swales in Caltrans District 7*. May 1999 to April 2001.



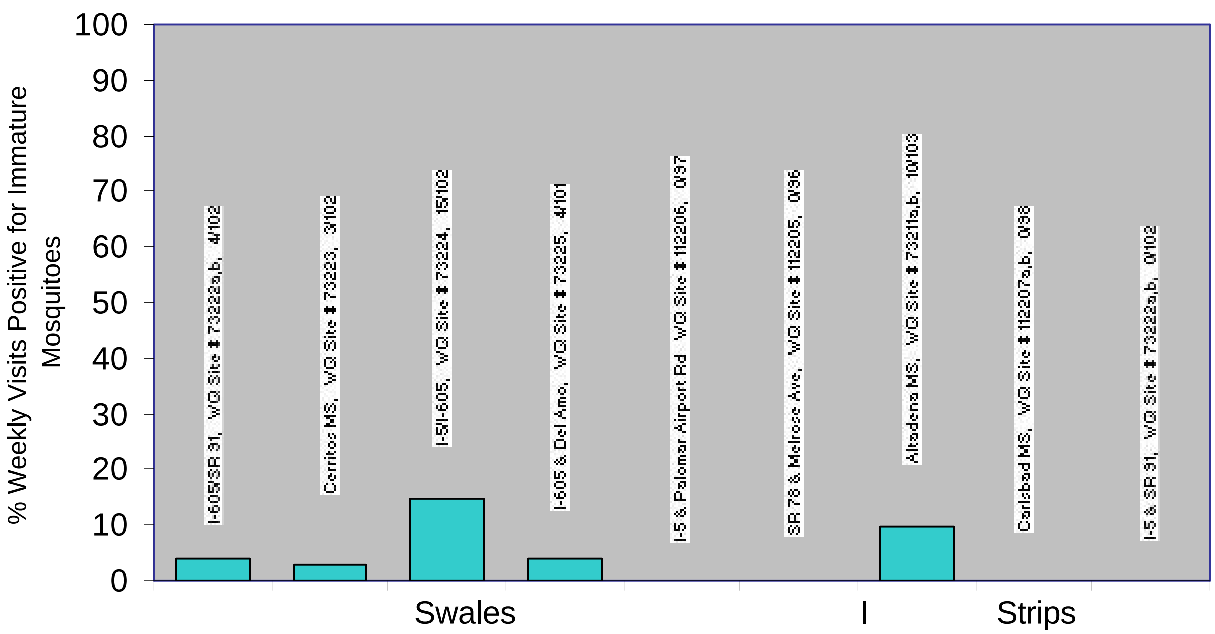
*Immature mosquitoes were not detected in Biofiltration Swales constructed at I-5 & Palomar Airport Rd. (WQ Site No. 112206) or SR 78 and Melrose Ave. (WQ Site No. 112205) in Caltrans District 11.
Source: California Department of Health Services

Figure 23. Monthly collection of immature mosquitoes from Altadena Maintenance Station Biofiltration Strip in Caltrans District 7 (WQ Site No. 73211a,b). May 1999 to April 2001.



Note: Immature mosquitoes were not detected in association with Biofiltration Strips constructed at Carlsbad MS or at the I-605 /SR91 interchange in Caltrans Districts 11 and 7, respectively.
Source: California Department of Health Services

Figure 24. Weekly vector monitoring of individual Biological Filtration Swales and Strips May 1999 to April 2001.



Source: California Department of Health Services

Conclusions

Vector production at the Caltrans BMP structures was influenced not only by design, but also by factors such as location, immediate and large-scale surroundings, non-stormwater discharges (e.g., irrigation), site maintenance, and various other unexpected events. Because of this, direct comparisons among structures of similar design were difficult, if not impossible. BMP design features identified during this study that contributed to vector production should be avoided in future construction plans. Some examples include the use of any sump, catch basin, or spreader trough that does not drain down completely, loose rip rap, pumps or motors that "automatically" drain water, and effluent pipes with small diameter discharge orifices that may be prone to clogging. If absolutely necessary, sumps should be covered by a suitable mosquito-tight cover that is inspected and maintained or replaced on a regular basis. Permanent ponds will often be a source of some vectors regardless of design. To minimize vector production, ponds should be stocked with mosquitofish and constructed with steep banks to reduce potential breeding habitats. Although shallow pond grades and emergent vegetation increase water quality benefits, steep banks would reduce potential vector sources and vegetation density, benefiting long-term water quality and vector control. In general, a 72 hour draw-down period of structural BMPs has become the "unofficial" accepted standard used by many agencies nationwide to reduce or prevent vector production. Adequate safe vehicular access should be provided to all structural BMPs to facilitate routine vector monitoring and abatement when necessary.

Many of the vector-proofing efforts have greatly suppressed or prevented vector breeding. For example, the aluminum covers on the MCTT settling basins appear to have provided mosquito exclusion from the time they were installed through April 2002. However, other modifications such as those made to the CDS™ devices will require further evaluation since vector breeding still occurred.

The wet basin poses one of the greatest challenges to both maintenance crews and vector control because of the incredible speed at which the cattail plants grow and invade the site. Although the mosquito fish population in the pond remained very dense and stable between during this 3-year study, the cattails threaten to exclude these predators from shoreline habitats when they become dense. To further complicate matters, mosquito surveillance is extremely difficult along these shorelines and likely does not represent the true breeding potential of these types of habitats. Our observations suggest that the Caltrans Vegetation Management Plan may need to be re-appraised. This pilot study site clearly illustrates why vector control agencies recommend steep shorelines and deep ponds to suppress vector breeding. A pond designed in such a way would probably require much less maintenance while allowing it to perform at an optimal level for volume reduction and water quality purposes.

This report provides an initial assessment of the potential public health risks involved with the construction of some structural BMPs in southern California, thanks to the collaborative effort between Caltrans, VBDS, GLACVCD, SGVMVCD, LACWVCD, and SDCVSC. Few studies have addressed vector issues in artificial habitats created by structural BMPs built specifically for reducing non-point source pollution in stormwater runoff. Results from this two-year study indicate that much research remains to be conducted in order to better satisfy water quality and volume reduction goals while preventing vector production. The fact that two previously undetected species of mosquito were found in structures in Caltrans District 11 in 2001 suggests that structures may support species not detected during this study as they age and "mature". The addendum study conducted between May 2001 and April 2002 provides additional evidence that continued collaboration between Caltrans, public health, and vector control is needed to improve mosquito and vector management in stormwater management structures such as treatment BMPs. It is critical that the public health impact of BMP design and construction be considered.