An Initial Assessment of Vector Production in Structural Best Management Practices in Southern California

*Addendum

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. 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 original two-year contractual 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 agreed to extend the VBDS contract through June 2003 based on their need for further monitoring and evaluation of water quality and vectors.

VBDS, in collaboration with 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, mosquito breeding habitats were 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 report is an addendum to the 1999-2001 mosquito production study report, which provides 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.

Introduction

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 to provide the most cost-effective solutions for mitigating the harmful effects of stormwater runoff. In 1997, Caltrans initiated a Stormwater Best Management Practice (BMP) Retrofit Pilot Study. This extensive program included the retrofit of 33 selected facilities with 39 structural treatment BMPs for improving water quality in Los Angeles County (Caltrans District 7) and San Diego County (Caltrans District 11). 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 this special study.

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 original two-year contractual agreement (1999 - 2001) 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
- conduct focused studies to identify which designs were least conducive to vector production

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. In

[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.

addition, VBDS has also reviewed and commented on a number of BMP project plans outside the study.

Since completing the mosquito production study report, those BMPs that had been most problematic in the mosquito production study were monitored further. Three local mosquito and vector control agencies, Greater Los Angeles County Vector Control District (GLACVCD), San Gabriel Valley Mosquito and Vector Control District (SGVMVCD), and San Diego County Vector Surveillance and Control (SDCVSC) continued to monitor these sites weekly. A total of 12 devices were scheduled for further monitoring; 6 in San Diego and 6 in Los Angeles County (Table 1). This purpose of continued monitoring was to evaluate:

- previously problematic designs for further mosquito breeding
- the efficacy and field-longevity of mosquito-proofing modifications made to MCTT and CDS devices
- the vegetation management plan at the San Diego wet basin.

This report summarizes findings between May 1, 2001 and April 30, 2002.

Table 1. Caltrans BMPs monitored for vectors between May 1, 2001 and April 30, 2002.

BMP Technology-Type	Site Name	Water Quality Site Number
Wet Basin	I-5/La Costa Ave. (east)	111104*
Extended Detention Basin (EDB)	I-5/SR 56	111101*
Media Filters	Eastern Regional Maintenance Station[c]	74202
	Termination Park and Ride[a]	74204
	SR 78/I-5 Park and Ride[a]	112204*
	La Costa Park and Ride[a]	112203*
	Escondido Maintenance Station[b]	112202*
	Kearny Mesa Maintenance Station[c]	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

*San Diego Couny
[a]Austin-Type Media Filter; [b]Delaware-Type Media Filter; [c]StormFilter™

Vectors

The period between May 1, 2001 and April 30, 2002 was an extremely dry year with rain events alarmingly below average. However, despite the notable lack of rain, several BMPs held permanent standing water for most of the year. Mosquitoes were collected from 7 of the 12 BMP devices, including one CDS device previously modified in November 2000 in an attempt to exclude mosquitoes.

Six different species of larval mosquitoes, in three different genera, were collected during the course of this one-year addendum study and identified by the three collaborating vector control districts (Table 2). Four of these mosquito species are known vectors of diseases that can be transmitted to humans. An overall summary of immature mosquitoes detected from different BMP technology types is presented in Figure 1 and site-specific information is provided in Table 3.

Table 2. Species of mosquito larvae collected from BMPs between May 1, 2001 and April 30, 2002.

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

Figure 1. Weekly Vector Monitoring of BMPs between May 1, 2001 and April 30, 2002.

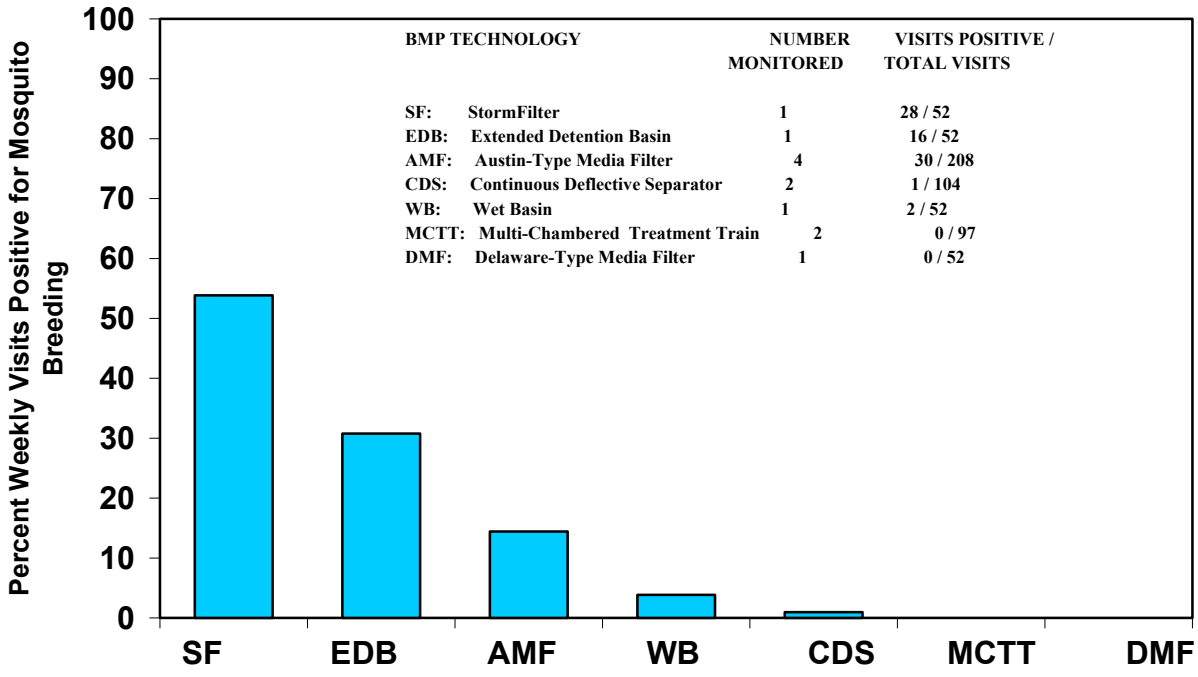

Table 3. Weekly monitoring of BMPs for immature mosquitoes between May 1, 2001 and April 30, 2002.

			Weekly Mosquito Monitoring		
BMP Type	**Site Name**	**WQ Site #**	**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™

Multi-Chambered Treatment Trains (MCTT)

Multi-Chambered Treatment Train (MCTT) devices were previously found to support the greatest number of mosquitoes over the longest period of time (year-round in southern California) compared to other designs in the Caltrans BMP Retrofit Pilot Study. Current MCTT design creates three sources of permanent standing water; the large-debris catchment basin, the settling basin, and the media filtration basin pump sump.

In response to the severe mosquito breeding noted during 1999 and 2000 at the MCTT sites, and recommendations made by VBDS, GLACVCD, and SGVMVCD, Caltrans authorized the installation of a tight-fitting aluminum lid over the settling basin. These were installed in late February and early March, 2001 at the Via Verde and Lakewood Park & Ride sites, respectively. VBDS, GLACVCD, and SGVMVCD cautioned Caltrans that this modification would require continued monitoring to determine its long-term efficacy and longevity under field conditions. In addition, mosquitoes could still access permanent standing water present in the large-debris catchment 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 large-debris catchment basins at either MCTT device during this time. 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.

Continuous Deflective Separators (CDS)

The CDS devices were previously found to be the source of thousands of mosquitoes, which bred in the permanent water sump and in the influent / effluent weir box. Female mosquitoes could access standing water from several entry points, including gaps under loose-fitting lids, hoist-chain support holes in the side of the sump, and through influent and effluent pipes.

In response to the intense mosquito breeding noted in 2000 at the CDS sites, and recommendations made by VBDS and GLACVCD, Caltrans authorized extensive mosquito-proofing modifications. In early August 2000, the weir box depressions were grouted-in to eliminate one source of standing water. Additional modifications were made in November 2000 in an attempt to prevent access to the sump including: 1) the addition of foam seals to the sump and weir box covers, 2) sealed holes in the side of the sump with caulk, and 3) the fitment of a collapsible "mosquito proof" bag around the effluent pipe. The number of mosquito larvae steadily decreased following the November 2000 modifications and no larvae were detected in either CDS sump after December 20, 2000. Different mosquito-proof bag designs were tested at the effluent pipe during early 2001. The current design, implemented in March 2001, utilizes a heavy steel chain sewn into the bag. VBDS and GLACVCD cautioned Caltrans that these modifications would require continued monitoring to determine their long-term efficacy and longevity 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, GLACVCD detected second-instar *Culex quinquefasciatus* mosquito larvae in 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.

Wet Basin

The wet basin has undergone dramatic changes typical of permanent pools of water in southern California, and continues to do so. Mosquitofish were introduced into the pond by SDCVSC soon after it was completed in June 1999 to serve as biological control agents of immature mosquitoes. Cattails grew rapidly and effectively out-competed all other emergent vegetation by spring of 2000. By May 2000, the cattails averaged over 2 meters in height and extended 2 meters or more in width from the shoreline.

June is typically when cattails begin to die and fall over, which eventually results in a dense thatch on the water surface and creates excellent mosquito habitat. 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 had 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 hand-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. In 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.

SDCVSC monitored this site 52 times between May 1, 2001 and April 30, 2002. Surprisingly, mosquito larvae were only detected on May 14, 2001 and on April 8, 2002 (4%) during this time period. Three species, *Culex stigmatosoma, Cx. tarsalis*, and *Anopheles hermsi* were collected and identified. However, these findings may not accurately represent the true vector breeding potential of this site given the large

surface area of this site (approx. 1,371 m^2) and the difficulty in obtaining dip samples along the densely-vegetated shoreline.

Extended Detention Basin (EDB)

The "Sorrento Valley" EDB site has two areas of large rock rip rap within the basin that created depressions in the basin floor. Water remained standing in these depressions for weeks and months, creating protected microhabitats for mosquitoes among the rocks and making effective vector monitoring and abatement difficult or impossible. Between May 1, 2001 and April 30, 2002, this situation worsened, possibly due to decreased infiltration or by undetected sources of urban runoff (i.e., the hillside irrigation system noted during the 1999-2001 study). 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. However, these findings may not accurately represent the true vector breeding potential of this site 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.

Media Filters

Caltrans implemented three types of media filters for this study; Austin, Delaware, and a proprietary device called StormFilter™. Differences in design and construction required that each type be evaluated separately with regards to vector production.

Austin-Type in Caltrans District 7. Early in the 1999-2001 mosquito production study, GLACVCD detected mosquitoes breeding in the effluent pump sumps at both Eastern Regional MS and Termination P&R sites. These pump sumps were tightly covered with mosquito-proof screen shortly thereafter. However, soon after, the settling

basins at both sites were found to also provide significant mosquito breeding habitats as result of construction, clogging, and pump failure.

Between late September and early November 2000, 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.

GLACVCD monitored each of these sites 52 times between May 1, 2001 and April 30, 2002. 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. 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.

Austin-Type in Caltrans District 11. The two units 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 previously found to be consistent

sources of mosquito larvae. Water remained in these depressions for most of the monitoring period between May 1, 2001 and April 30, 2002.

The settling basins at both sites also 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.

SDCVSC monitored these sites 52 times between May 1, 2001 and April 30, 2002. 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, the former which held standing water following storm events. 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. During the 1999-2001 mosquito production study, mosquito larvae were detected in the settling basin water on several occasions, despite its relatively cryptic location below ground. Small gaps between the individual door covers allowed adult females to access the water in the settling chamber.

SDCVSC visited this site 52 times between May 1, 2001 and April 30, 2002. Surprisingly, no mosquitoes were detected breeding in the standing water during this time period.

StormFilter™. This 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 StormFilter™ 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.

Between May 1, 2001 and April 30, 2002, SDCVSC visited this site 52 times and mosquito larvae were detected on 28 (54%) of these visits; the most of any BMP in this one-year addendum 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.

Conclusions

Many of the vector-proofing efforts have prevented breeding. For example, the aluminum covers on the MCTT settling basins appear to have provided mosquito exclusion during this monitoring period. 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 has remained very dense and stable, 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 addendum to the mosquito production study 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.