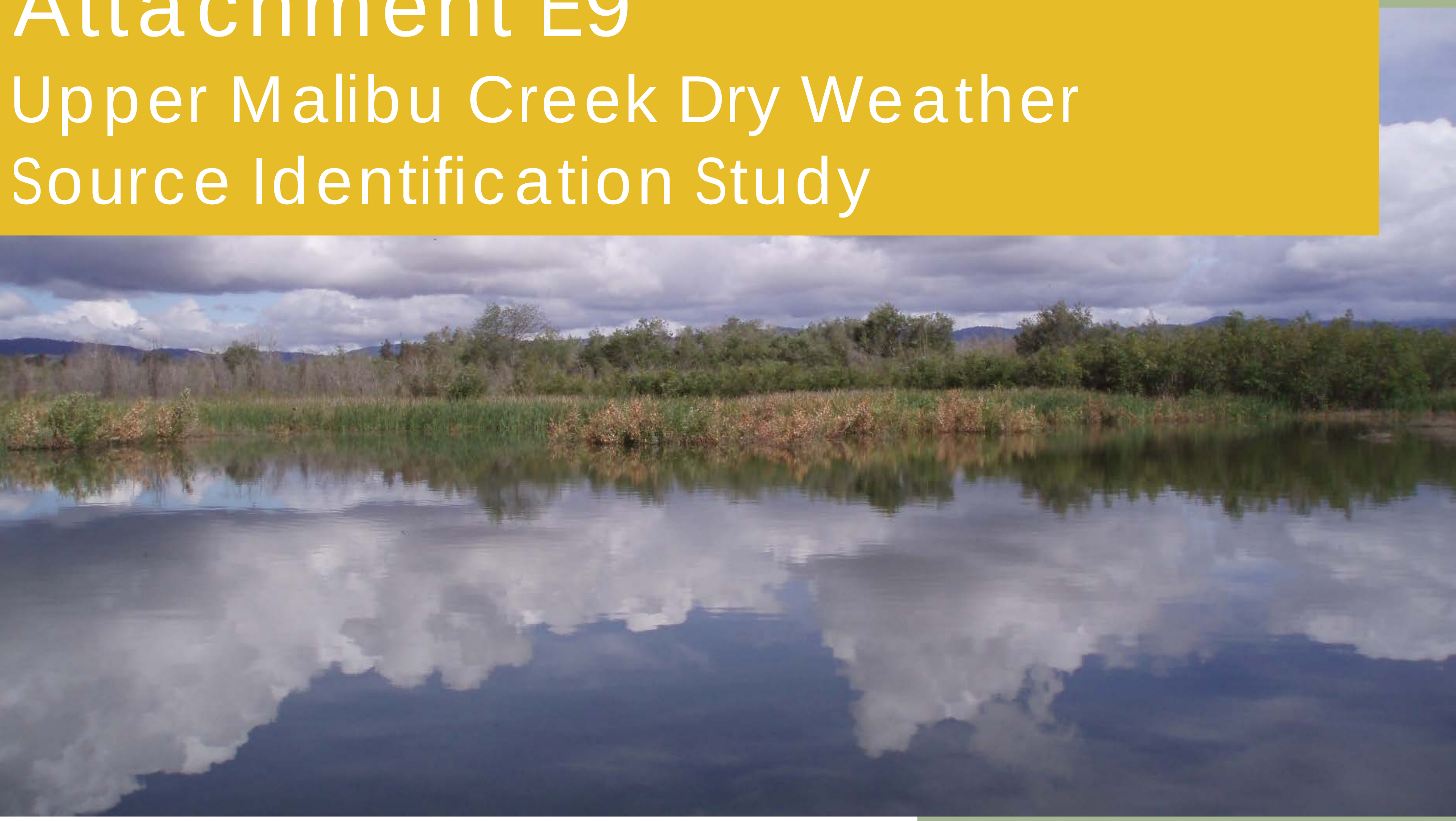
Ventura Countywide Stormwater Quality Management Program

2014-2015 Permit Year

Ventura Countywide Stormwater Quality Management Program Annual Report

Attachment E9

Upper Malibu Creek Dry Weather Source Identification Study



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County of Ventura
Fillmore
Moorpark
Ojai
Oxnard
Port Hueneme
Santa Paula
Simi Valley
Thousand Oaks
Ventura
Ventura County Watershed Protection District

December 14, 2015

Prepared for:

County of Ventura **City of Thousand Oaks**

UPPER MALIBU CREEK WATERSHED
DRY WEATHER SOURCE IDENTIFICATION STUDY

MEMORANDUM REPORT

November, 2014

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Executive Summary

A dry weather source identification study was performed in the urbanized Upper Medea and Lindero drainage areas of the Upper Malibu Creek Watershed, including jurisdictions of the County of Ventura and the City of Thousand Oaks. The study goals included identifying sub-drainages contributing the highest loads of *E. coli*, anthropogenic inputs of fecal pollution (e.g. human, dog, irrigation runoff, etc.), nutrients (total nitrogen and phosphorus), and estimating the relative contributions of natural vs. anthropogenic sources of fecal pollution. While these goals have largely been met, this study identified that in-stream, non-MS4 sources, are contributing significantly to *E. coli* and potentially nutrient concentrations in receiving waters. The relative importance of urban outfalls and these non-MS4 sources are crucial for optimizing strategies for TMDL compliance, but are still incompletely understood.

In Upper Medea Creek drainage area, approximately 80% of urban land use did not contribute flow, or contributed insignificant amounts of *E. coli* and nutrients to the bacteria TMDL compliance station. Only four urban outfalls, south of Oak Hills Dr., were discharging significant amounts of *E. coli* and nutrients, and could potentially affect the bacteria TMDL compliance station. Human and dog waste was detected in some of these outfalls, but additional, non-identified sources of *E. coli* were implied. There was strong evidence for birds as an in-stream source of *E. coli*, while bird fecal waste was clearly absent from the storm drains. The relative contributions of storm drains and birds to *E. coli* at the bacteria TMDL compliance station are uncertain at this point. The nutrient TMDL numeric target and load allocations for nitrogen were not exceeded in the receiving water, but those for total phosphorus were. However, the impact of urban outfalls on in-stream phosphorus concentrations in the receiving water is still unclear.

In the Upper Lindero Creek drainage area, most of the storm drains under County jurisdiction had relatively high *E. coli* and nutrient concentrations, but concentrations generally decreased closer to the common point of discharge into the creek. One storm drain had significant dog waste inputs, and was identified as a high priority *E. coli* source area, in addition to another area with mostly unknown *E. coli* sources. A significant portion of the flow in the former storm drain was likely from reclaimed water, which could be the source of high total phosphorus concentrations observed there.

In the Upper Lindero Creek drainage area, only a small area under City jurisdiction potentially contributed *E. coli* and nutrients to the bacteria TMDL compliance station. Areas in the upper reaches of the drainage area (draining to the creek north of Rockfield St.) did not contribute any surface flow. These high priority drains are situated along Rockfield St. and Lindero Cyn Rd., and drain about 20% of the urban land area in the City. Dog waste was shown to be the most significant source of *E. coli* in the Rockfield St. drain, but human markers were consistently detected there as well. Low frequencies of dog and human markers were detected in the Lindero Cyn Rd. drain, but additional sources of *E. coli* are suspected there.

Birds in the creek were also identified as a source of *E. coli* to Upper Lindero Creek. Birds near the bacteria TMDL compliance station likely have a significant influence on *E. coli* concentrations there, and may be causing exceedances as well.

Nitrogen and phosphorus loads measured at the downstream receiving water station exceeded nutrient TMDL load allocations assigned to the Upper Lindero Creek drainage area. However, the nitrogen numeric target was not exceeded. While County and City storm drains discharge relatively high nutrient concentrations into the creek, their impact on the receiving water is unclear, because the extent of natural attenuation and additional inputs by in-stream sources (birds, litter) has not been quantified.

Acknowledgements

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JoAnne Kelly (City of Thousand Oaks) and Ewelina Mutkowska (Ventura County Watershed Protection District) for reviewing reports and providing a management perspective.

1. Introduction

County of Ventura retained services of Ventura County Watershed Protection District to conduct a dry weather source identification study in the Upper Medea and Lindero drainage areas of the Upper Malibu Creek Watershed (MCW) in accordance with the Work Plan submitted to the Los Angeles Regional Water Quality Control Board (Ventura County Watershed Protection District, 2013). The study in the Upper Lindero drainage area was conducted jointly by the County of Ventura and the City of Thousand Oaks, in accordance with a Memorandum of Agreement between the City of Thousand Oaks and County of Ventura.

The goals of the study, as stated in the Work Plan, included:

- Identify sub-drainages that contribute the highest loads of *E. coli*.
- Identify sub-drainages with anthropogenic inputs of fecal pollution (e.g. human, dog, irrigation runoff, etc.).
- Identify sub-drainages that contribute the highest loads of human fecal contamination (if any).
- Estimate relative contributions of natural vs. anthropogenic sources of fecal pollution at key locations in each drainage area.
- Identify sub-drainages that contribute the highest loads of total nitrogen and phosphorous

This memorandum is intended to summarize the results and conclusions of the study, and provide potential action items for management. More detailed information on methods and quality control, field survey results and lab results are provided as Attachments A through D.

2. Upper Medea Creek Drainage Area

2.1. Field Surveys and Flow Mapping

Twenty-three storm drain outfalls and eight creek locations were identified using GIS and surveyed in the field for access, flow and potential sources of fecal pollution (Fig. 2.1). Average flows, where measureable, are reported in Table 2.1, and summarized in Fig. 2.2. Appendices B and C include maps and photos of all locations. High-flow events temporarily increased flow in the morning, and originated from a large outfall upstream of M31 and were observed downstream at M27b and M10. While the increased discharge at the outfall was a potential illicit discharge (Fig. 2.3), water quality sampling at M31 suggested the flow inputs did not contribute significant *E. coli*, nutrients or detergents (as MBAS) to the receiving water (see sections below).

Based on flow assessment on four occasions between May 30th and July 11th of 2013, it was determined that large portions of the drainage area did not contribute surface flow to the compliance station (MCW12), because there was no discharge from the storm drain, or because the discharge infiltrated before reaching the compliance station. These areas were therefore not targeted for sampling.

Four outfalls and three open creek locations were selected for sampling, in addition to the bacteria TMDL compliance station, based on their significant contributions of surface flow to the compliance station and their potential to locate sources of fecal pollution from distinct neighborhoods in the drainage area. Note that the duck pond north of Kanan Rd. was sampled near the spillway into the creek, to assess potential input by duck pond, even though no discharge was observed after July 8th, 2013.

Field work in the Upper Medea drainage area suggested that flow in urban outfalls originated mostly from irrigation overspray, curb drains, manual watering and rinsing. For example, a curb drain at 21 N. Sabre Ave. was found to be responsible for all flow at M2 on two occasions.

Table 2.1. Average baseflow and high-event flow rates (cfs) at outfalls and creek locations in Upper Medea drainage area.

Location	Average baseflow	Average flow – high flow events
MCW12	0.028	
M1	0.005	
M2	0.003	
M5	0.008	
M8	0.005	
M10	0.006	0.188
M27b	0.054	0.174
M28	0.002	
M30	0.023	
M31	0.032	0.125
M17	0.012	

2.2. *E. coli*

Concentrations of *E. coli* at MCW12 exceeded the single sample maximum (SSM) in 40% of samples (n = 5). Concentrations in urban outfalls consistently exceeded the SSM, and were especially high in outfalls M2, M5 and M8 (504 – 58,100 MPN/100 ml); in contrast, *E. coli* concentrations in remaining creek locations were all (but one) below the SSM (Fig. 2.4). Reclaimed water *E. coli* concentrations were very low on two occasions, although somewhat high (327 MPN/100 ml) on one occasion.

E. coli concentrations in the duck pond were close to 1000 MPN/100 ml. While there was no discharge from the pond into the creek during sampling, concentrations indicate a potential contribution by the duck pond when discharge occurs (e.g. during spring), although the potential net effect on concentrations at the compliance station is unknown, given the significant natural attenuation that could occur before the flow reaches the compliance station.

Sampling in the storm drain network upstream of M8 was performed once, at a storm drain outlet into the gutter contributing flow to M8 (Fig. 2.5). *E. coli* concentrations were very high (727,000 MPN/100 ml), suggesting a potential source in the drainage area to this outlet. However, more field work is required to determine the potential impact of this drainage area to M8.

2.3. Host-specific markers

Human markers were analyzed at a subset of locations with elevated *E. coli* concentrations, including MCW12 and storm drain outfalls M1, M2, M5 and M8; duck pond and reclaimed water samples were included as reference samples for potential sources. The same samples were analyzed for dog and bird markers, with the addition of M10 to include a reference locations with low *E. coli* concentrations upstream of the samples urban outfalls (Fig. 2.6)

Human markers were quantified in 50% (1 in 2) of outfall M2 and 33% (1 in 3) of outfall M5 samples. Concentrations were in the low range (< 1,000 copies/100 ml), just above the method limit of quantification (286 copies/100 ml). None of the other samples, including compliance station, duck pond and reclaimed water had detectable levels of human markers.

Dog markers were quantified in 50% (1 in 2) of outfall M2 and 50% (1 in 2) of duck pond (DP) samples. None of the other samples had detectable levels of dog markers.

Bird markers were detected, mostly at quantifiable levels, in all creek locations, including compliance station (100% detection), M10 (75% detection) and duck pond (50% detection). Concentrations were in the low range (2,800 – 9,900 copies/100 ml), within an order of magnitude of the method limit of quantification (1,800 copies/100 ml). None of the storm drain samples had detectable levels of bird markers.

Sources and impacts of human waste

The point of entry of human waste in the storm drains has not been identified, but a detailed investigation of sanitary sewer infrastructure in relation to storm drain infrastructure offers some guidance. Most of the sanitary sewers in the Upper Medea drainage area are PVC, with low risk of exfiltration (Fig. 2.7). At two locations older clay or concrete sanitary sewer mains cross above the storm drain. In one outfall downstream of these crossings (M8), human markers were never detected, therefore sewage contamination is likely not an issue. In the other case, at M5, human markers were detected. A detail of the infrastructure there (Fig. 2.8, left) shows the location of the sanitary sewer main – storm drain crossing. However, more work is needed to determine if sewer main leakage, leakage from compromised sewer laterals or other sources are causing detection of human markers at M0.

The potential source of human markers at M2 is unclear. The storm drain towards M2 is essentially a long outfall (~ 80 ft.), conveying surface runoff from the catch basin on Tamarind St. to the creek (Fig. 2.8, right). The sewer mains are at least 20 ft. from the storm drain pipe and sewer laterals are expected to be even further away. Televising the storm drain pipe to verify illicit connections and additional sampling of surface runoff and pipe discharge should be helpful for better assessing of the degree of contamination and formulating hypotheses regarding potential sources of human waste. Note that location M2 was visited four times, but only on two occasions enough flow was present for sampling. Therefore, the 50% detection frequency of human markers is approximate, and more sampling would be required for a more accurate estimate of occurrence frequency.

Sources and impacts of bird waste

The Upper Medea Creek is clearly impacted by bird waste, but urban outfalls are not the source. Occurrence of in-stream sources was confirmed by bird (mostly duck) sightings on multiple occasions near MCW12, and just downstream of M8 and M10. The absence of a correlation between bird markers and *E. coli* concentrations at the compliance station suggest that fresh bird feces are not the dominant source of *E. coli* there (Fig. 2.9).

2.4. Nutrients

Nutrient concentrations at all sampled locations are shown in Fig. 2.10. Locations include receiving water stations (MCW12, M10, M30, M31), outfalls (M1 – M8), duck pond (DP) and reclaimed water from Mae Boyar Park pump station (REC). The significance of the measured nutrient concentrations was assessed by comparing to TMDL numeric targets (as monthly averages) and load allocations (Tables 2.2 and 2.3) (U.S. Environmental Protection Agency, 2003). This comparison is for informational purposes only and is not suitable to determine compliance with the nutrient TMDL. The load targets for Upper Medea Creek were calculated from the total load allocation for the watershed (5 lbs N/day and 0.5 lbs TP/day) and percentage of load contribution by Upper Medea Creek used in the TMDL (4%; includes loads from effluent irrigation, imported water, developed areas, agriculture, open space). Note that the load targets include contributions from many non-MS4 sources that potentially impact MCW12.

Total nitrogen concentrations were lowest (0.2 – 0.7 mg/l) in the East fork of Upper Medea Creek (M10, M30, M31). Higher and quite variable concentrations were observed in urban outfalls (1 – 60 mg/l; average = 7.7 mg/l). Concentrations were intermediate at the most downstream receiving water station MCW12 (0.9 – 3.4 mg/l), suggesting inputs from storm drains affected in-stream total nitrogen concentrations. Concentrations in the duck pond and reclaimed water were in the range of those in the outfalls.

Inorganic nitrogen concentrations (nitrate + nitrite-N) were low in the East fork of Upper Medea Creek (all < 0.1 mg/l), and elevated in urban outfalls (0.2 – 4.8 mg/l). Impact of inorganic nitrogen from urban outfalls on the creek was low as concentrations at MCW12 were below the limit of detection (< 0.1 mg/l) in 4 out of 5 samples. Reclaimed water had consistently the highest concentrations of inorganic nitrogen (4.3 – 6.8 mg/l).

Total phosphorus concentrations exhibited the similar patterns as nitrogen concentrations, with high concentrations in reclaimed water (1.8 – 2.5 mg/l) and urban outfalls (0.3 – 1.1 mg/l), lowest concentrations in the East fork of Upper Medea Creek (< 0.02 – 0.3 mg/l). Total phosphorus concentrations at M10, where 10-20% of flow was suspected to be reclaimed water (see Section 2.5), were relatively low, likely because of dilution of reclaimed water and/or settling of particle-associated phosphorus. Still, it's unknown how much of the phosphorus at M10 is derived from reclaimed water. The impact of urban outfalls on in-stream phosphorus concentrations at MCW12 is also uncertain, as the average concentration increased between M10 (East fork location upstream of these outfalls) and MCW12, but the differences were not statistically significant (Wilcoxon-Mann-Whitney test, $p < 0.05$). More sampling is therefore needed to assess the impact of urban outfalls.

Nitrogen concentrations at all creek locations were below the nitrogen numeric target concentration, and the nitrogen load at MCW12 was below the nitrogen load allocation. The TP concentrations were higher than TP numeric target concentrations at all creek locations, and the TP load at MCW12 was slightly higher than TP load allocations.

Table 2.2. Observed concentrations and loads of nitrite + nitrate in Upper Medea Creek drainage area compared to TMDL numeric target and target load (na = not applicable)

Receiving water location	Numeric target (mg/l nitrite + nitrate N)	Observed average (mg/l nitrite + nitrate N)	Target load (lbs/d nitrite + nitrate N)	Observed average (lbs/d nitrite + nitrate N)
MCW12	1	0.15	0.2	0.023
M10		< 0.1	na	na
M30		< 0.1	na	na
M31		< 0.1	na	na

Table 2.3. Observed concentrations and loads of TP in Upper Medea Creek drainage area compared to TMDL numeric target and target load (na = not applicable)

Receiving water location	Numeric target (mg/l TP)	Observed average (mg/l TP)	Target load (lbs/d TP)	Observed average (lbs/d TP)
MCW12	0.1	0.19	0.025	0.029
M10		0.11	na	na
M30		0.25	na	na
M31		0.13	na	na

2.5. Potential chemical sewage indicators

Four chemicals with potential to indicate sewage pollution or other anthropogenic inputs were analyzed: caffeine, cotinine (nicotine metabolite), carbamazepine (anticonvulsant and mood-stabilizing drug) and sucralose (artificial sweetener). All are present in relatively high concentrations in raw sewage, but rates of degradation in the environment vary (very low for sucralose and carbamazepine). Due to the cost of the analysis, a subset of locations was analyzed for these constituents: compliance station (MCW12), urban outfalls M2, M5, and M8, creek location M10 and reclaimed water (Fig. 2.11).

Concentrations ranges of these chemicals in raw sewage and drinking water, and those measured in reclaimed water in Oak Park, are summarized in Table 2.4. Reported concentrations in literature in raw sewage and drinking water are highly variable, and it should also be noted that often times these chemicals are not detectable in drinking water. Concentrations of carbamazepine and sucralose in reclaimed water were much higher than those commonly observed in drinking water, and in the case of sucralose also compared to concentrations in raw sewage. Therefore, these chemicals are potentially useful tracers for reclaimed water in the Upper Medea Creek drainage area. However, it is recommended to verify concentrations in drinking water in the study area.

Table 2.4. Observed concentrations of potential chemical sewage indicators in raw sewage, drinking water and Oak Park reclaimed water (ng/l).

Chemical	Sewage	Drinking water	Reclaimed Oak Park
Caffeine	220 – 43,900[1]	NA	1.5 – 13
Cotinine	800 – 2,900[2]	NA	8.2 – 15
Carbamazepine	6 – 3,780 [1,3,4]	0.3 – 721 (average = 1 - 6)[5]	37 - 81
Sucralose	200 - 8,000[6,7]	48 – 2,400[8]	6,100 – 31,000

References: [1]Santos et al. (2009), [2]Buerge et al. (2008), [3]Celiz et al. (2009), [4]Alshouli (2012), [5]Daughton (2010), [6]Tran et al. (2014), [7]Lubick (2008), [8]Mawhinney et al. (2011)

Concentrations patterns of **caffeine** and **cotinine** were similar, with highest concentrations in urban outfalls M2 and M5, lowest in the east fork creek location (M10) and intermediate at the compliance station and outfall M8. Concentrations in reclaimed water were in the low (caffeine) to intermediate (cotinine) range of observed concentrations. Caffeine and cotinine correlations with *E. coli* or human markers were weak or insignificant, suggesting that these chemicals are not useful for identifying sources of fecal pollution.

Concentration patterns of **carbamazepine** and **sucralose** were also similar, but different from those of caffeine and cotinine. Concentrations were consistently highest in reclaimed water, intermediate in the Medea east fork creek location (M10), and lowest in urban outfall and compliance locations. The patterns suggest that carbamazepine and sucralose can be used as a tracer for reclaimed water, rather than sewage, and that flow at M10 consists of 10-20% reclaimed water. While the input of reclaimed water is plausible, given the proximity of the recycled water system, it should be further validated by confirming reclaimed water usage in the area and measuring carbamazepine and sucralose concentrations in drinking water at the point of distribution. It's very unlikely that the elevated carbamazepine and sucralose concentrations at M10 are due to sewage pollution given the consistent absence of human markers there and in reclaimed water.

2.6. IC/ID Indicators

The IC/ID indicators, fluoride, MBAS and ammonium/potassium ratio were analyzed for potential identification of sources of flow and fecal pollution, based on a flow chart in the Center for Watershed Protection's Illicit Discharge Detection and Elimination manual (Fig. 2.12) (Center for Watershed Protection, 2004). Criteria for sewage contamination were never exceeded. Detergents did not indicate potential wash water contamination, using the threshold of 0.25 mg/l MBAS (Fig. 2.13).

Fluoride concentrations in most creek locations were between 0.66 – 0.88 mg/l, but higher concentrations were observed in the urban outfalls (0.88 – 1.38 mg/l) (Fig. 2.13). It's unclear why the latter concentrations are higher than those measured in recycled water (~ 0.8 mg/l) and reported in tap water (0.6 – 1.0 mg/l) (Calleguas Municipal Water District, 2013), and therefore fluoride was deemed unsuitable to distinguish flow inputs from natural sources versus tap/reclaimed water.

2.7. Conclusions

A combination of flow surveys and *E. coli* concentration measurements showed that only a fraction (~ 20%) of the urban land use (commercial, residential, facilities) in Upper Medea Creek drainage area potentially contributed to elevated *E. coli* concentrations measured at the compliance station during the period of the study (yellow areas in Fig. 2.14). Note that flow and *E. coli* concentration patterns within these areas have not been investigated, but it should not be assumed that sources are uniformly distributed. In fact, field work indicated that irrigation/curb drains from a subset of parcels and cleaning activities often caused most of the flow to storm drains.

Within the area identified to contribute most of the *E. coli*, human genetic markers were detected in two urban outfalls (Tamarind St. and Conifer St.), and dog genetic markers in one outfall (Tamarind St.). *E. coli* concentrations were high in all of the four urban outfalls sampled, therefore, a substantial portion of the *E. coli* was from unidentified sources, potentially urban wildlife or regrowth in the environment. The latter sources pose a significantly lower risk to human health compared to human sources. Note that urban outfall sites were visited on four occasions, therefore a frequency of occurrence of host-specific markers less than approximately 25% cannot be ruled out at locations were none were detected.

In addition to urban outfalls, birds in the creek were also identified as a source of *E. coli* to Upper Medea Creek. The relative importance of urban outfalls and birds for causing exceedances of *E. coli* numeric limits at the compliance station is uncertain, but has important implications for MS4 compliance.

Nutrient loads measured in the receiving water are below the 2003 EPA Nutrients TMDL for nitrogen but not for phosphorus. Total phosphorus concentrations were highest in reclaimed water, but impacts of reclaimed water inputs on phosphorus concentrations in Upper Medea Creek remain unknown. Urban outfall discharges may impact total phosphorus concentrations in the receiving water, but more sampling is needed to confirm.

The goals of this study included identifying sub-drainages contributing the highest loads of *E. coli* and nutrients, identifying sub-drainages with anthropogenic inputs of fecal pollution (e.g. human, dog, irrigation runoff, etc.), and estimating the relative contributions of natural vs. anthropogenic sources of fecal pollution. These goals have largely been met, with the exception that the relative contributions of birds vs. storm drains are still unclear.

3. Upper Lindero Creek Drainage Area

3.1. Field Surveys and Flow Mapping

The Upper Lindero Creek drainage area falls under jurisdiction of the County of Ventura (east of Lindero Cyn Rd.) and the City of Thousand Oaks (west of Lindero Cyn Rd., including Lindero Cyn Rd). The County area is drained for the most part by one large storm drain network, with an outfall into the creek approximately 3500 ft. upstream of the bacteria TMDL compliance station (Fig. 3.1, brown lines). Two small areas with apartment complexes feed into the City's storm drain along Lindero Cyn Rd., and one other small neighborhood is served by a storm drain discharging into the creek approximately 1000 ft. downstream of the County's main outfall. The City area consists of multiple smaller neighborhoods with many storm drain outfalls into Upper Lindero Creek (Fig. 3.1, green lines). The City area also includes the North Ranch Country club consisting of residences along a golf course, with the west fork of the Upper Lindero Creek flowing through the golf course.

One outfall and eleven manhole locations were identified using GIS and surveyed in the field for access, flow and potential sources of fecal pollution within the County area (Fig. 3.1). Locations in the upper storm drain network had the lowest flows, and often runoff from lawn irrigation could be identified as a dominant source of observed flows. Location L3 was the most downstream point surveyed and the network's outfall to the creek.

Three manholes, seven outfalls and eleven creek locations were identified using GIS and surveyed in the field for access, flow and potential sources of fecal pollution within the City area (Fig. 3.1). Flow in the upper east fork (TL7) originated from urban outfalls, with some contribution from groundwater seepage, but no flow at the most upstream creek location draining open space. Flow in the upper west fork (TL9) originated from the North Ranch Country club and potentially from parts of the neighborhood off of Windy Mountain Ave. (surface flow connectivity between flowing storm drain and creek is unclear), with no flow in creeks draining open space. Flow in Upper Lindero creek disappeared before the spillway just west of Lindero Cyn Rd., and only minimal seepage contributed flow to the culvert under Linder Cyn. Rd. Manholes TL2 and TL3 were consistently flowing, and contributed most of the surface flow to the creek downstream of the culvert (TL1). In other words, portions of the drainage area in Thousand Oaks upstream of the spillway did not contribute surface flow to the bacteria TMDL compliance station (MCW14B).

Average flows, where measureable, are reported in Table 3.1, and summarized in Fig. 3.2. Appendix C includes a map and photos of all assessed locations. The average flow contribution was higher for the County (0.2 cfs at L3) compared to the City (0.04 cfs at TL1).

Five storm drain locations were selected for sampling within County area, and three creek and two storm drain locations within City area, in addition to the bacteria TMDL compliance station MCW14B (Fig. 3.1). Selection was based on their locations' contributions of surface flow to the compliance station and their potential to locate sources of fecal pollution from distinct neighborhoods in the drainage area. Locations TL07 and TL09 did not contribute surface flow to the compliance station, but were sampled anyways at the request of the City for a general characterization of fecal pollution and nutrients from these drainage areas.

Table 3.1. Average baseflow (cfs) at outfalls and creek locations in Upper Lindero drainage area.

Location	Average baseflow
MCW14B	0.634
L3	0.199
TL1	0.044
TL6	0.074
TL6D	0.003
TL7	0.032
TL7D	0.002
TL9	0.020
TL10	0.012
TL8	0.083
TL8D2	0.002
TL14	0.012
TL14D	0.004

3.2. *E. coli*

Concentrations of *E. coli* at MCW14 exceeded the single sample maximum (SSM) in 40% of samples (n = 5). Concentrations in storm drains in the County consistently exceeded the SSM, and were especially high at locations L8 and L9 (767 – 866,400 MPN/100 ml) (Fig 3.3). Concentrations for the City were lowest at the most upstream creek locations (≤ 1017 MPN/100 ml), and higher and almost always exceeding the SSM at downstream creek (TL1) and storm drain (TL2 and TL3) locations (146 -15,530 MPN/100 ml) (Fig. 3.3). Concentrations at the most downstream locations for the County (L3) and City (TL1) were very similar.

3.3. Host-specific markers

Human-, dog-, and bird-specific markers were analyzed at all sampling locations (Fig. 3.4).

Human markers were not detected at the bacteria TMDL compliance station or in any of the County samples. For the City, human markers were detected in 100% of TL2 samples, at low concentrations (within order of magnitude of limit of quantification of 286 copies/100 ml). Also one out of the four TL3 samples was positive for human markers (detectable but not quantifiable).

Dog markers were not detected in any of the samples at the compliance station. However, many County samples showed consistent detection of dog markers. Based on consistent detections and a decreasing concentration pattern, results indicate that the source of dog markers was upstream of L8. Decreasing concentrations were consistent with decay and/or dilution upon transport to L6 and L3. Dog markers were also detected at L9 (detectable but not quantifiable), but not at L5. For the City, dog markers were detected at variable frequencies (25 – 80%) at TL1, TL2 and TL3, but not at the upstream creek locations TL7 and TL9.

Bird markers were detected in 83% of samples at the compliance station. However, bird markers were not detected in any of the County samples (all storm drains). For the City, bird markers were detected at all creek locations, with the highest detection frequencies at TL1 (100%), and lower frequencies at upstream creek locations TL7 and TL9 (50%). When quantifiable, concentrations were in the low range (2,000 – 4,600 copies/100 ml), close to the method limit of quantification (1,800 copies/100 ml).

Sources and impacts of human waste

The point of entry of human waste in the City storm drains has not been identified, but a detailed investigation of sanitary sewer infrastructure in relation to storm drain infrastructure offers some insights. Two locations were identified where older concrete sanitary sewer mains cross above the storm drain (Fig. 3.5), and the storm drain samples near these crossings all had detectable human markers. In the case of TL2 (Rockfield St.), this crossing was just downstream of the sampling location (Fig. 3.6). It is possible that sanitary sewers in this area are generally above the storm drain, however, storm drain depth data were not available. Therefore, potential sources of human waste to TL2 include leakage from sewer mains and laterals in the relatively small area. Concentrations of human markers and *E. coli* were not correlated (Fig. 3.7), suggesting that human inputs did not consist of fresh sewage, and had limited impacts on *E. coli* concentrations in the storm drain.

In the case of TL3, two "high risk" sanitary sewer-storm drain crossings were upstream of the storm drain sampling location, in the North Ranch Pavilions area (Fig. 3.8), therefore this area should be highest priority for investigating sources of human waste. However, the storm drain also receives potential runoff from the St. Maximilian Kolbe Catholic Church, and from County storm drains draining portions of the Oak Park Apartments on Skyridge Ln. and Oak Park Ln. These apartments are served by PVC sewer mains, which are less likely to leak. Potential sources from the church area are unknown.

All sanitary sewers mains in the County jurisdiction of the Upper Lindero drainage area are PVC, with low risk of exfiltration, which corroborate the absence of human markers in the County samples (Fig. 3.5).

Sources and impacts of dog waste

The high concentrations of dog markers at the County location L8 likely originated from dog waste that ended up in a catch basin, or from runoff from one or more residences, in the Cremona Way/Pesto Way area (Fig. 3.9). *E. coli* and dog marker concentration for locations L8, L6 and L3 were correlated (Tau correlation = 0.48, p = 0.024; Fig 3.10), suggesting that dog waste was a significant contributor to *E. coli* concentrations, and consequently, that removing the source of the dog waste could significantly reduce *E. coli* concentrations at all locations.

Dog markers were detected at multiple City locations. At TL2 (Conifer St.), concentrations of dog markers and *E. coli* were correlated (Tau correlation = 1, p = 0.042; Fig. 3.7), suggesting that dog waste inputs had a significant impact on *E. coli* concentrations in the storm drain. Moreover, dog marker concentrations at TL1, TL2 and TL3 were related, suggesting that dog waste from the storm drains was impacting the downstream creek location (Fig 3.11, top). At TL1, dog marker and *E. coli* concentrations were no longer correlated, reflecting the multiple sources of *E. coli* there (Fig. 3.11, bottom).

Sources and impacts of bird waste

The Upper Lindero Creek is impacted by bird waste, but urban outfalls are not the source. Occurrence of in-stream sources was confirmed by duck sightings on two occasions just upstream of MCW14B. Concentrations of bird markers and *E. coli* at the compliance location were positively but not significantly correlated (Tau correlation = 0.6, p = 0.09), and duck observations coincided with the highest *E. coli* and bird marker concentrations (Fig. 3.12). Therefore, data suggest that fresh duck feces are the dominant source of *E. coli* and may even cause of numeric limit exceedances at MCW14B, although more sampling is needed to confirm.

At the City creek location TL1, bird markers and *E. coli* concentrations did not correlate (Fig 3.11, bottom), suggesting that non-bird fecal sources are contributing significantly to *E. coli*. Here, these sources are likely the storm drains along Rockfield St. (TL2) and Lindero Cyn Rd. (TL3), contributing significant amounts of dog waste (especially TL2), but also other non-identified sources (especially TL3).

3.4. Nutrients

Nutrient concentrations at all sampled locations are shown in Fig. 3.13. Locations include creek locations (MCW14B, TL1, TL7, TL9), outfalls (L3 – L9; TL2, TL3), and reclaimed water from Mae Boyar Park pump station (REC). The significance of the measured nutrient concentrations was assessed by comparing to TMDL numeric targets (as monthly averages) and load allocations (Tables 3.2 and 3.3) (U.S. Environmental Protection Agency, 2003). This comparison is for informational purposes only and is not suitable to determine compliance with the nutrient TMDL. The load targets for Upper Lindero Creek were calculated from the total load allocation for the watershed (5 lbs N/day and 0.5 lbs TP/day) and percentage of load contribution by Upper Lindero Creek used in the TMDL (4%; includes loads from effluent irrigation, imported water, developed areas, agriculture, open space). Note that the load targets include contributions from many non-MS4 sources that potentially impact MCW12.

Total nitrogen concentrations between 0.3 - 0.6 mg/l at MCW14B. The County storm drain locations had higher and quite variable concentrations (1.7 – 10.6 mg/l; average = 3.6 mg/l). The City Upper Lindero Creek locations TL7 and TL9 also had relatively low total nitrogen concentrations (0.2 – 1.3 mg/l), but the City storm drain locations and TL1 just downstream had higher concentrations (1.3 – 7.9 mg/l; average = 3.0 mg/l). Concentrations in reclaimed water were higher than those in most storm drains.

Inorganic nitrogen concentrations (nitrate + nitrite-N) were low at MCW14B (≤ 0.25 mg/l). The County storm drain locations had higher concentrations (1.0 – 3.7 mg/l). The City Upper Lindero Creek locations TL7 and TL9 also had low total nitrogen locations (≤ 0.20 mg/l), but the City storm drain locations and TL1 just downstream had higher concentrations (0.2 – 3.8 mg/l). Concentrations in reclaimed water were consistently higher than in the storm drains.

Total phosphorus concentrations exhibited the similar patterns as nitrogen concentrations, with the exception of a more modest concentration decrease between the storm drains and MCW14B. Total phosphorus concentrations were highest in reclaimed water (1.8 – 2.5 mg/l), follow by storm drain samples in City and County (0.1 – 1.5 mg/l), MCW14B (0.1 – 0.3 mg/l) and Upper Lindero Creek receiving water locations (< 0.1 mg/l). Total phosphorus concentrations at L8, where 30-40% of flow was suspected to be from reclaimed water (see Section 3.5), were higher than at other storm drain locations, suggesting reclaimed water could be an important source of phosphorus there.

Nitrogen concentrations at MCW14B were below the nitrogen numeric target concentration, but were slightly higher than numeric targets at locations representing the combined flow of the City (TL1) and County (L3). The nitrogen load at MCW14B was greater than the load allocation. The TP concentrations at MCW14B and combined flows from City (TL1) and County (L3) were above the TP numeric target. The TP load at MCW14B was also greater than the TP load allocation.

Table 3.2. Observed concentrations and loads of nitrite + nitrate in Upper Lindero Creek drainage area compared to TMDL numeric target and target load (na = not applicable)

Receiving water location	Numeric target (mg/l nitrite + nitrate N)	Observed average (mg/l nitrite + nitrate N)	Target load (lbs/d nitrite + nitrate N)	Observed average (lbs/d nitrite + nitrate N)
MCW14B	1	0.15	0.2	0.48
TL1		1.04	na	na
L3	na	1.25	na	na

Table 3.3. Observed concentrations and loads of TP in Upper Lindero Creek drainage area compared to TMDL numeric target and target load (na = not applicable)

Receiving water location	Numeric target (mg/l TP)	Observed average (mg/l TP)	Target load (lbs/d TP)	Observed average (lbs/d TP)
MCW14B	0.1	0.17	0.025	0.55
TL1		0.46	na	na
L3	na	0.28	na	na

3.5. Potential chemical sewage indicators

Four chemicals with potential to indicate sewage pollution or other anthropogenic inputs were analyzed: caffeine, cotinine (nicotine metabolite), carbamazepine (anticonvulsant and mood-stabilizing drug) and sucralose (artificial sweetener). All are present in relatively high concentrations in raw sewage, but rates of degradation in the environment vary (very low for sucralose and carbamazepine). Concentrations ranges of these chemicals in raw sewage and drinking water, and those measured in reclaimed water in Oak Park, are summarized in Table 3.4. Reported concentrations in literature in raw sewage and drinking water are highly variable, and it should also be noted that often times these chemicals are not detectable in drinking water. Concentrations of carbamazepine and sucralose in reclaimed water were much higher than those commonly observed in drinking water, and in the case of sucralose also compared to concentrations in raw sewage. Therefore, these chemicals are potentially useful tracers for reclaimed water in the Upper Lindero Creek drainage area. However, it is recommended to verify concentrations in drinking water in the study area.

Table 3.4. Observed concentrations of potential chemical sewage indicators in raw sewage, drinking water and Oak Park reclaimed water (ng/l).

Chemical	Sewage	Drinking water	Reclaimed Oak Park
Caffeine	220 – 43,900[1]	NA	1.5 – 13
Cotinine	800 – 2,900[2]	NA	8.2 – 15
Carbamazepine	6 – 3,780 [1,3,4]	0.3 – 721 (average = 1 - 6)[5]	37 - 81
Sucralose	200 - 8,000[6,7]	48 – 2,400[8]	6,100 – 31,000

References: [1]Santos et al. (2009), [2]Buerge et al. (2008), [3]Celiz et al. (2009), [4]Alshouli (2012), [5]Daughton (2010), [6]Tran et al. (2014), [7]Lubick (2008), [8]Mawhinney et al. (2011)

Caffeine and **cotinine** were detected in almost all samples, with highly similar concentrations patterns (Fig. 3.14). Concentrations at the compliance station were 18 – 41 ng/l (caffeine) and 6 – 29 ng/l (cotinine). Concentrations in County samples were similar to those at the compliance station, except for a spike at L9 for caffeine. Concentrations in City samples were even lower at the Upper Lindero Creek locations TL7 and TL9 (caffeine ≤ 25 ng/l; cotinine ≤ 7.3 ng/l), but relatively high at TL3 (up to 2900 ng/l for caffeine and up to 130 ng/l for cotinine). Concentrations in reclaimed water were in the low (caffeine) to intermediate (cotinine) range of observed concentrations. Across the drainage area, concentrations of *E. coli* were strongly correlated with those of caffeine (Tau correlation = 0.36, p = 0.0003) and cotinine (Tau correlation = 0.29, p = 0.005), however caffeine and cotinine concentrations were not related to human marker concentrations. Given the many potential non-sewage sources of caffeine and cotinine in the urban environment (drinks, trash) and the fact that concentrations were not related to human marker concentrations, it can be concluded that these sewage chemicals are an indicator for general urban contributions from storm drains, but not useful for identifying human sources of fecal pollution.

Carbamazepine and **sucralose** were detected in many samples, with highly similar concentrations patterns, although different from those of caffeine and cotinine (Fig. 3.14). Concentrations were consistently highest in reclaimed water (37 – 81 ng/l for carbamazepine; 6,100 – 31,000 ng/l for sucralose). Concentrations at the compliance station were much lower, between 4 – 8 ng/l (carbamazepine) and 1,000 – 2,500 ng/l (sucralose). Concentrations in County samples were high at L8, progressively decreasing downstream at L6 and L3. Concentrations in other County storm drain samples (L5 and L9) were very low (carbamazepine ≤ 1 ng/l; sucralose ≤ 370 ng/l). Concentrations in City samples were also very low at the Upper Lindero Creek locations TL7 and TL9 and storm drain TL2 (carbamazepine ≤ 1 ng/l; sucralose ≤ 210 ng/l), but somewhat higher at TL3 and TL1. Concentrations patterns indicate that sources from County (L3) and City (TL1) affect the concentration at the compliance station, with lower loads from the City due to the lower flows from its drainage area.

Concentrations patterns also suggest that carbamazepine and sucralose can be used as a tracer for reclaimed water, and consequently that flow at L8 consists of 30 - 40% of reclaimed (based on two end member mixing model). While the input of reclaimed water is plausible, given the proximity of the recycled water system (Fig. 3.15), it should be further validated by confirming reclaimed water usage in the area and measuring carbamazepine and sucralose concentrations in drinking water at the point of distribution. It's very unlikely that the elevated carbamazepine and sucralose concentrations at L8 are due to sewage pollution given the consistent absence of human markers there and in reclaimed water.

3.6. IC/ID Indicators

The IC/ID indicators fluoride, MBAS and ammonium/potassium ratio were analyzed for potential identification of sources of flow and fecal pollution, based on a flow chart in the Center for Watershed Protection's Illicit Discharge Detection and Elimination manual (Fig. 3.16) (Center for Watershed Protection, 2004). Criteria for sewage contamination were never exceeded. Detergents did not indicate potential wash water contamination, using the threshold of 0.25 mg/l MBAS, except twice at TL3 (Fig. 3.17, top).

Fluoride concentrations in the Upper Lindero Creek locations TL7 and TL9 were between 0.62 – 0.82 mg/l, but higher concentrations were observed in the urban outfalls in City and County (0.70 – 1.1 mg/l) (Fig. 3.17, bottom). It's unclear why the latter concentrations are higher than the approximately 0.8 mg/l measured in reclaimed water and the range of 0.6 – 1.0 mg/l reported for local drinking water (Calleguas Municipal water district, 2013), therefore fluoride was deemed unsuitable to distinguish flow inputs from natural sources versus tap/reclaimed water.

3.7. Conclusions

For the County, consistent flow was observed in most of the storm drain locations that were surveyed, and relatively high *E. coli* concentrations occurred at all sampling locations, including the most downstream location discharging into Upper Lindero Creek. Relatively high flows, very high *E. coli* concentrations and high dog marker concentrations were observed at L8, providing compelling evidence that dog waste was a significant source of fecal pollution from the relatively small area upstream of this location (Cremona Way/Pesto Way area). The area upstream of location L9 also provided relatively high loads of *E. coli*, as flow there was relatively high (based on visual observations), and *E. coli* concentrations were among the highest observed. Dog markers were detected at low frequency, but given the consistent high *E. coli* concentrations, additional sources of *E. coli* must be present as well. The latter could include urban wildlife or regrowth in the environment. These two high priority drainage areas are highlighted in red in Fig. 3.18. Most other areas within the County jurisdiction of the Upper Lindero Creek drainage area also contributed *E. coli* to the storm drain network, but relative flows from each area were not quantified due to the difficulty in obtaining flow measurements in deep storm drain manholes, and the sources of *E. coli* there remain unknown.

For the City, the area upstream of the spillway just north of Rockfield St. did not contribute surface flow to the compliance location. Only two drains (Rockfield St. and Lindero Cyn Rd.) contributed flow and potentially *E. coli* directly to Upper Lindero Creek and the compliance station. Their drainage areas only constitute about 20% of the urban land area in the City, and are highlighted yellow in Fig. 3.18. Note that flow and *E. coli* concentration patterns within these City areas have not been investigated, but it should not be assumed that sources are uniformly distributed. For example, the Lindero Cyn Rd. storm drain services a shopping plaza, a large church and two smaller apartment complexes (within County area), and relative flow and *E. coli* contributions from each of these areas are unknown. Dog waste was suspected to be the most significant source of *E. coli* in the Rockfield St. drain, even though human markers were consistently detected as well. While the human waste may not contribute much of the *E. coli*, it may be a risk to human health. Low frequencies of dog and human markers were detected in the Lindero Cyn Rd. drain, and additional sources of *E. coli* are suspected. These could include urban wildlife or regrowth in the environment.

Note that urban storm drain locations were visited on up to five occasions, therefore a frequency of occurrence of host-specific markers less than approximately 20% cannot be ruled out at locations were none were detected.

In addition to urban outfalls, birds in the creek were also identified as a source of *E. coli* to Upper Lindero Creek. The data suggest that birds near the compliance station have a significant influence on *E. coli* concentrations there, and may be causing the exceedances, which has important implications for MS4 compliance.

Nutrient (nitrogen and phosphorus) loads measured at the compliance station were higher than load allocations assigned to the Upper Lindero Creek drainage area in the 2003 EPA Nutrients TMDL. However, the nitrogen numeric target was not exceeded. Nutrient concentrations were often highest in reclaimed water, and there was evidence that reclaimed water contributed nutrients (especially phosphorus) to the County storm drain at L8. Storm drains in both the County and City areas had higher nutrient concentrations compared to creek locations, and provided most, if not all, flow to the most downstream creek location. Therefore, storm drains could be a significant source of nutrients to the latter station. However, the net effects of natural attenuation along Lindero Creek and additional in-stream sources (e.g. birds, litter) should be better understood.

The goals of this study included identifying sub-drainages contributing the highest loads of *E. coli* and nutrients, identifying sub-drainages with anthropogenic inputs of fecal pollution (e.g. human, dog, irrigation runoff, etc.), and estimating the relative contributions of natural vs. anthropogenic sources of fecal pollution. These goals have largely been met, but the relative contributions of birds and storm drains to *E. coli* concentrations at the compliance station need further study.

4. Implications for TMDL Compliance

4.1. Data gaps

While this study has largely met the goals as defined in the Work Plan, a number of data gaps remain or were identified as a result of this study.

1) Flow surveys and water quality sampling occurred between July and September of 2013. During this period, the west fork of Upper Medea Creek and most of the Upper Lindero Creek were not contributing surface flow to the downstream receiving water station, and therefore there was no impact of runoff from these areas on *E. coli* and nutrient concentrations downstream. However, field recon indicated that flow in the upper reaches was occurring earlier in the season. Therefore, the results of this study may not be fully representative of conditions earlier in the season.
2) This study found that birds likely contribute to *E. coli* concentrations at the Upper Medea Creek and Upper Lindero Creek bacteria TMDL compliance stations. However, the study had limited sample size, and was not designed to quantify the relative importance of urban outfalls and birds at these locations. Given the importance of the issue for MS4 compliance, this should be a high priority for further study.
3) This study found evidence of human waste at several storm drain locations, and potential inputs from sanitary sewer mains were assessed. However, leaking laterals are also a potential input of human waste, but were not investigated. Determining the exact cause(s) and location(s) of human waste inputs was outside the scope of this study, but will need to be performed in order to remediate the human waste inputs.
4) A number of storm drains exhibited consistent high concentrations of *E. coli*, but inconsistent or no detection of human, dog or bird host-specific markers. In these causes, the sources of *E. coli* remain elusive.

4.2. *E. coli* as indicator for MS4 compliance

This study convincingly showed that non-MS4 sources (i.e. birds) can contribute significantly to *E. coli* concentrations at the compliance station, and perhaps cause exceedances of TMDL numeric limits. Therefore, more comprehensive monitoring and/or special studies are needed to link *E. coli* in urban outfalls with *E. coli* exceedances in the Upper Medea Creek and Upper Lindero Creek, and determine compliance with TMDL targets.

4.3. Natural Source Exclusion

Pursuing natural source exclusion is not recommended at this point given the detection of human markers in Upper Medea Creek and Upper Linder Creek drainage areas. In case human inputs can be remediated, the natural source exclusion approach will likely still be challenging given the consistently high levels of *E. coli* observed in urban outfalls in both drainage areas. Issues that may need to be addressed include whether the non-human sources of *E. coli* in urban outfalls are considered anthropogenic, the extent of natural attenuation of *E. coli* between point of discharge to the creeks and compliance point, and the risk to human health associated with anthropogenic sources of *E. coli*.

4.4. Recommendations for Best Management Practices

This study showed that a number of areas in Upper Medea Creek and Upper Lindero Creek drainage areas contribute high loads of *E. coli*. These areas should be considered high priority areas for implementing dry-weather BMPs for reducing *E. coli* inputs from urban land uses. Based on the findings of this study, the following BMPs are likely to be most effective:

- Dry weather diversions to sanitary sewer. If selected, it is recommended to obtain better estimates of diurnal flow patterns and average flows over longer time periods at the selected outfalls.
- Infiltration BMPs to reduce or eliminate dry weather nuisance flow. Geotechnical studies have indicated infiltration BMPs are not feasible in Upper Medea Creek drainage area, but they may be feasible in the Upper Lindero Creek drainage area. Additional geotechnical studies will be needed.
- Treatment-type BMPs that effectively remove bacteria from dry weather nuisance flow.
- Outreach or other actions to reduce or eliminate the sources of dry weather nuisance flow (mostly runoff associated with lawn irrigation and washing activities).
- Outreach to dog owners, especially in areas where inputs of dog waste were demonstrated.

5. References

Alshouli MM (2012). Wastewater tracer study utilizing carbamazepine, triclorocarban and triclosan in the Philadelphia waterway. MSc. Thesis, Drexel University.

Buerge IJ, Kahle M, Buser HR, Muller MD, Poiger T (2008). Nicotine derivatives in wastewater and surface waters: Application as chemical markers for domestic wastewater. Environ. Sci. Technol. 42: 6354-6360.

Calleguas Municipal Water District (2013). Annual Water Quality Report.

Center for Watershed Protection (2004). Illicit Discharge Detection and Elimination. A guidance manual for program development and technical assessments, University of Alabama, October 2004.

Celiz MD, Perez S, Barcelo D, Aga DS (2009). Trace analysis of polar pharmaceuticals in wastewater by LC-MS-MS: Comparison of membrane bioreactor and activated sludge systems.

Daughton CG (2010). Pharmaceutical ingredients in drinking water: Overview of occurrence and significance of human exposure. Technical Report, National Exposure Research Laboratory, U.S. EPA.

Lubick N (2008). Artificial sweetener persists in the environment. Environ. Sci. Technol. 42: 3125

Mawhinney DB, Young RB, Vanderford BJ, Borch T, Snyder SA (2011). Artificial sweetener surcralose in U.S. drinking water systems. Environ. Sci. Technol. 45: 8716-8722.

Santos JL, Aparicio I, Callejon M, Alonso E (2009). Occurrence of pharmaceutically active compounds during 1-year period in wastewaters from four wastewater treatment plants in Seville (Spain). J. Hazard. Mat. 164: 1509-1516.

Tran NH, Hu J, Li J, Ong SL (2014). Suitability of artificial sweeteners as indicators of raw wastewater contamination in surface water and groundwater. Water Res. 48: 443-456.

U. S. Environmental Protection Agency (2003). Total Maximum Daily Loads for Nutrients. Malibu Creek Watershed.

Ventura County Watershed Protection District (2013). Malibu Creek Bacteria and Nutrient Total Maximum Daily Load – Implementation Plan Addendum for Unincorporated Ventura County and Watershed Protection District.

UPPER MALIBU CREEK WATERSHED

DRY WEATHER SOURCE IDENTIFICATION STUDY

DRAFT MEMORANDUM REPORT

FIGURES

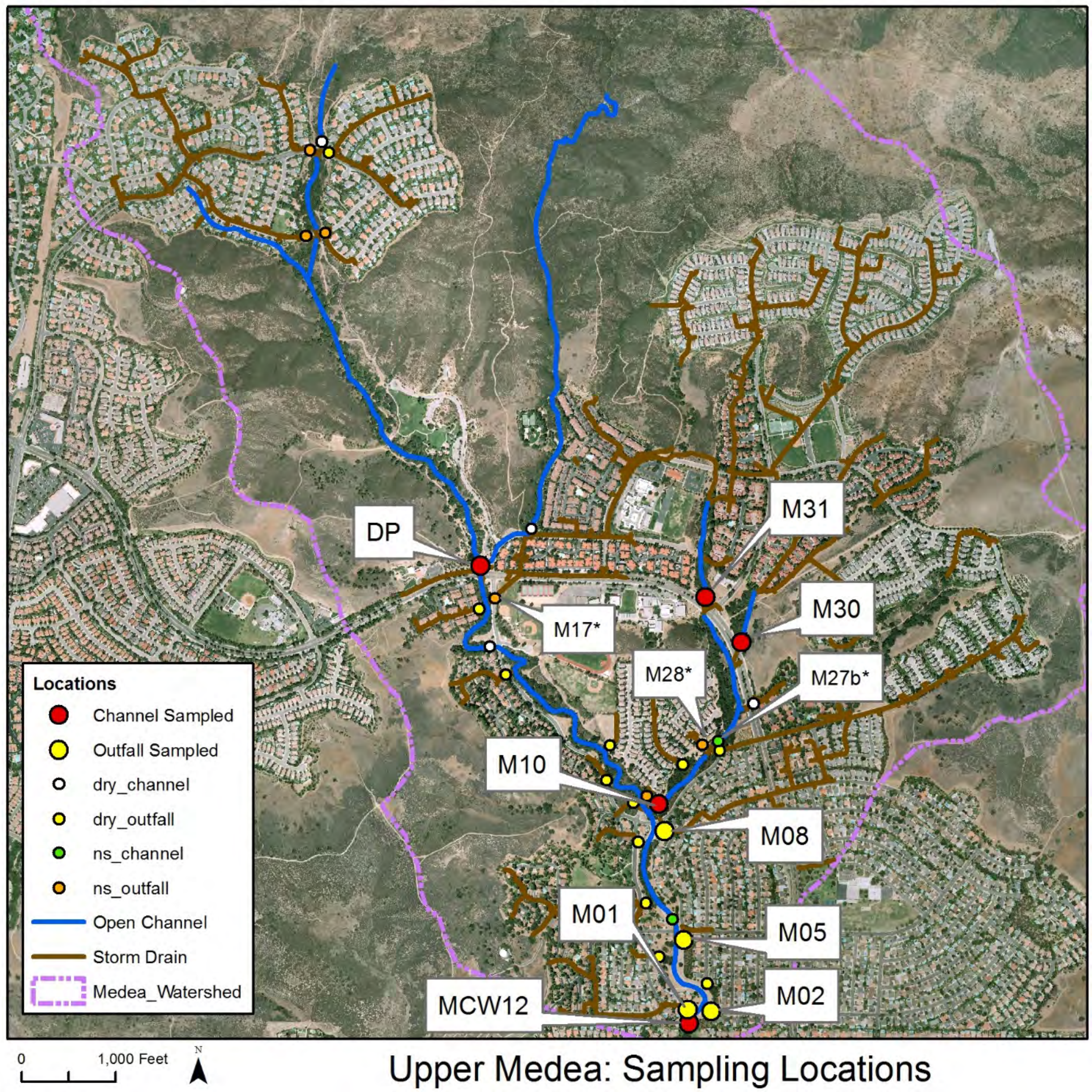


Fig. 2.1 Surveyed and sampled locations in Upper Medea Creek drainage area. Large symbols and labels indicate sampled locations with flow measurements. Small symbols indicate locations surveyed but not sampled because dry (white, yellow) or other reason (green, orange); small symbols with labels indicate locations with flow measurements.

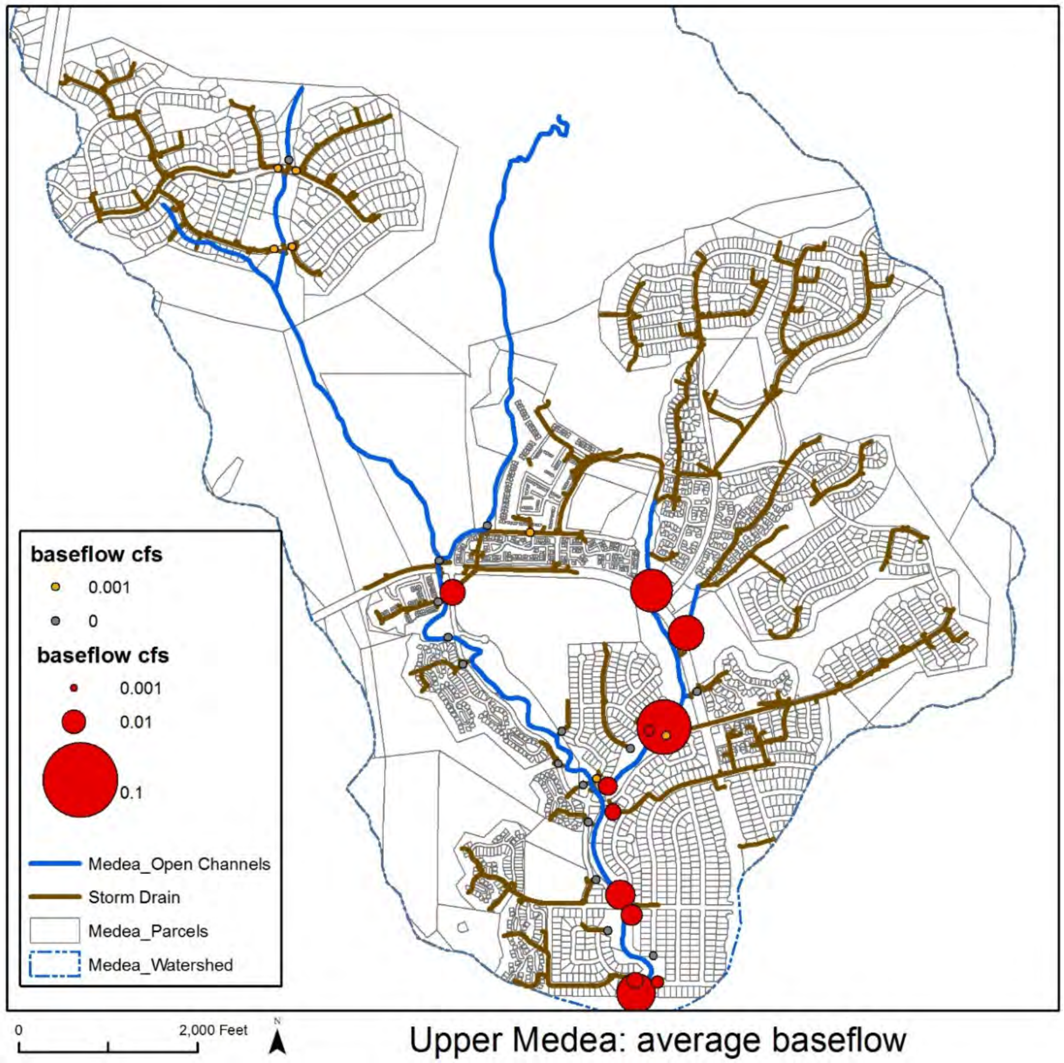


Fig. 2.2. Average baseflow in Upper Medea Creek drainage area. Only surface flows linked to MCW12 are indicated, by red circles proportional to flow. Dry reaches of the creek are highlighted with text.

Fig. 2.3. Storm drain outfall with temporary high flow outputs (left) and resulting foam in creek downstream (right)

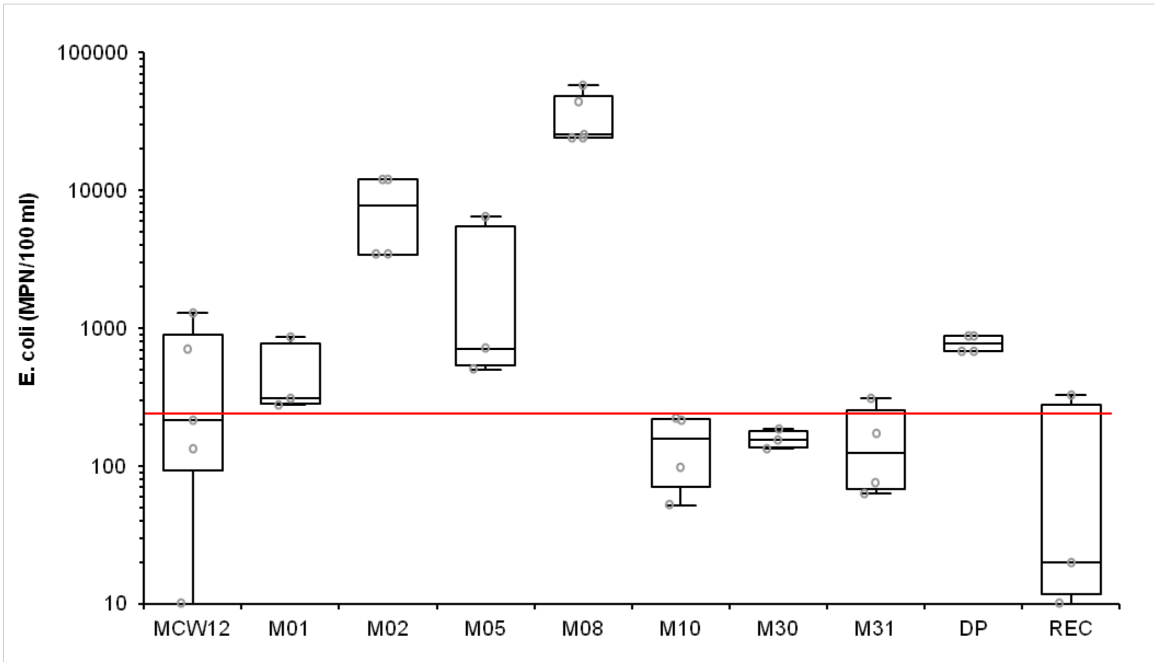


Fig. 2.4. ***E. coli*** **concentrations in Upper Medea drainage area. Numeric limit is indicated by red line (235 MPN/100 ml). Box plots indicate median, and 25th and 75th percentiles; whiskers indicate minima and maxima. M01 – M08: storm drain outfalls, M10 – M31: upper creek, DP: duck pond, REC; reclaimed water.**

Fig. 2.5. Gutter sampling location (red circle) with potential gutter flow (red dotted line) to storm drain at M08 (yellow circle)

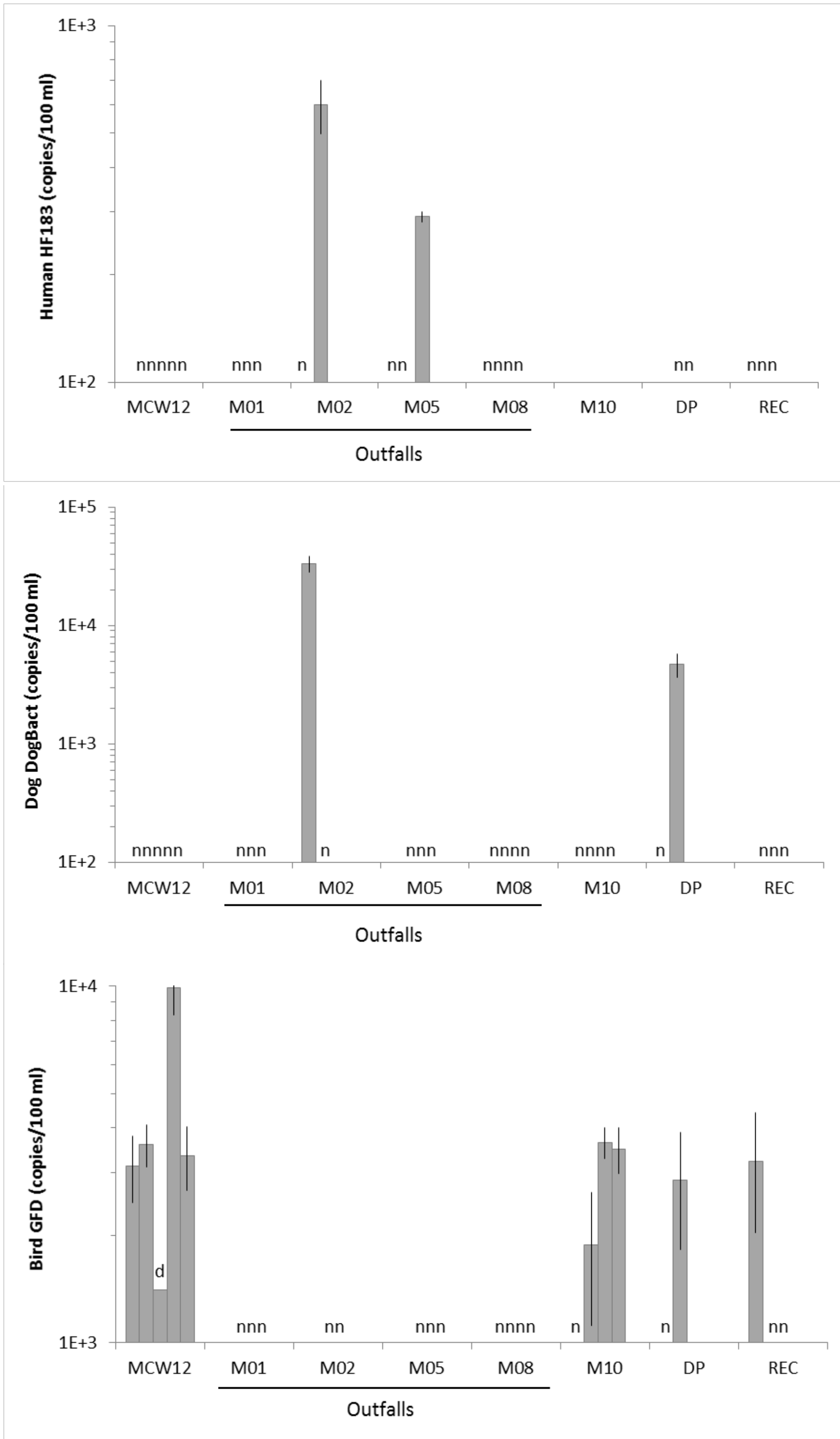


Fig. 2.6. Concentrations of host-specific markers in Upper Medea Creek drainage area. Error bars indicated standard deviation of technical replicates. Symbol "n" indicates non-detects, "d" indicates detected but not quantifiable.

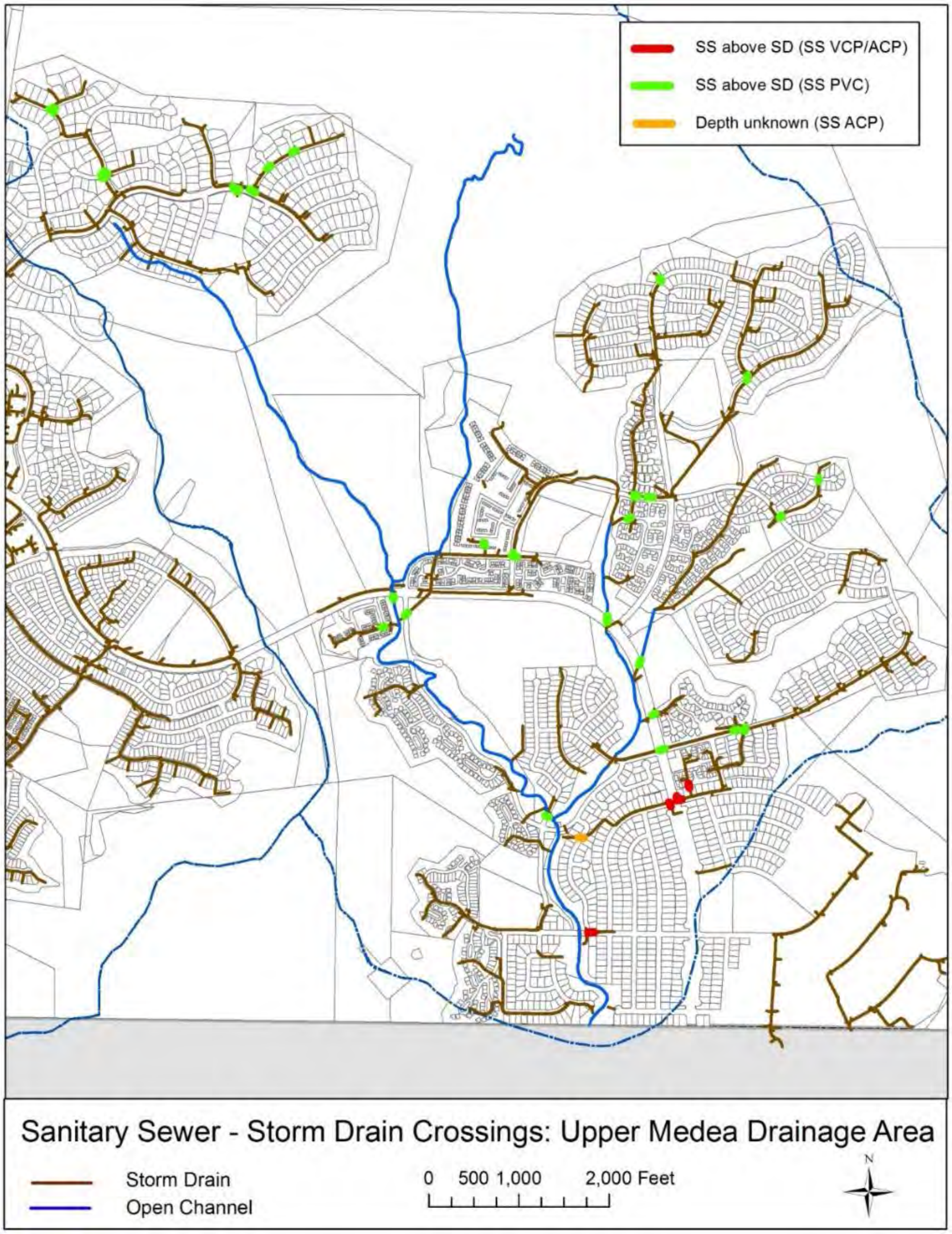


Fig. 2.7. Crossings with sanitary sewer overlaying storm drain in Upper Medea drainage area. Crossings are coded according to construction material of sanitary sewer: clay or concrete (red), PCV (green), unknown storm drain depth (orange).

Fig.2.8. Detail of storm drain (brown) and sanitary sewer (red) infrastructure near M05 (yellow circle, left map) and M02 (yellow circle, right map). Sanitary sewer crossing above storm drain is indicated by dotted red circle.

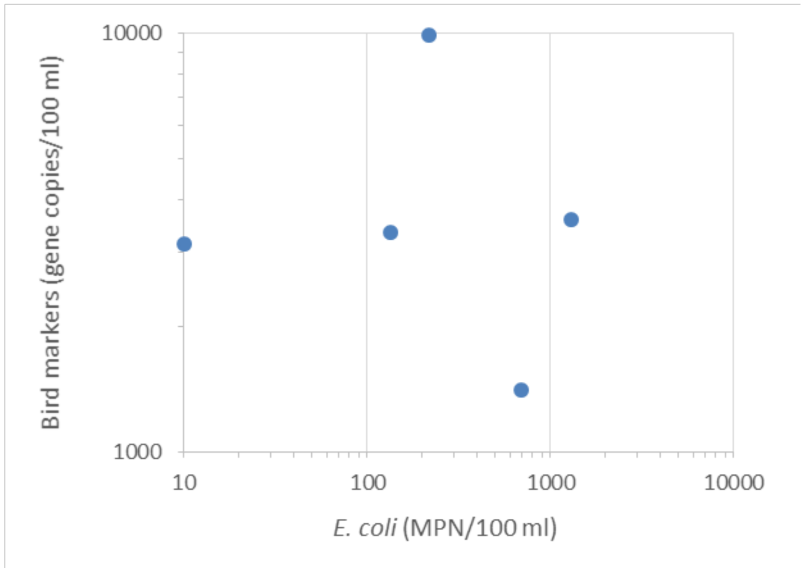


Fig. 2.9. Correlation between bird marker and *E. coli* concentrations at MCW12.

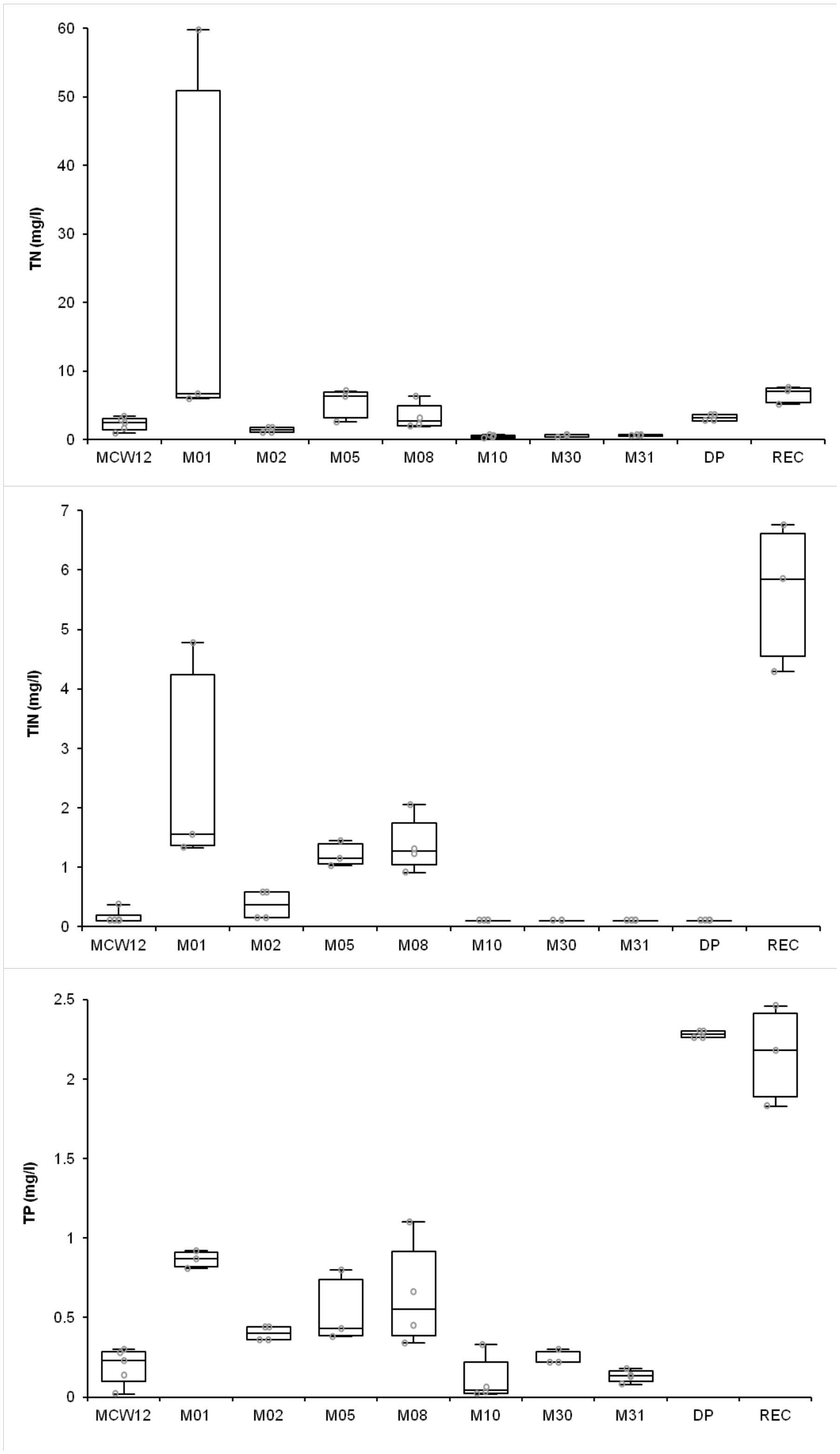


Fig. 2.10. Nutrient concentrations in Upper Medea Creek drainage area. TN: total nitrogen, TIN: total inorganic nitrogen (nitrate and nitrite), TP: total phosphorus.

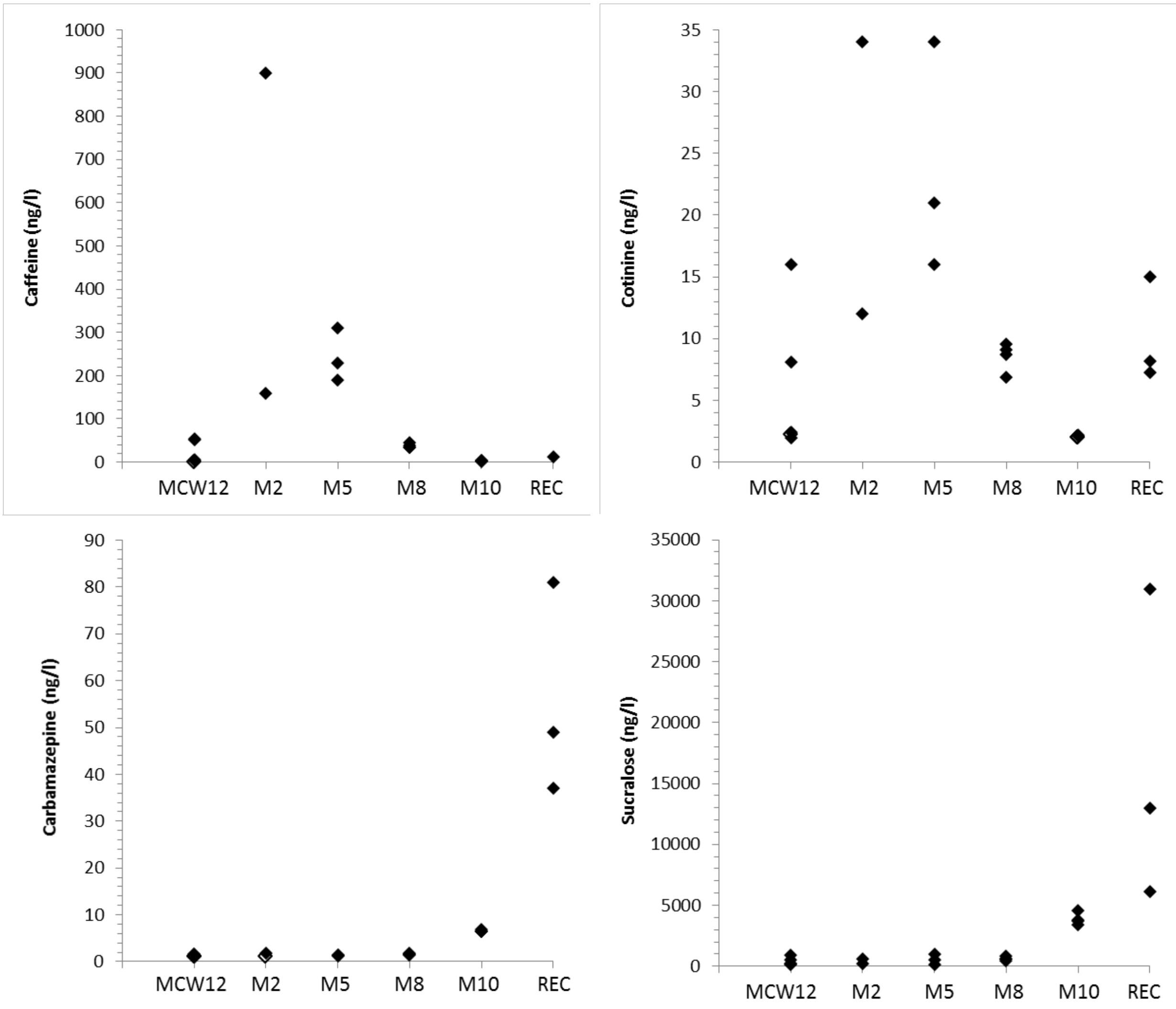


Fig. 2.11. Concentrations of potential chemical sewage indicators in Upper Medea Creek drainage area.

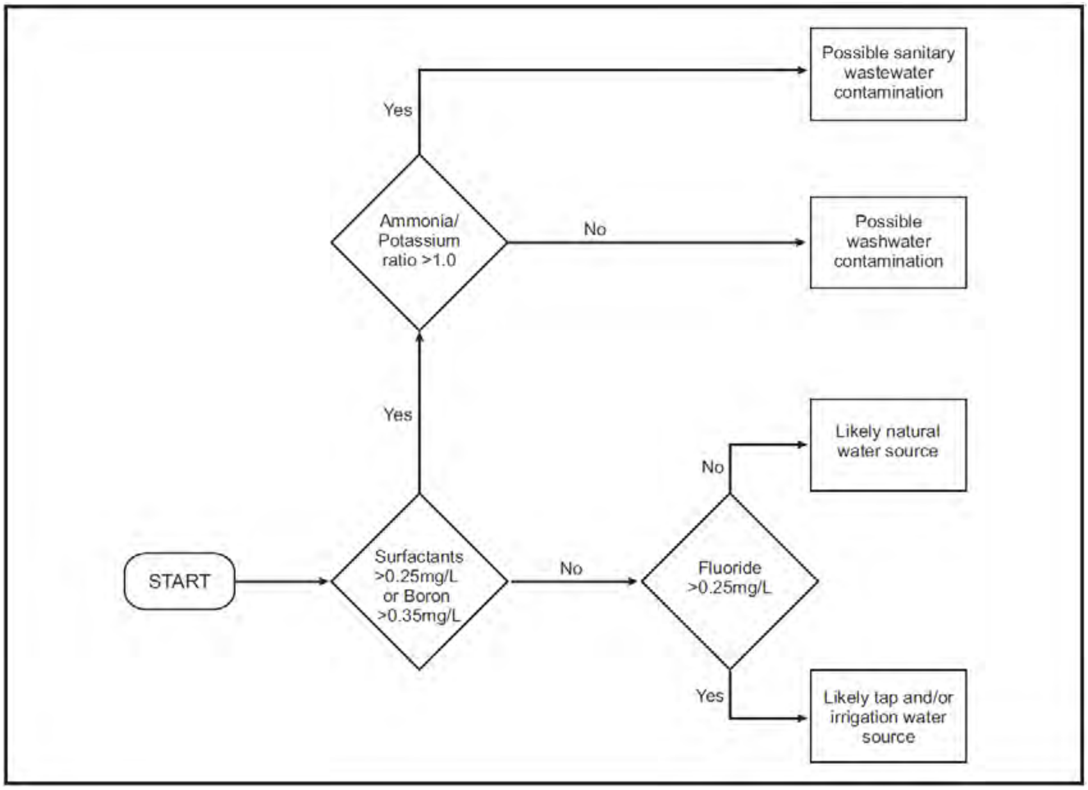


Fig. 2.12. Flow chart to identify illicit discharges in residential watersheds.

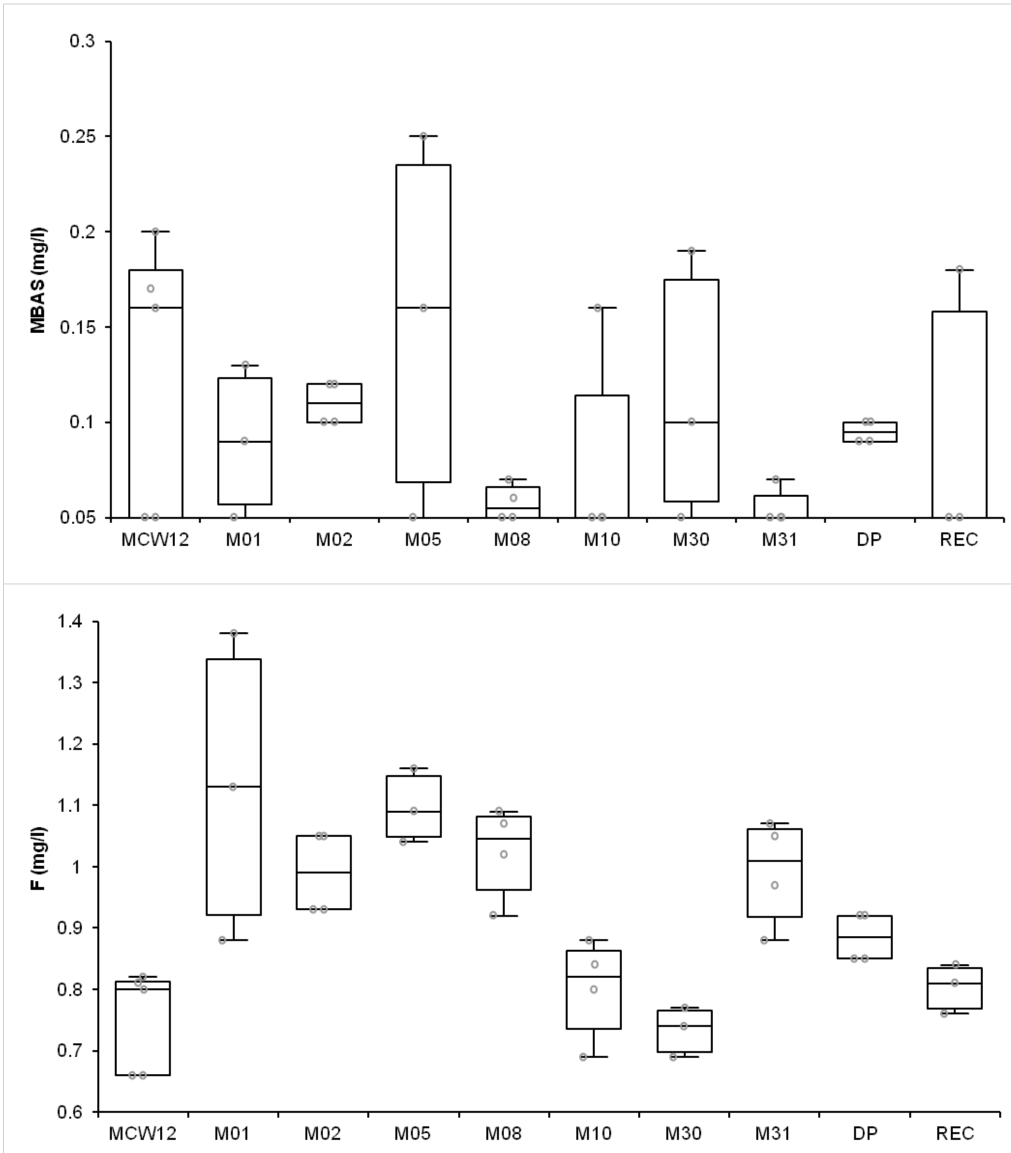


Fig. 2.13. Concentrations of MBAS (top) and fluoride (bottom) in Upper Medea Creek drainage area.

Fig. 2.14. Urban areas (yellow) potentially contributing to elevated *E. coli* concentrations at the compliance station (red dot). Storm drains are indicated in brown, creek in blue lines. Detected fecal sources are indicated in blue (creek) and brown (storm drain) text boxes.

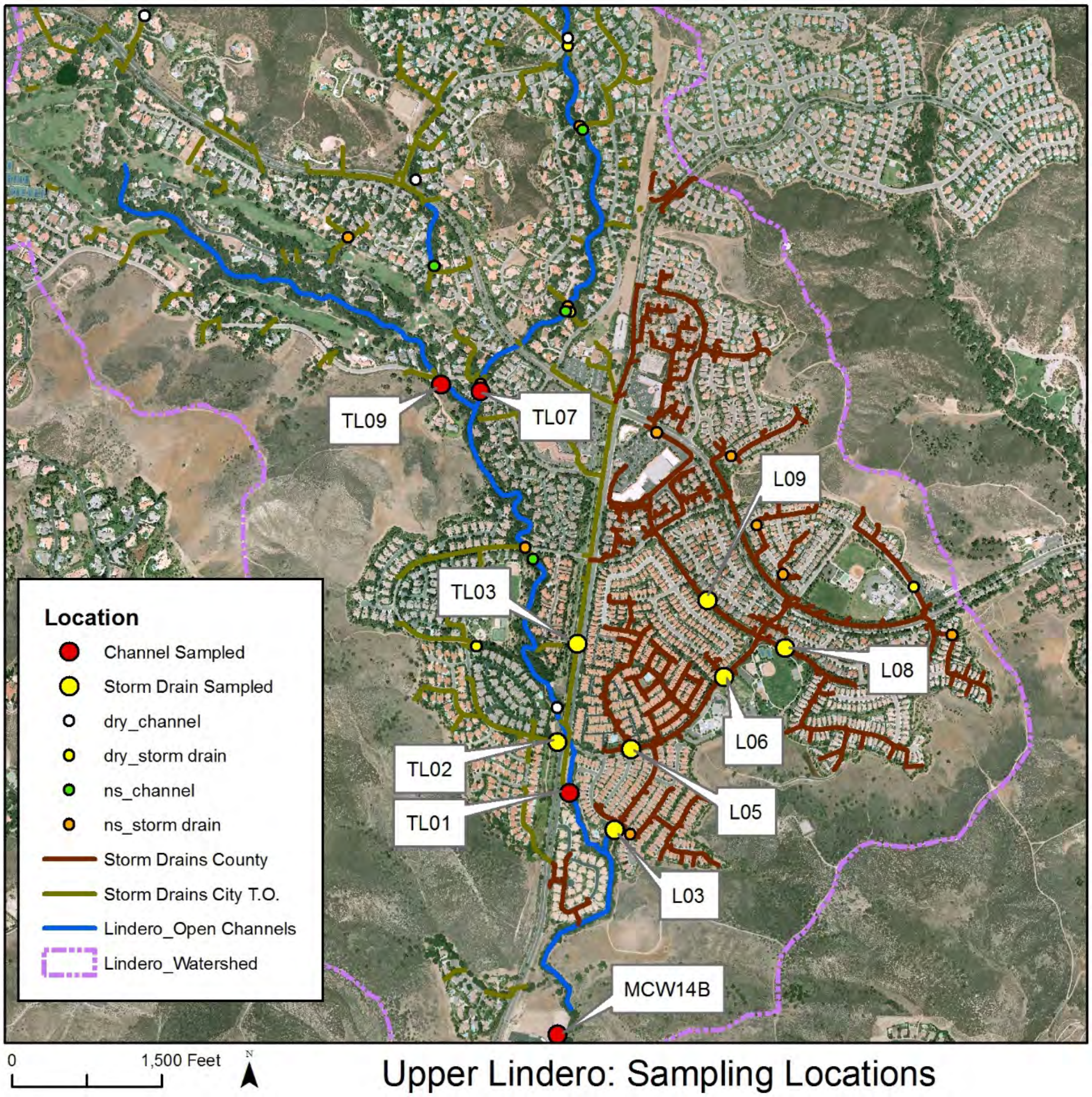


Fig. 3.1. Surveyed and sampled locations in Upper Lindero Creek drainage area. Large symbols and labels indicate sampled locations with flow measurements. Small symbols indicate locations surveyed but not sampled because dry (white, yellow) or other reason (green, orange); small symbols with labels indicate locations with flow measurements.

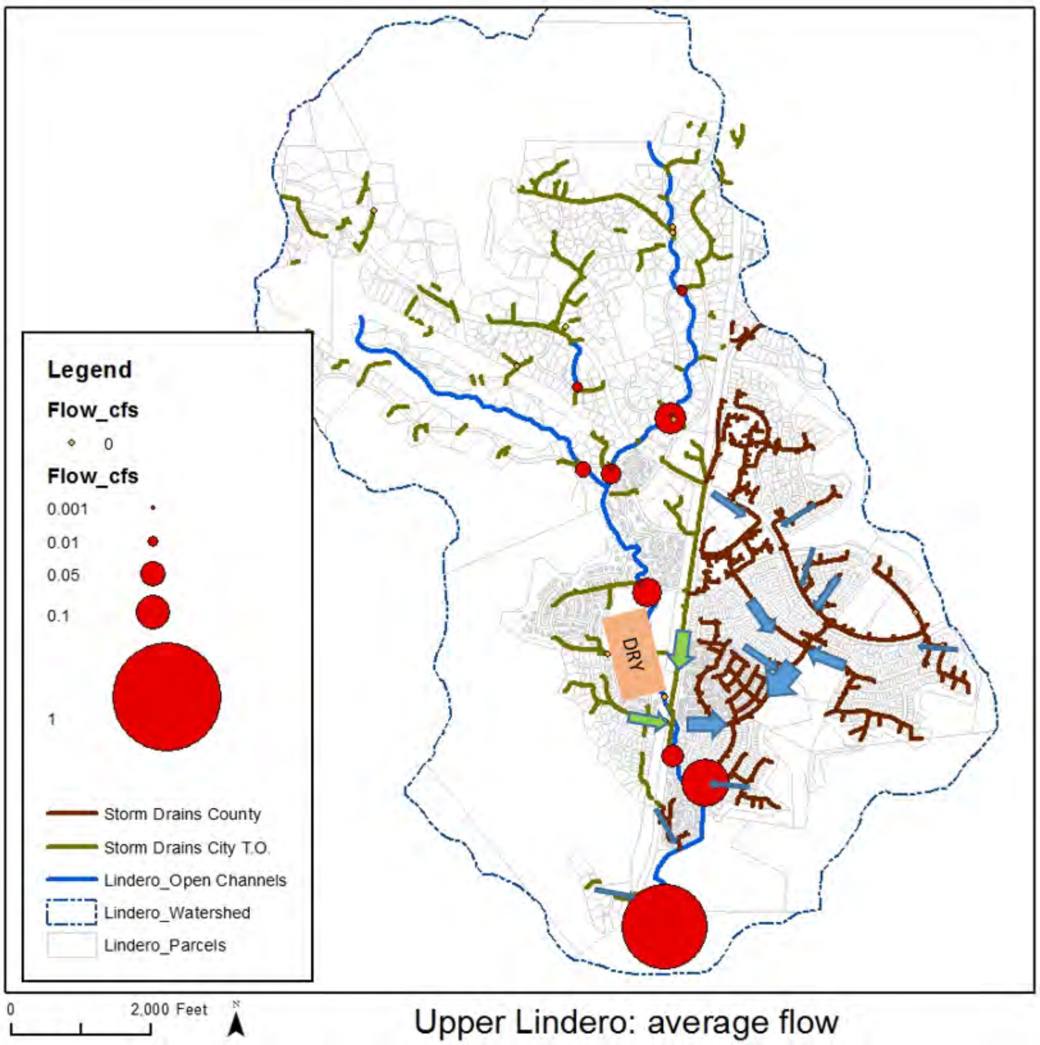


Fig. 3.2. Average baseflow in Upper Lindero Creek drainage area. Red circles are proportional to flow, arrows sizes indicate semi-quantitative flow assessment based on visual observations. Dry reaches of the creek are highlighted with text.

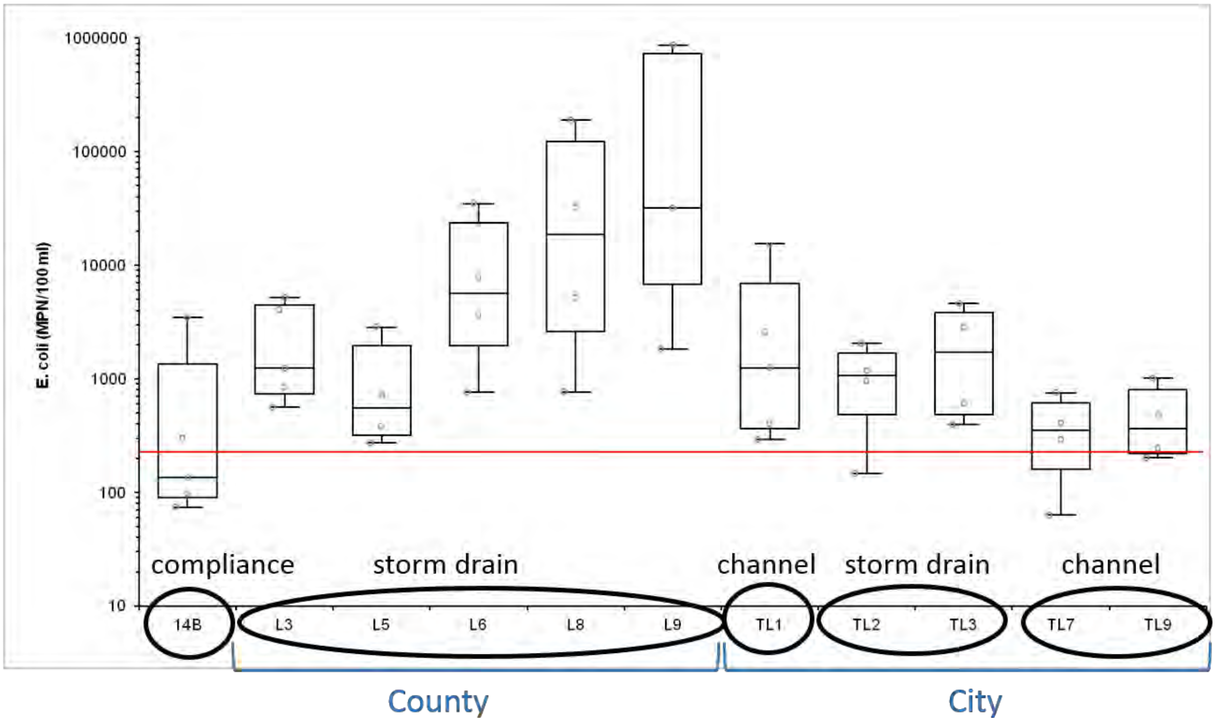


Fig. 3.3. *E. coli* concentrations in Upper Lindero drainage area. Numeric limit is indicated by red line (235 MPN/100 ml). Box plots indicate median, and 25th and 75th percentiles; whiskers indicate minima and maxima.

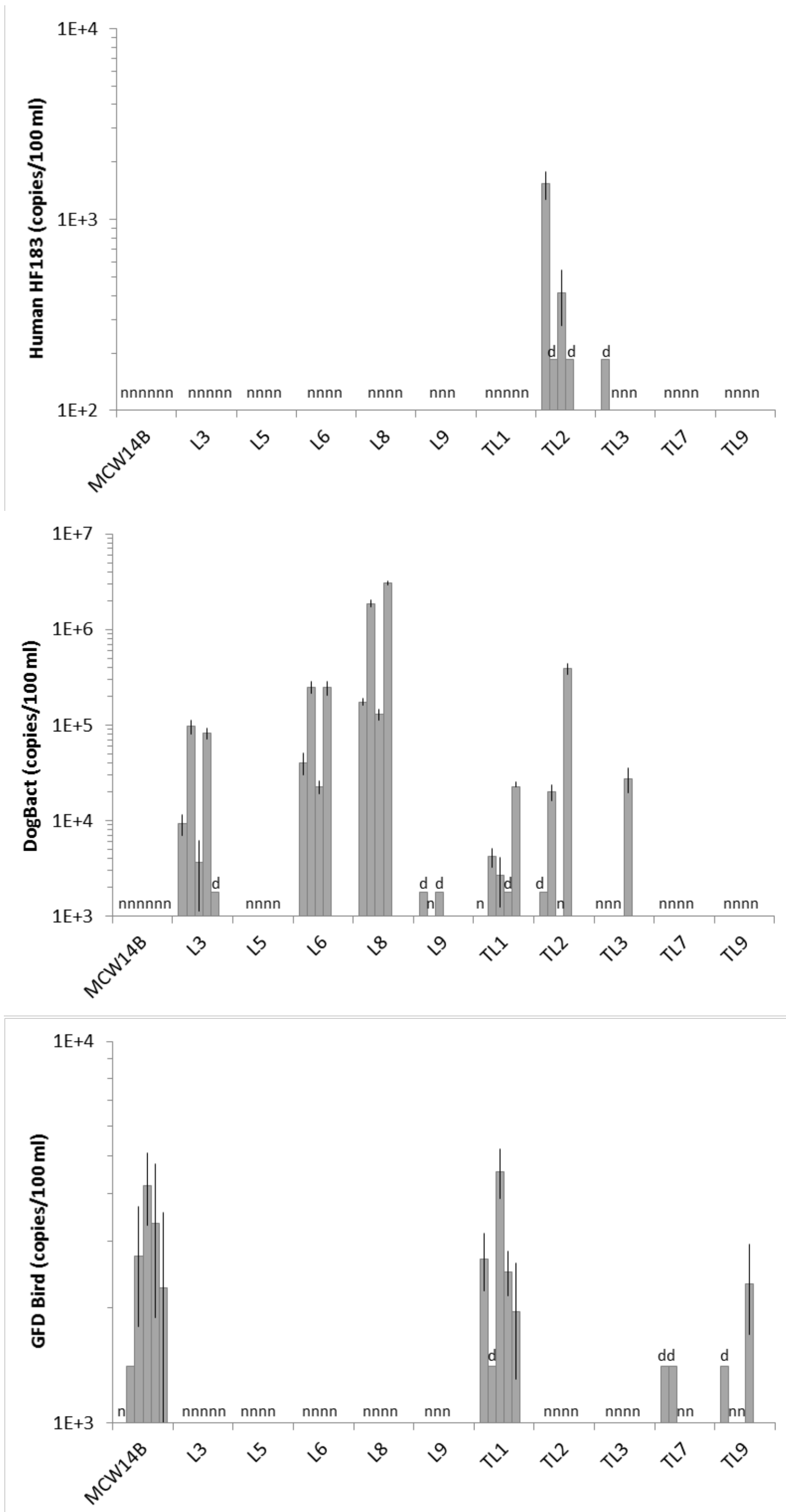


Fig. 3.4. Concentrations of host-specific markers in Upper Lindero Creek drainage area. Error bars indicated standard deviation of technical replicates. Symbol “n” indicates non-detects, “d” indicates detected but not quantifiable.

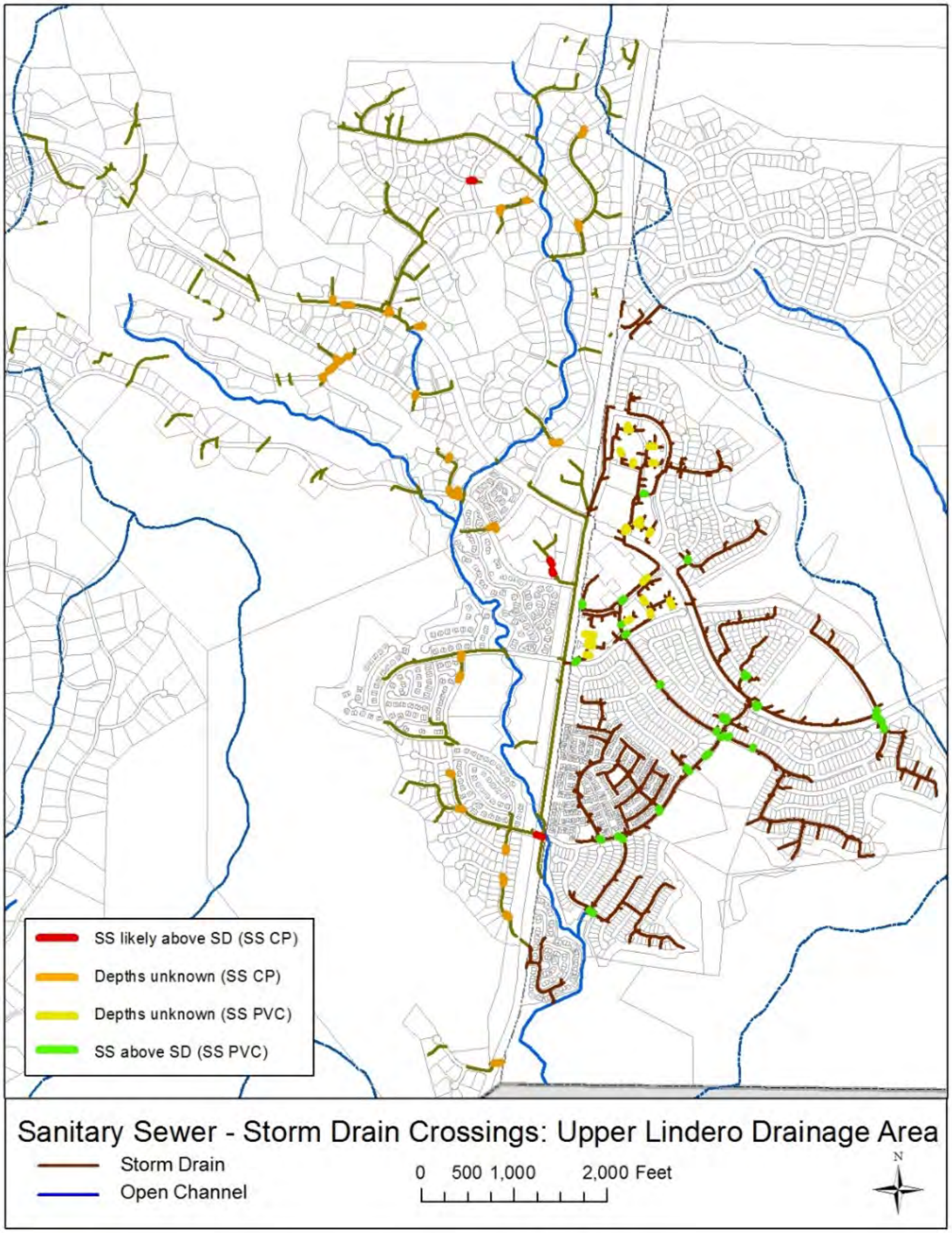


Fig. 3.5. Crossings with sanitary sewer overlaying storm drain in Upper Lindero drainage area. Crossings are coded according to construction material of sanitary sewer: concrete (red), PCV (green). Crossings where storm drain depths are unknown are indicated in yellow (PVC) and orange (concrete).

Fig.3.6. Detail of storm drain with manholes (green) and sanitary sewer infrastructure (red) near TL2 (yellow circle). Sanitary sewer crossing above the storm drain is indicated by dotted red circle.

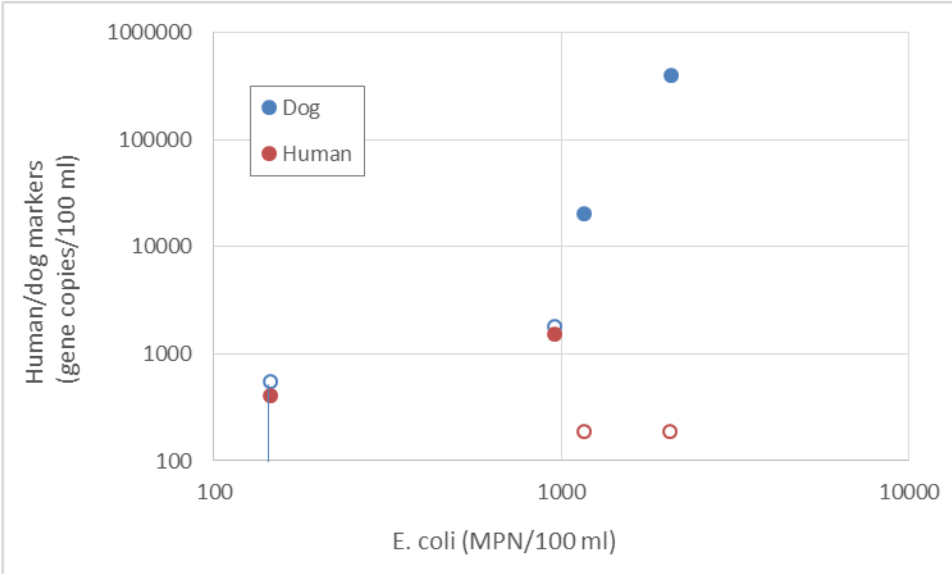


Fig. 3.7. Correlation between human or dog markers and *E. coli* concentrations at TL2. Open symbols indicate samples below the limit of quantification (DNQ and ND). Vertical lines are used to indicate range between zero and limit of detection for samples qualified as ND.

Fig.3.8. Detail of storm drain with manholes (City: green, County: brown) and sanitary sewer infrastructure (red) near TL3 (large yellow circle). Sanitary sewer crossings above the storm drain are indicated by dotted red circles.

Fig.3.9. Detail of area upstream of L8 (yellow circle) where high concentrations of dog markers were found.

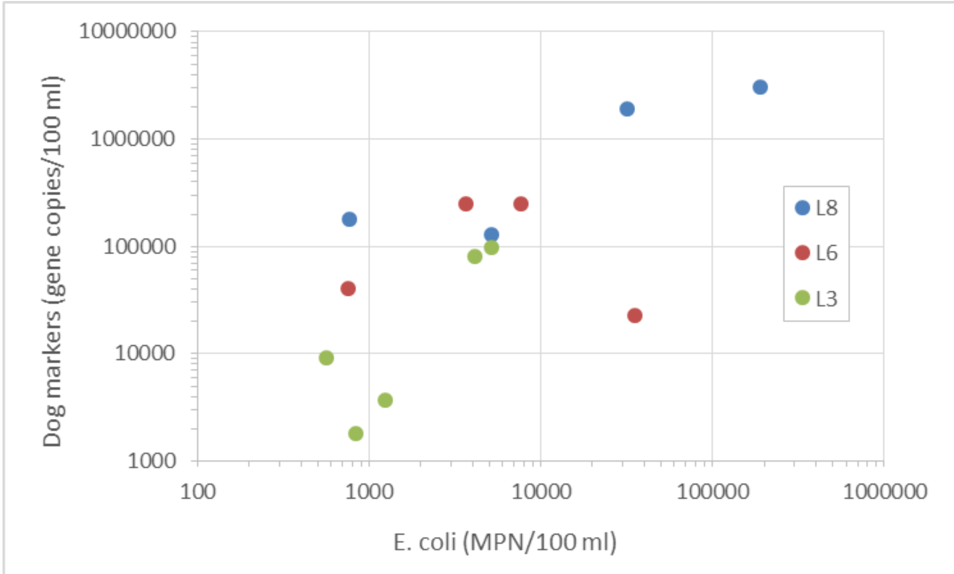


Fig. 3.10. Correlation between dog marker and *E. coli* concentrations at County locations L3, L6 and L8.

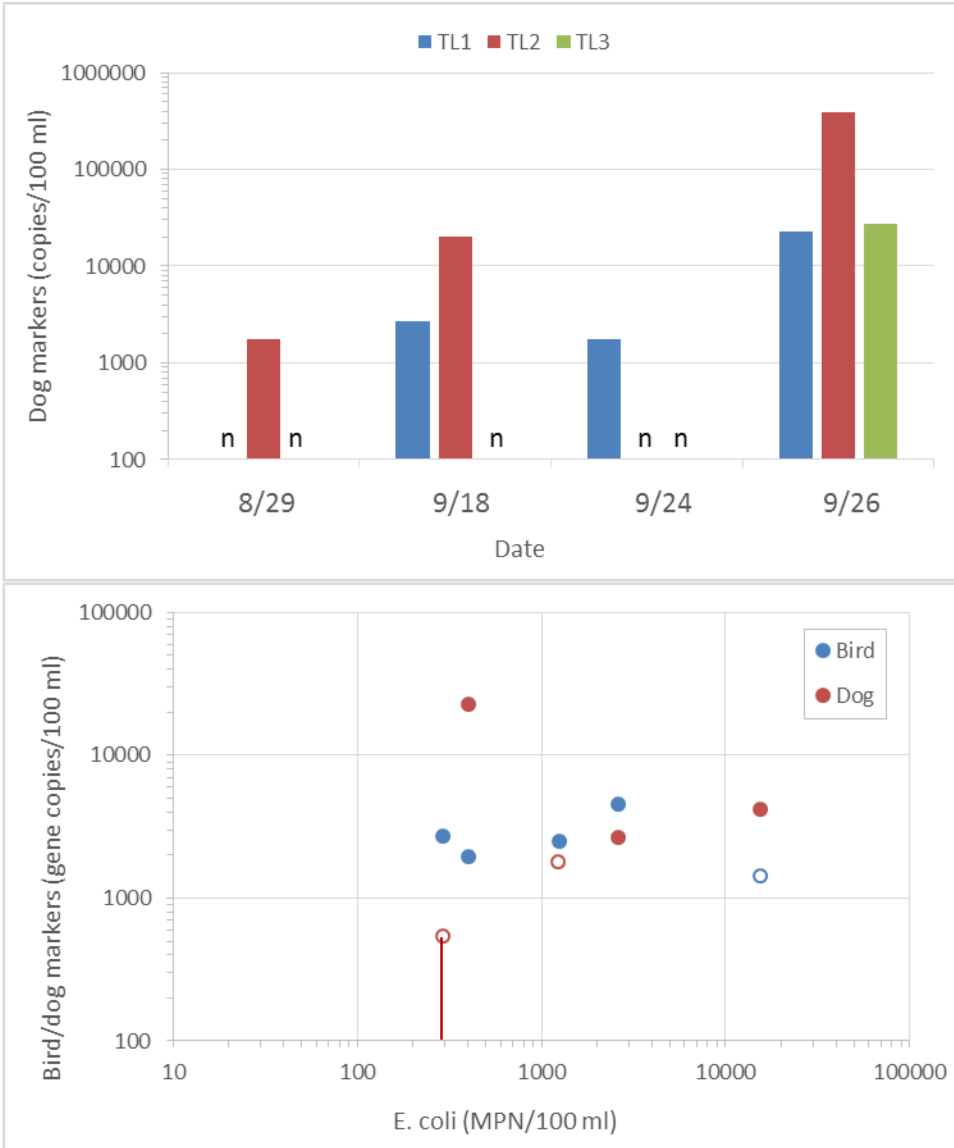


Fig. 3.11. Dog marker concentrations at TL1, TL2 and TL3 (top) and correlation between bird or dog marker and *E. coli* concentrations TL1 (bottom). Open symbols indicate samples below the limit of quantification (DNQ and ND). Vertical lines are used to indicate range between zero and limit of detection for samples qualified as ND.

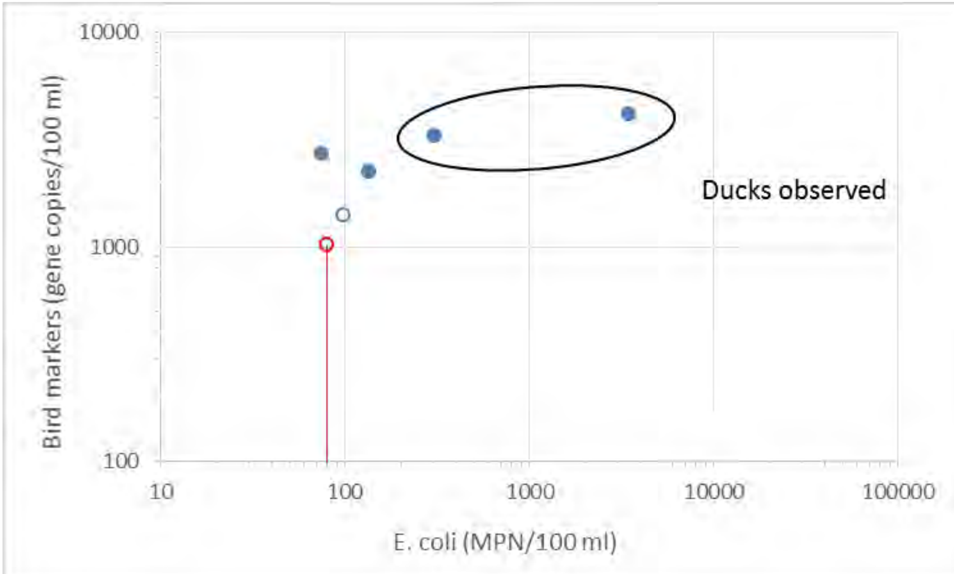


Fig. 3.12. Correlation between bird marker and *E. coli* concentrations at MCW14B. Open symbols indicate samples below the limit of quantification (blue: DNQ, red: ND). Vertical lines indicate range below limit of detection for samples qualified as non-detectable.

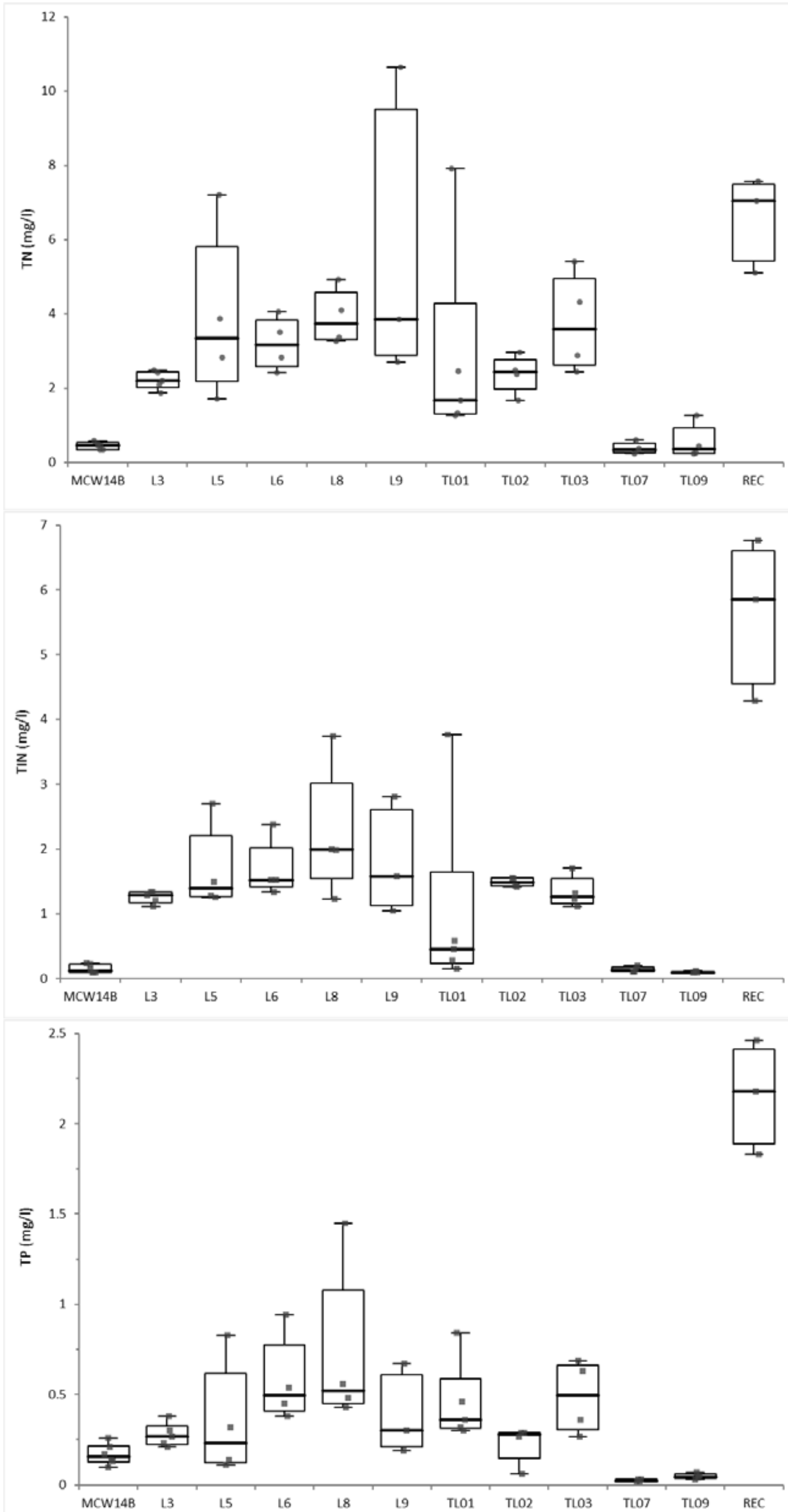


Fig. 3.13. Nutrient concentrations in Upper Lindero Creek drainage area. TN: total nitrogen, TIN: total inorganic nitrogen (nitrate and nitrite), TP: total phosphorus.

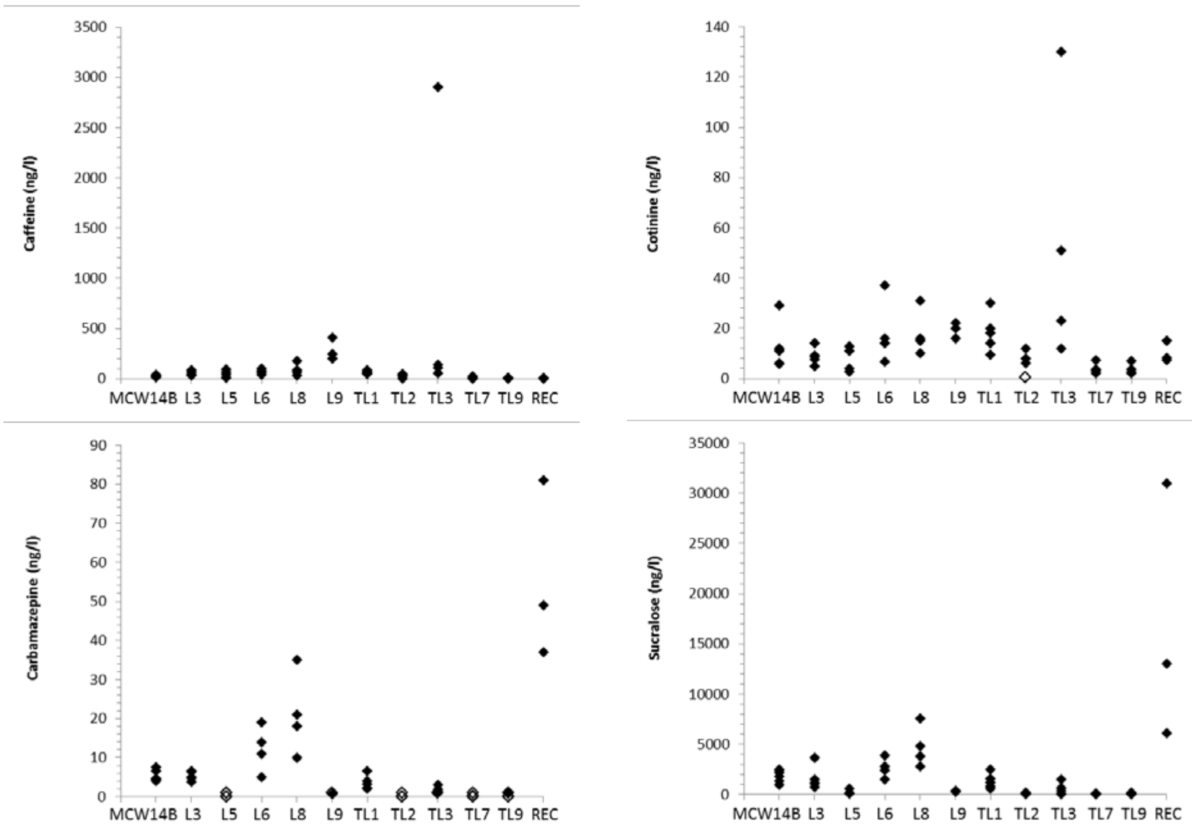


Fig. 3.14. Concentrations of potential chemical sewage indicators in Upper Lindero Creek drainage area.

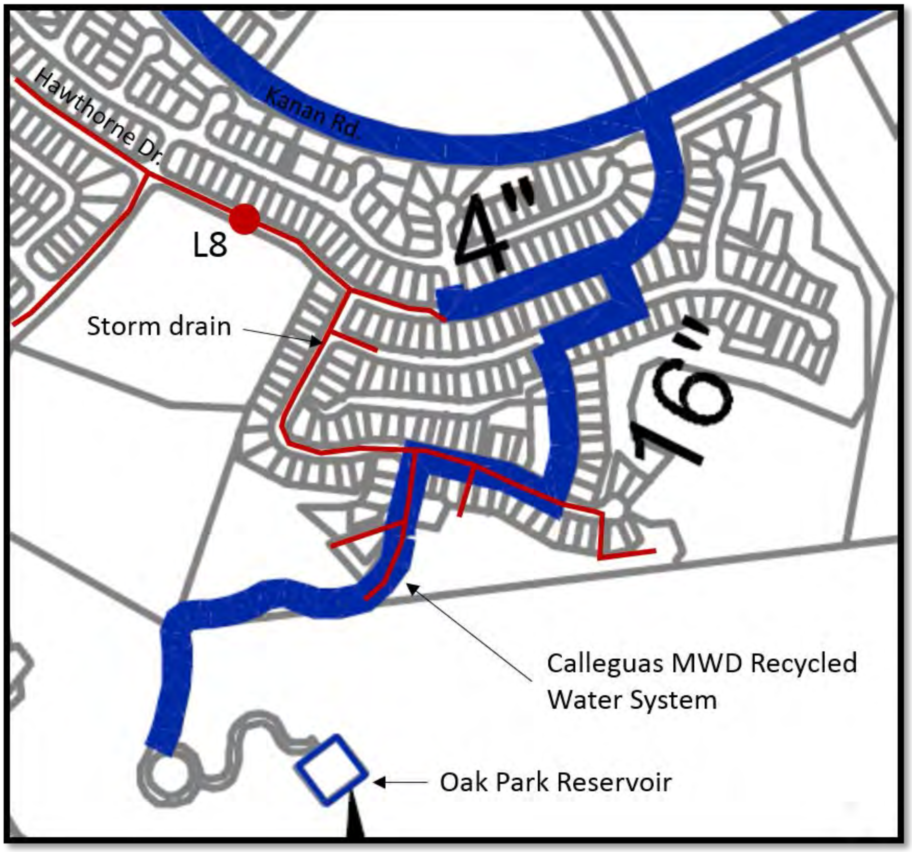


Fig. 3.15. Reclaimed and storm drain infrastructure upstream of location L8.

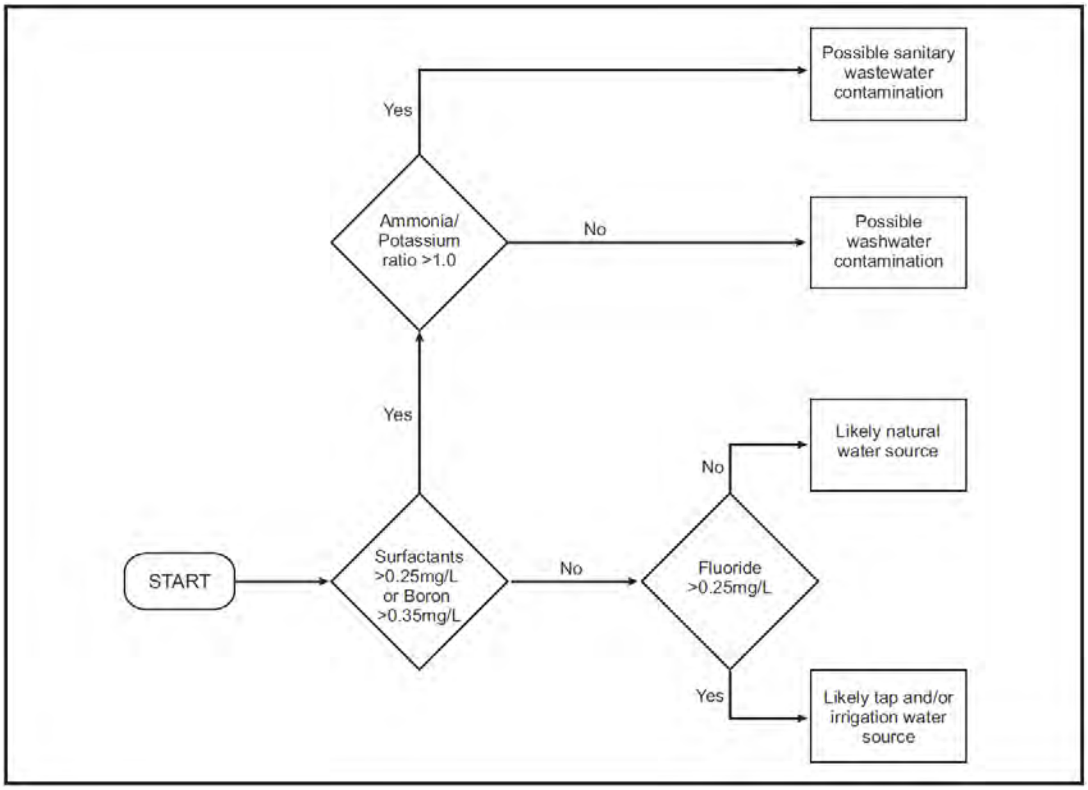
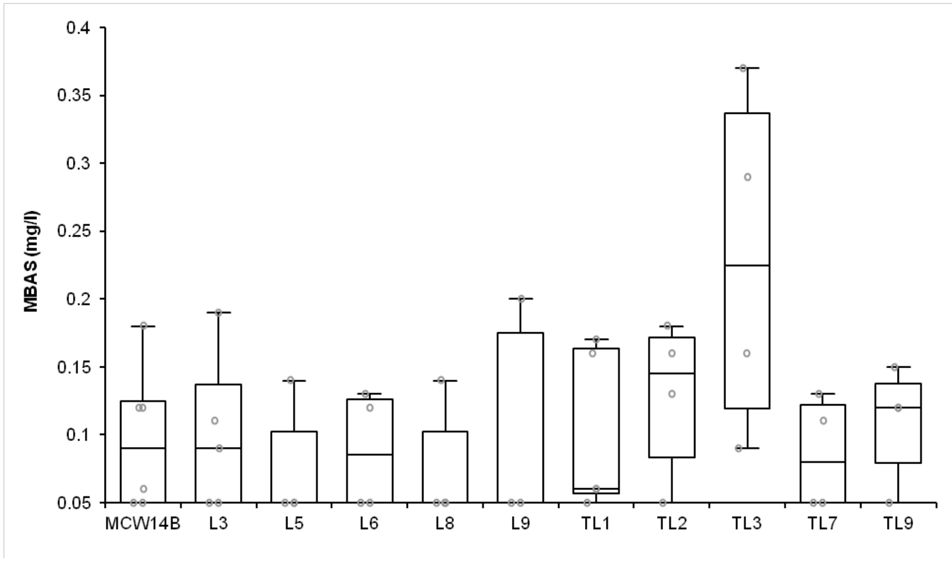


Fig. 3.16. Flow chart to identify illicit discharges in residential watersheds.



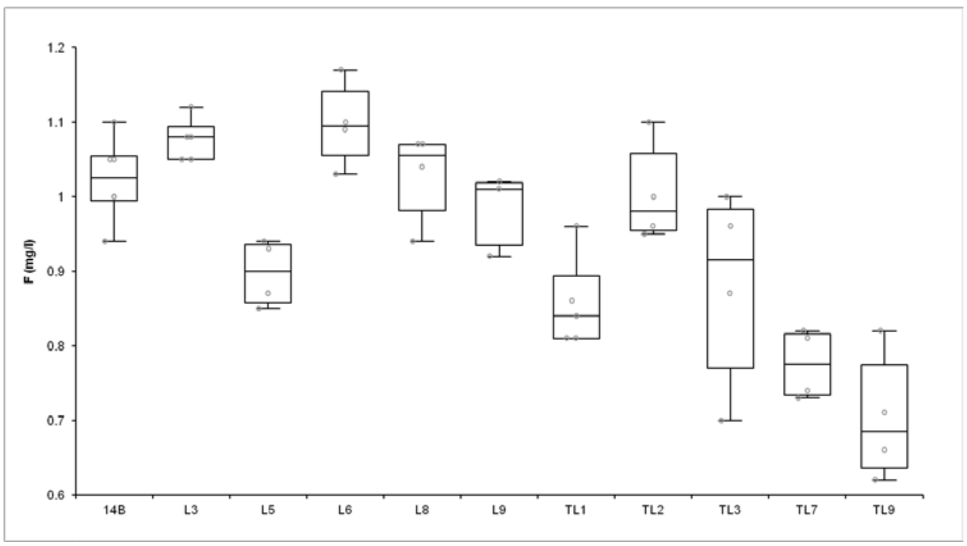


Fig. 3.17. Concentrations of MBAS (top) and fluoride (bottom) in Upper Lindero Creek drainage area.

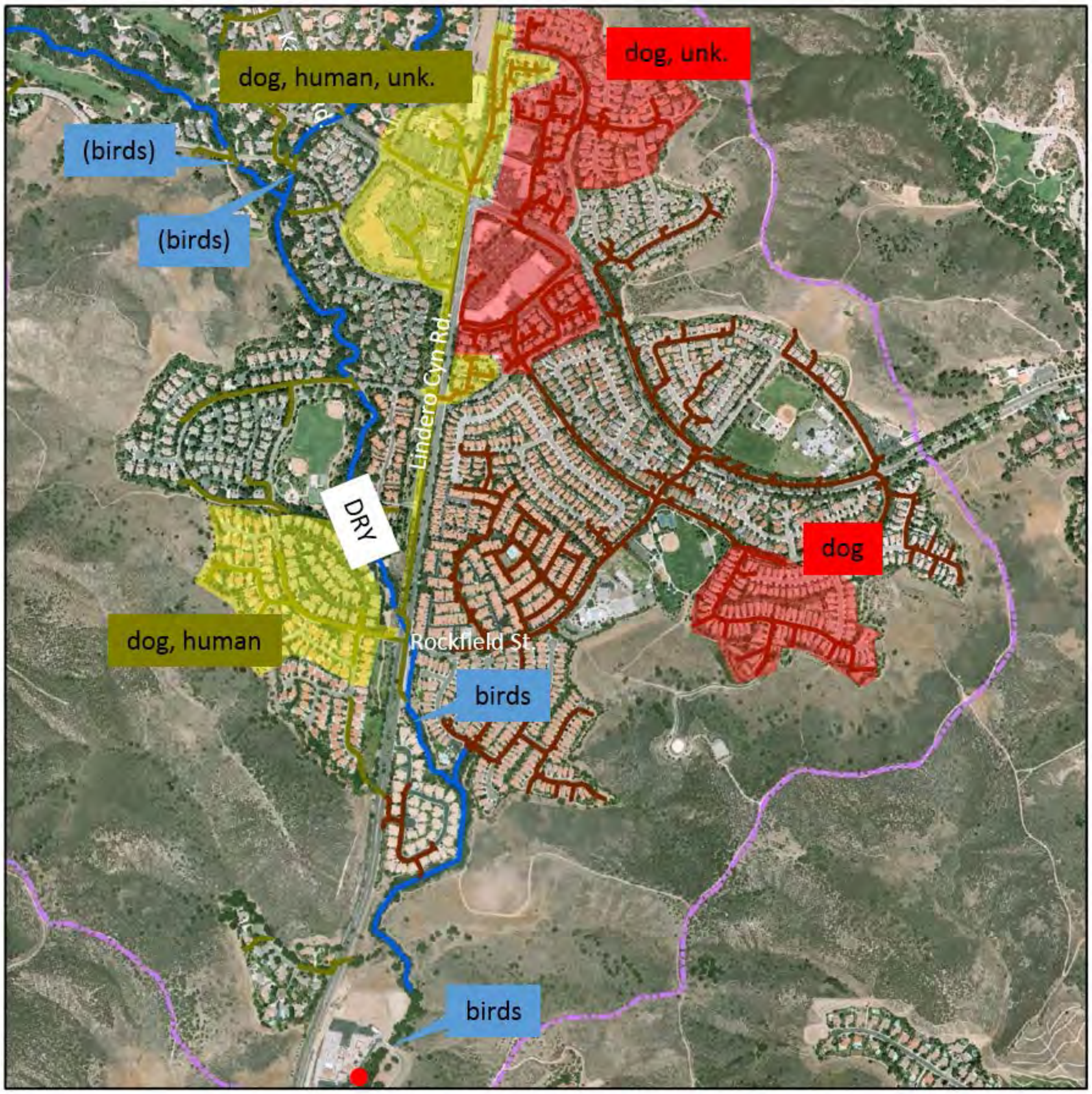


Fig. 3.18. Approximate urban areas (yellow/red) potentially contributing to elevated *E. coli* concentrations at the compliance station (red dot). Storm drains are indicated in brown (County) or green (City), creek in blue lines. Detected fecal sources are indicated in blue (creek) and green/red (storm drain) text boxes. Sources in parentheses do not contribute to the compliance station. Unknown sources are included as "unk.".

UPPER MALIBU CREEK WATERSHED SOURCE IDENTIFICATION STUDY – MEMORANDUM REPORT

APPENDIX A - METHODS

1. Source Identification Methodology

The general approach to identifying the sources of *E. coli* in the Upper MCW watershed consists of desktop surveys, field surveys and flow mapping, followed by targeted sampling and tiered analyses of *E. coli*, nutrients, IC/ID markers, host-specific DNA markers and chemical sewage indicators. This general approach was consistent with the Work Plan submitted to the Regional Board (Fig. 1). Proposed sampling in Las Virgenes and Potrero drainage areas were not performed because channels were dry for the duration of the study.

2. Level and Flow Measurements

Manual flow measurements in open channels and large storm drains with sufficient flow were obtained using the area-velocity method, using at least using at least five depth measurements per transect. Velocity readings were taken using a Marsh-McBirney velocity probe. When flow depth was insufficient, the "floating object" method was used, by measuring time-of-travel of a floating object (e.g. small leaf), travel distance and cross-sectional area. The latter method was done in triplicate at each location.

Occurrence of flow and temporal flow variation were also determined at selected locations using Solinst Levelogger Edge (2 m range) water level loggers. Sensitivity in stagnant water was tested before deployment, and levelloggers were sensitive enough to detect water levels/incremental changes of at least 1/8" (Fig. 2). Loggers were deployed attached to rocks placed in open channels or attached to the bottom of storm drain pipes (Fig. 3). One Solinst Barologger was deployed in the watershed (within 2 miles of each water level logger) for barometric pressure compensation.

It was also attempted to measure maximum flow depths in storm drain outfalls by application of chalk lines. However, the method was prone to false-positives (chalk removal occurred without flow, likely due to damp concrete surfaces) as well as false negatives (chalk lines were not always removed following flow), and therefore the use of this method was discontinued early in the study.

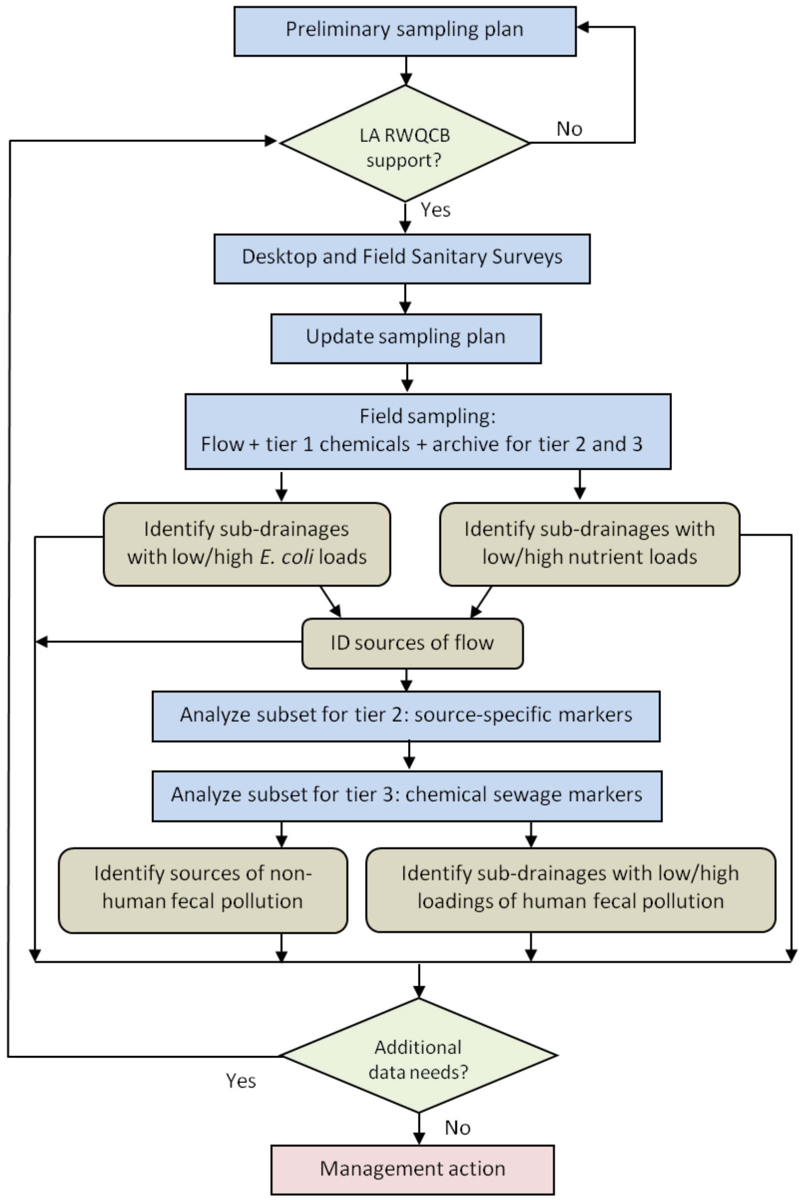


Figure 1. Source identification study general approach

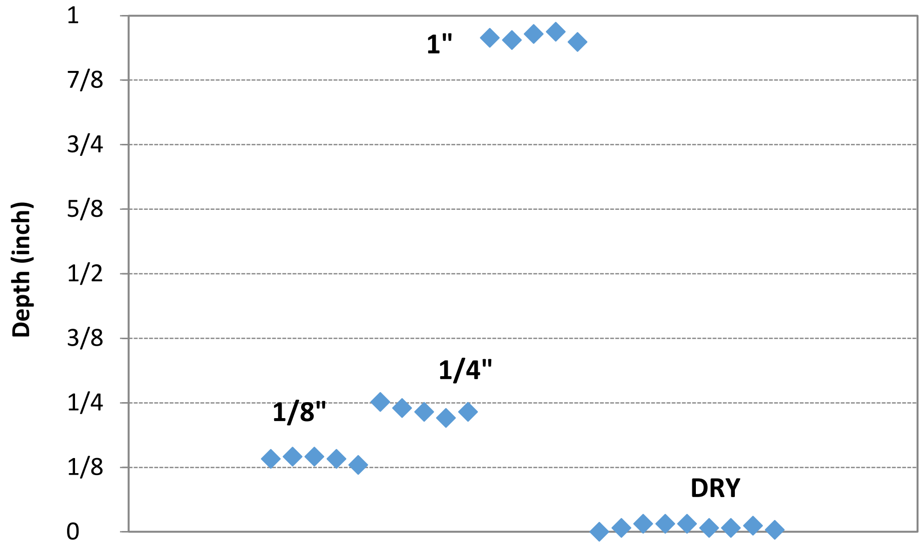


Fig. 2. Solinst Levellogger response in stagnant water depths between zero and 1 inch.

Fig. 3. Deployment of Solinst Leveloggers in storm drains and open channels

3. Chemical and Microbiological Analyses

Analytes, analytical methods, detection limits and analytical labs are summarized in the table below. Water samples for analysis of host-specific DNA markers were processed at the Ventura County Public Health Laboratory, using protocols recommended by Weston Solutions. In summary, the protocol consisted of filtering 100 ml of sample on a 0.2 µm Pall Supor filter (in duplicate), flash-freezing filters in 2 ml screw-cap tubes in liquid nitrogen and archiving frozen filters at -80 °C until shipment to analytical lab using overnight shipping.

Analyte	Method	MDL	Units	Laboratory
E. coli	SM 9223 B	10	MPN/100 ml	Pat-Chem Laboratories (Moorpark, CA)
Ammonia as N	EPA 350.2	5	µg/l	
Nitrate + nitrite as N	EPA 353.2	10	µg/l	
Total Kjeldahl Nitrogen	EPA 351.2	40	µg/l	
Total Phosphorus, as P	EPA 365.3	10	µg/l	
MBAS	SM 5540C	10	µg/l	
Fluoride	EPA 340.2	10	µg/l	
Potassium, dissolved	EPA 200.7	15	µg/l	
Caffeine	EPA 1694M-ESI+	0.31	ng/l	Weck Laboratories (City of Industry, CA)
Cotinine	EPA 1694M-ESI+	0.59	ng/l	
Carbamazepine	EPA 1694M-ESI+	0.08	ng/l	
Sucralose	EPA 1694M-ESI+	5	ng/l	
HF183 TaqMan	n/a	n/a	n/a	Weston Solutions (Carlsbad, CA)
DogBact	n/a	n/a	n/a	
GFD Bird	n/a	n/a	n/a	

4. Quality Control

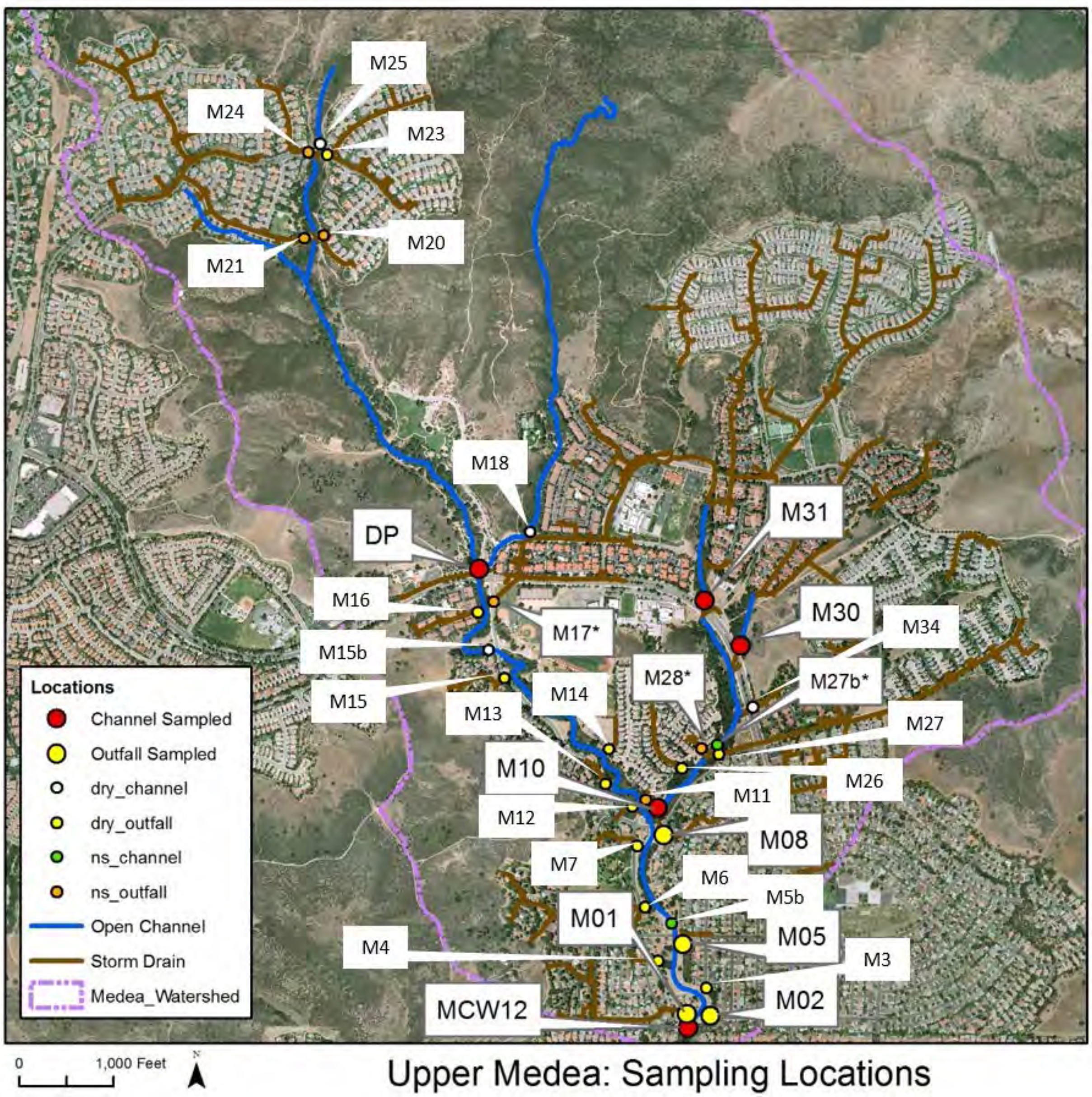
Field blanks were prepared using distilled water (Arrowhead) for *E. coli* and chemistry, and molecular grade water for host-specific markers. One line blank was prepared by pumping distilled water into sample bottles for all constituents, after rinsing by pumping two liter of distilled water, following manhole sampling at TL2.

Constituent	Units	Field blank (8/20)	Field blank (9/5)	Field blank (9/24)	Field blank (9/26)	Line blank (9/26)
E. coli	MPN/100 ml	< 10	< 10	< 1	< 10	< 10
Human marker (HF183)	copies/100 ml	ND	ND	n/a	ND	ND
Dog marker (DogBact)	copies/100 ml	ND	ND	n/a	ND	ND
Bird marker (GFD Bird)	copies/100 ml	ND	ND	n/a	ND	ND
Caffeine	ng/l	1.0	1.3	4.7	n/a	n/a
Cotinine	ng/l	< 0.59	< 0.59	< 0.59	n/a	n/a
Carbamazepine	ng/l	< 0.08	< 0.08	< 0.08	n/a	n/a
Sucralose	ng/l	< 5	< 5	< 5	n/a	n/a
Fluoride	mg/l	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Potassium, dissolved	mg/l	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
MBAS	mg/l	< 0.05	< 0.05	0.07	0.08	0.11
NO2+NO3-N	mg/l	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Total Kjeldahl Nitrogen	mg/l	0.59	< 0.05	< 0.05	< 0.05	< 0.05
Ammonium-N	mg/l	0.2	< 0.01	< 0.01	< 0.01	< 0.01
Total phosphorus	mg/l	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02

UPPER MALIBU CREEK WATERSHED SOURCE IDENTIFICATION STUDY – MEMORANDUM REPORT

APPENDIX B – FIELD SURVEY RESULTS UPPER MEDEA CREEK

1. Map of field survey locations



2. Description of field survey locations

ID	Type	Flow	Photo
MCW12	Compliance	Yes	
M01	Outfall	Yes	

M02	Outfall	Yes	
M03	Outfall	Trickle	

M04	Outfall	No	
M05	Outfall	Yes	

M06	Outfall	No	
M07	Outfall	No	

M08	Outfall	Yes	
M09	Outfall	Trickle	

M10	Culvert (2 pipes)	Yes	
M11	Outfall	Yes	

M12	Outfall	No	
M13	Outfall	No	

M14	Outfall	No	
M15	Outfall	No	

M16	Outfall	Trickle	
M17	Outfall	Yes	

M18	Channel (open space)	Dry	
M20	Outfall	Yes	

M21	Outfall	Yes	
M23	Outfall	unknown	

M24	Outfall	Trickle	
M26	Outfall	Unknown	Submerged in pond (no photo)
M27	Outfall	Yes	

M27b	Channel	Yes	
M28	Outfall	Yes	

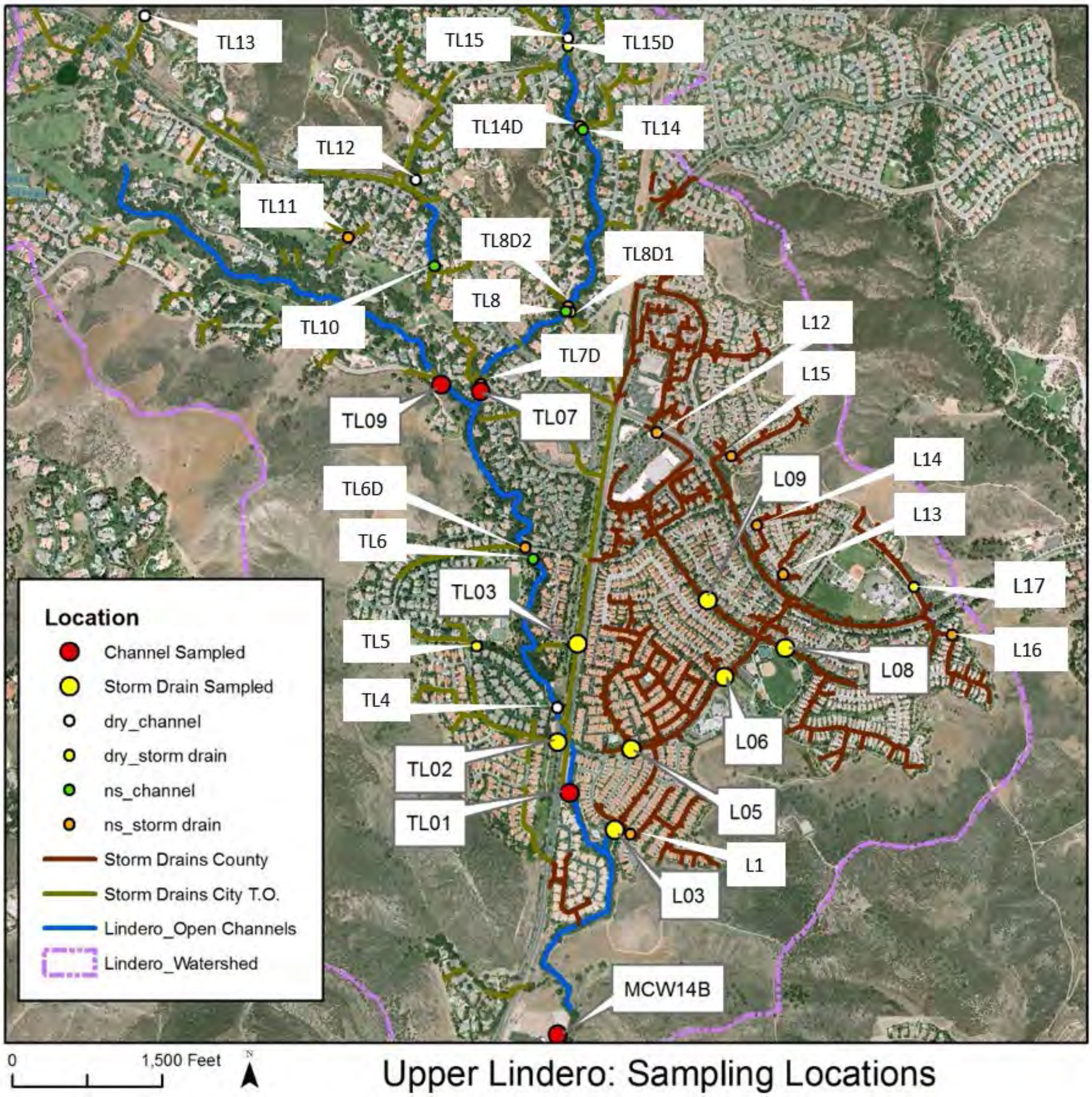
M30	Box culvert	Yes	
M31	Box culvert	Yes	

M34	Pipe culvert	No	
DP	Duck pond	Intermittent	

UPPER MALIBU CREEK WATERSHED SOURCE IDENTIFICATION STUDY – MEMORANDUM REPORT

APPENDIX B – FIELD SURVEY RESULTS UPPER LINDERO CREEK

1. Map of field survey locations



2. Characterization of field survey locations

ID	Type	Flow	Photo
MCW14B	Compliance	Yes	
L1	Storm drain manhole	Trickle	

L3	Storm drain outfall	Yes	
L4	Storm drain manhole	Trickle	

L5	Storm drain manhole	Yes	
L6	Storm drain manhole	Yes	

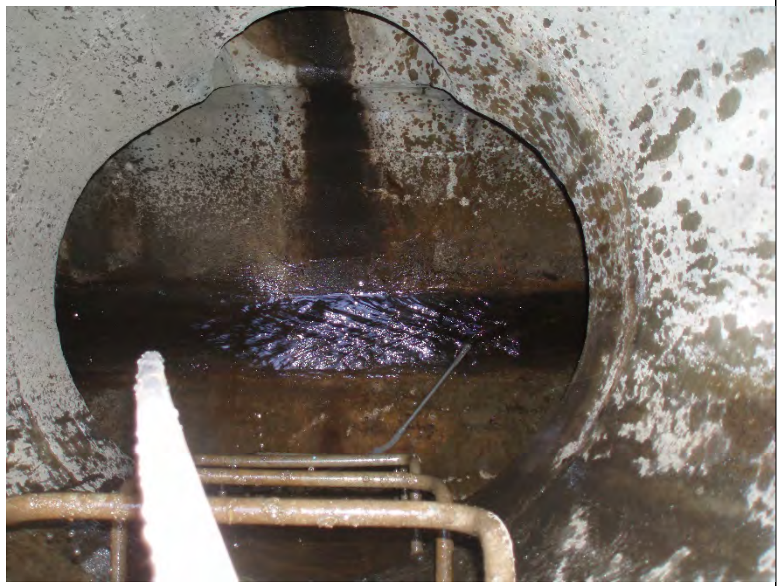
L8	Storm drain manhole	Yes	
L9	Storm drain manhole	Yes	

L12	Storm drain manhole	Yes	
L13	Storm drain manhole	Yes	

L14	Storm drain manhole	Trickle	
L15	Storm drain manhole	Trickle	

L16	Storm drain manhole	Trickle	
L17	Storm drain manhole	No	

TL1	Open channel	Yes	
TL2	Storm drain manhole	Yes	

TL3	Storm drain manhole	Yes	
TL4	Open channel	Trickle	

TL5	Storm drain outfall	Trickle	
TL6	Open channel	Yes	

TL6D	Storm drain outfall	Trickle	
TL7	Open channel	Yes	

TL7D	Storm drain outfall	Trickle	
TL8	Open channel	Yes	

TL8D1	Storm drain outfall	Trickle	
TL8D2	Storm drain outfall	Trickle	

TL9	Open channel	Yes	
TL10	Open channel (storm drain inlet)	Trickle	

TL11	Storm drain manhole	Trickle	
TL12	Open channel (culvert inlet)	No	

TL13	Open channel (storm drain inlet)	No	
TL14	Open channel	Yes	

TL14D	Storm drain outfall	Trickle	
TL15D	Storm drain outfall	Trickle	

TL15	Open channel (culvert inlet)	No	

UPPER MALIBU CREEK WATERSHED SOURCE IDENTIFICATION STUDY – MEMORANDUM REPORT

APPENDIX D – LABORATORY RESULTS

No.	ID	Date	Time	sEC	EC	sF	F	sK	K, diss	sMBAS	MBAS	sNOx	NOx
9	DP	8/15/2013	9:50		883		0.92		14.2		0.09	<	0.1
22	DP	8/20/2013	10:55		677		0.85		13.3		0.1	<	0.1
23	FB	8/20/2013	11:00	<	10	<	0.02	<	0.5	<	0.05	<	0.1
63	FB	9/5/2013	11:05	<	10	<	0.02	<	0.5	<	0.05	<	0.1
88	FB	9/24/2013	12:00	<	1	<	0.02	<	0.5		0.07	<	0.1
97	FB	9/26/2013	10:40	<	10	<	0.02	<	0.5		0.08	<	0.1
46	L3	8/29/2013	12:50		563		1.08		5.14		0.09		1.33
56	L3	9/5/2013	9:30		5172		1.08		5.39	<	0.05		1.21
65	L3	9/18/2013	11:20		1246		1.12		4.38	<	0.05		1.11
78	L3	9/24/2013	10:25		4106		1.05		4.22		0.11		1.33
90	L3	9/26/2013	11:28		833		1.05		3.89		0.19		1.29
47	L5	8/29/2013	12:25		723		0.85		2.83	<	0.05		2.7
57	L5	9/5/2013	8:05		2851		0.94		5.59	<	0.05		1.25
66	L5	9/18/2013	9:50		272		0.93		3.34		0.05		1.5
79	L5	9/24/2013	9:45		383		0.87		2.82		0.14		1.28
48	L6	8/29/2013	12:00		759		1.1		10.4		0.12		2.38
58	L6	9/5/2013	8:30		7701		1.03		7.88	<	0.05		1.52
67	L6	9/18/2013	9:30		35000		1.17		7.23	<	0.05		1.34
80	L6	9/24/2013	10:05		3654		1.09		7.15		0.13		1.52
49	L8	8/29/2013	11:15		767		0.94		10.4	<	0.05		3.74
59	L8	9/5/2013	9:10		32200		1.07		6.42	<	0.05		1.98
68	L8	9/18/2013	8:45		5172		1.07		6.37	<	0.05		1.23
81	L8	9/24/2013	9:20		189000		1.04		6.63		0.14		2
60	L9	9/5/2013	8:45		1835		0.92		5.21	<	0.05		1.04
69	L9	9/18/2013	9:10		31800		1.02		6.56	<	0.05		1.58
82	L9	9/24/2013	8:50		866400		1.01		8.93		0.2		2.81
4	M01	8/15/2013	10:50		309		1.13		11.4		0.09		4.78
12	M01	8/20/2013	8:00		279		0.88		8.78	<	0.05		1.33
27	M01	8/22/2013	7:35		862		1.38		8.63		0.13		1.55
13	M02	8/20/2013	8:35		3436		0.93		7.04		0.1		0.15
14	M02	8/20/2013	14:08										
28	M02	8/22/2013	7:55		12030		1.05		5.84		0.12		0.58
15	M05	8/20/2013	9:05		504		1.04		9.56	<	0.05		1.44
29	M05	8/22/2013	8:20		712		1.09		8.26		0.25		1.15
40	M05	8/26/2013	8:25		6488		1.16		8.9		0.16		1.03
16	M05b	8/20/2013	14:12										
30	M05b	8/22/2013	11:42										
31	M05b	8/22/2013	13:30										
5	M08	8/15/2013	10:10	>	24200		1.02		6.65		0.07		1.31
17	M08	8/20/2013	9:30		25300		0.92		5.71	<	0.05		0.91
32	M08	8/22/2013	8:50		58100		1.07		8.87		0.05		2.05
41	M08	8/26/2013	8:50	>	24200		1.09		6.27		0.06		1.22
76	M08	9/19/2013	9:00		44100								
6	M10	8/15/2013	9:30		221		0.8		8.37	<	0.05	<	0.1
18	M10	8/20/2013	9:45		216		0.69		7.8	<	0.05	<	0.1
19	M10	8/20/2013	14:32										
33	M10	8/22/2013	9:10		52		0.84		7.57	<	0.05	<	0.1
34	M10	8/22/2013	11:51										
35	M10	8/22/2013	13:35										
42	M10	8/26/2013	9:30		98		0.88		7.88		0.16	<	0.1
7	M30	8/15/2013	9:10		155		0.69		6.2	<	0.05	<	0.1
36	M30	8/22/2013	9:35		185		0.74		4.88		0.1	<	0.1
43	M30	8/26/2013	10:05		134		0.77		5.03		0.19	<	0.1
8	M31	8/15/2013	8:42		75		0.97		11.3	<	0.05	<	0.1
20	M31	8/20/2013	10:35		309		0.88		0.65	<	0.05	<	0.1
21	M31	8/20/2013	14:55										
37	M31	8/22/2013	10:20		173		1.07		9.59		0.07	<	0.1
44	M31	8/26/2013	10:30		63		1.05		9.33	<	0.05	<	0.1
75	MBP	9/19/2013	8:50		727000								
1	MCW12	8/13/2013	12:00	<	10		0.66		2.65	<	0.05		0.37
3	MCW12	8/15/2013	8:00		1296		0.82		7.51		0.16	<	0.1

No.	ID	Date	Time	sEC	EC	sF	F	sK	K, diss	sMBAS	MBAS	sNOx	NOx
10	MCW12	8/20/2013	7:35		697		0.66		5.17	<	0.05	<	0.1
11	MCW12	8/20/2013	14:05										
24	MCW12	8/22/2013	7:20		216		0.81		4.38		0.2	<	0.1
25	MCW12	8/22/2013	11:30										
26	MCW12	8/22/2013	13:40										
39	MCW12	8/26/2013	7:50		134		0.8		3.14		0.17	<	0.1
2	MCW14B	8/13/2013	11:15		80		0.94		3.93		0.06	<	0.1
45	MCW14B	8/29/2013	13:20		98		1.05		4.01	<	0.05	<	0.1
55	MCW14B	9/5/2013	10:20		74		1.05		4.66		0.18	<	0.1
64	MCW14B	9/18/2013	11:42		3441		1.1		4.32	<	0.05		0.14
77	MCW14B	9/24/2013	11:45		301		1		4.73		0.12		0.24
89	MCW14B	9/26/2013	11:50		135		1		4.05		0.12		0.22
38	REC	8/22/2013	10:20		327		0.84		11.3		0.05		4.29
62	REC	9/5/2013	11:00		20		0.81		11.1	<	0.05		6.76
96	REC	9/26/2013	8:45	<	10		0.76		12.8		0.18		5.85
50	TL01	8/29/2013	10:55		292		0.86		5.53		0.06		0.45
61	TL01	9/5/2013	9:50		15530		0.84		5.85		0.06		0.15
70	TL01	9/18/2013	8:52		2609		0.96		5.55	<	0.05		0.58
83	TL01	9/24/2013	8:58		1250		0.81		4.59		0.17		0.28
91	TL01	9/26/2013	11:05		399		0.81		7.33		0.16		3.77
51	TL02	8/29/2013	11:30		959		1.1		5.48		0.18		1.54
71	TL02	9/18/2013	10:42		1169		1		5.51	<	0.05		1.41
84	TL02	9/24/2013	11:15		146		0.95		4.65		0.16		1.44
92	TL02	9/26/2013	10:20		2064		0.96		5.05		0.13		1.56
52	TL03	8/29/2013	10:25		2809		0.96		4.36		0.37		1.23
72	TL03	9/18/2013	10:23		4611		1		5.39		0.09		1.12
85	TL03	9/24/2013	10:48		393		0.87		6.61		0.29		1.31
93	TL03	9/26/2013	10:10		613		0.7		6.23		0.16		1.7
53	TL07	8/29/2013	12:07		63		0.81		4.62	<	0.05		0.11
73	TL07	9/18/2013	9:22		754		0.82		4.66	<	0.05		0.2
86	TL07	9/24/2013	9:47		410		0.74		4.9		0.13		0.14
94	TL07	9/26/2013	9:45		292		0.73		4.59		0.11		0.11
54	TL09	8/29/2013	12:35		487		0.82		4.84	<	0.05	<	0.1
74	TL09	9/18/2013	9:45		1017		0.71		3.04		0.12	<	0.1
87	TL09	9/24/2013	10:10		201		0.66		3.56		0.12		0.12
95	TL09	9/26/2013	9:22		246		0.62		2.93		0.15	<	0.1
98	TL20	9/26/2013	10:45	<	10	<	0.02	<	0.5		0.11	<	0.1

No.	ID	Date	Time	sTKN	TKN	sNH3	NH3	sTP	TP	TN	NH3/K
9	DP	8/15/2013	9:50		3.51		0.26		2.3	3.61	0.02
22	DP	8/20/2013	10:55		2.62	<	0.01		2.26	2.72	0.00
23	FB	8/20/2013	11:00		0.59		0.2	<	0.02	0.69	0.49
63	FB	9/5/2013	11:05	<	0.05	<	0.01	<	0.02	0.15	0.02
88	FB	9/24/2013	12:00	<	0.05	<	0.01	<	0.02	0.15	0.02
97	FB	9/26/2013	10:40	<	0.05	<	0.01	<	0.02	0.15	0.02
46	L3	8/29/2013	12:50		0.77		0.06		0.38	2.1	0.01
56	L3	9/5/2013	9:30		0.99		0.16		0.27	2.2	0.04
65	L3	9/18/2013	11:20		0.76		0.18		0.3	1.87	0.05
78	L3	9/24/2013	10:25		1.09		0.17		0.21	2.42	0.05
90	L3	9/26/2013	11:28		1.2		0.25		0.23	2.49	0.08
47	L5	8/29/2013	12:25		4.51		0.17		0.83	7.21	0.07
57	L5	9/5/2013	8:05		1.58		0.11		0.32	2.83	0.02
66	L5	9/18/2013	9:50		2.38		0.16		0.14	3.88	0.06
79	L5	9/24/2013	9:45		0.43		0.03		0.11	1.71	0.01
48	L6	8/29/2013	12:00		1.67		0.1		0.94	4.05	0.01
58	L6	9/5/2013	8:30		1.3		0.1		0.54	2.82	0.02
67	L6	9/18/2013	9:30		2.18		0.05		0.38	3.52	0.01
80	L6	9/24/2013	10:05		0.9		0.16		0.45	2.42	0.03
49	L8	8/29/2013	11:15		1.18		0.04		1.45	4.92	0.00
59	L8	9/5/2013	9:10		2.12		0.08		0.48	4.1	0.02
68	L8	9/18/2013	8:45		2.14		0.06		0.43	3.37	0.01
81	L8	9/24/2013	9:20		1.26		0.09		0.56	3.26	0.02
60	L9	9/5/2013	8:45		1.66		0.37		0.19	2.7	0.09
69	L9	9/18/2013	9:10		9.06		0.08		0.3	10.64	0.01
82	L9	9/24/2013	8:50		1.04		0.19		0.67	3.85	0.03
4	M01	8/15/2013	10:50		55		0.75		0.87	59.78	0.08
12	M01	8/20/2013	8:00		4.61		0.01		0.92	5.94	0.00
27	M01	8/22/2013	7:35		5.11		1.64		0.81	6.66	0.23
13	M02	8/20/2013	8:35		0.9		0.1		0.44	1.05	0.02
14	M02	8/20/2013	14:08								
28	M02	8/22/2013	7:55		1.18		0.31		0.36	1.76	0.06
15	M05	8/20/2013	9:05		5.62		0.1		0.43	7.06	0.01
29	M05	8/22/2013	8:20		1.42	<	0.01		0.38	2.57	0.00
40	M05	8/26/2013	8:25		5.23		0.13		0.8	6.26	0.02
16	M05b	8/20/2013	14:12								
30	M05b	8/22/2013	11:42								
31	M05b	8/22/2013	13:30								
5	M08	8/15/2013	10:10		0.91		0.43		0.34	2.22	0.08
17	M08	8/20/2013	9:30		0.99		0.05		0.45	1.9	0.01
32	M08	8/22/2013	8:50		4.22		2.35		1.1	6.27	0.32
41	M08	8/26/2013	8:50		1.88		0.13		0.66	3.1	0.03
76	M08	9/19/2013	9:00								
6	M10	8/15/2013	9:30		0.42		0.12	<	0.02	0.52	0.02
18	M10	8/20/2013	9:45		0.2		0.07		0.03	0.3	0.01
19	M10	8/20/2013	14:32								
33	M10	8/22/2013	9:10		0.57		0.32		0.06	0.67	0.05
34	M10	8/22/2013	11:51								
35	M10	8/22/2013	13:35								
42	M10	8/26/2013	9:30		0.14		0.06		0.33	0.24	0.01
7	M30	8/15/2013	9:10		0.61		0.16		0.22	0.71	0.03
36	M30	8/22/2013	9:35		0.24	<	0.01		0.22	0.34	0.00
43	M30	8/26/2013	10:05		0.59		0.13		0.3	0.69	0.03
8	M31	8/15/2013	8:42		0.57		0.33		0.14	0.67	0.04
20	M31	8/20/2013	10:35		0.39	<	0.01		0.18	0.49	0.02
21	M31	8/20/2013	14:55								
37	M31	8/22/2013	10:20		0.62	<	0.01		0.13	0.72	0.00
44	M31	8/26/2013	10:30		0.4		0.19		0.08	0.5	0.02
75	MBP	9/19/2013	8:50								
1	MCW12	8/13/2013	12:00		0.55		0.49	<	0.02	0.92	0.22
3	MCW12	8/15/2013	8:00		2.77		0.22		0.23	2.87	0.04

No.	ID	Date	Time	sTKN	TKN	sNH3	NH3	sTP	TP	TN	NH3/K
10	MCW12	8/20/2013	7:35		2.31		0.3		0.28	2.41	0.07
11	MCW12	8/20/2013	14:05								
24	MCW12	8/22/2013	7:20		3.26		0.08		0.3	3.36	0.02
25	MCW12	8/22/2013	11:30								
26	MCW12	8/22/2013	13:40								
39	MCW12	8/26/2013	7:50		1.47		0.19		0.14	1.57	0.07
2	MCW14B	8/13/2013	11:15		0.23		0.22		0.21	0.33	0.07
45	MCW14B	8/29/2013	13:20		0.24		0.08		0.13	0.34	0.02
55	MCW14B	9/5/2013	10:20		0.37		0.14		0.14	0.47	0.04
64	MCW14B	9/18/2013	11:42		0.39		0.18		0.26	0.53	0.05
77	MCW14B	9/24/2013	11:45		0.34	<	0.01		0.17	0.58	0.00
89	MCW14B	9/26/2013	11:50		0.25	<	0.01		0.1	0.47	0.00
38	REC	8/22/2013	10:20		0.81		0.04		2.18	5.1	0.00
62	REC	9/5/2013	11:00		0.82	<	0.01		1.83	7.58	0.00
96	REC	9/26/2013	8:45		1.2		0.14		2.46	7.05	0.01
50	TL01	8/29/2013	10:55		0.88		0.25		0.46	1.33	0.05
61	TL01	9/5/2013	9:50		1.52	<	0.01		0.36	1.67	0.00
70	TL01	9/18/2013	8:52		1.88	<	0.01		0.3	2.46	0.00
83	TL01	9/24/2013	8:58		0.98		0.35		0.32	1.26	0.09
91	TL01	9/26/2013	11:05		4.14		2.82		0.84	7.91	0.47
51	TL02	8/29/2013	11:30		0.84		0.15		0.29	2.38	0.03
71	TL02	9/18/2013	10:42		1.56	<	0.01		0.29	2.97	0.00
84	TL02	9/24/2013	11:15		0.24		0.05		0.06	1.68	0.01
92	TL02	9/26/2013	10:20		0.93		0.29		0.27	2.49	0.07
52	TL03	8/29/2013	10:25		1.21		0.07		0.27	2.44	0.02
72	TL03	9/18/2013	10:23		3.19	<	0.01		0.63	4.31	0.00
85	TL03	9/24/2013	10:48		1.57	<	0.01		0.36	2.88	0.00
93	TL03	9/26/2013	10:10		3.71		0.41		0.69	5.41	0.08
53	TL07	8/29/2013	12:07		0.5		0.02		0.03	0.61	0.01
73	TL07	9/18/2013	9:22		0.18	<	0.01		0.03	0.38	0.00
86	TL07	9/24/2013	9:47		0.15	<	0.01	<	0.02	0.29	0.00
94	TL07	9/26/2013	9:45		0.13	<	0.01	<	0.02	0.24	0.00
54	TL09	8/29/2013	12:35		0.16		0.03		0.07	0.26	0.01
74	TL09	9/18/2013	9:45		0.34	<	0.014		0.05	0.44	0.01
87	TL09	9/24/2013	10:10		1.15	<	0.01		0.04	1.27	0.00
95	TL09	9/26/2013	9:22		0.13	<	0.01		0.03	0.23	0.00
98	TL20	9/26/2013	10:45	<	0.05	<	0.01	<	0.02	0.15	0.02

No.	ID	Date	Time	Human	sd	Dog	sd	Bird	sd	sCAF	CAF
9	DP	8/15/2013	9:50	nd		bdl		bdl			
22	DP	8/20/2013	10:55	nd		4671	1058	2854	1030		
23	FB	8/20/2013	11:00	nd		nd		nd			1
63	FB	9/5/2013	11:05	nd		nd		nd			1.3
88	FB	9/24/2013	12:00								4.7
97	FB	9/26/2013	10:40	nd		nd		nd			
46	L3	8/29/2013	12:50	bdl		9221	2267	bdl			37
56	L3	9/5/2013	9:30	bdl		96710	16034	bdl			88
65	L3	9/18/2013	11:20	bdl		3658	2527	bdl			38
78	L3	9/24/2013	10:25	nd		81751	11104	nd			29
90	L3	9/26/2013	11:28	bdl		DNQ		bdl			64
47	L5	8/29/2013	12:25	nd		nd		bdl			39
57	L5	9/5/2013	8:05	bdl		nd		bdl			62
66	L5	9/18/2013	9:50	nd		nd		bdl			92
79	L5	9/24/2013	9:45	nd		nd		nd			8.6
48	L6	8/29/2013	12:00	bdl		40451	10562	bdl			80
58	L6	9/5/2013	8:30	nd		250542	35895	bdl			98
67	L6	9/18/2013	9:30	nd		22683	3434	bdl			64
80	L6	9/24/2013	10:05	nd		246479	39993	bdl			42
49	L8	8/29/2013	11:15	bdl		174879	13767	bdl			180
59	L8	9/5/2013	9:10	bdl		1865472	149071	bdl			64
68	L8	9/18/2013	8:45	nd		128272	16628	bdl			90
81	L8	9/24/2013	9:20	nd		3082265	162195	bdl			33
60	L9	9/5/2013	8:45	nd		DNQ		bdl			200
69	L9	9/18/2013	9:10	nd		nd		nd			250
82	L9	9/24/2013	8:50	nd		DNQ		bdl			410
4	M01	8/15/2013	10:50	bdl		nd		bdl			
12	M01	8/20/2013	8:00	nd		nd		bdl			
27	M01	8/22/2013	7:35	nd		nd		bdl			
13	M02	8/20/2013	8:35	nd		33283	5174	bdl			900
14	M02	8/20/2013	14:08								
28	M02	8/22/2013	7:55	599	102	nd		bdl			160
15	M05	8/20/2013	9:05	nd		nd		bdl			190
29	M05	8/22/2013	8:20	nd		nd		bdl			230
40	M05	8/26/2013	8:25	291	9	nd		bdl			310
16	M05b	8/20/2013	14:12								
30	M05b	8/22/2013	11:42								
31	M05b	8/22/2013	13:30								
5	M08	8/15/2013	10:10	nd		nd		bdl			38
17	M08	8/20/2013	9:30	nd		bdl		bdl			35
32	M08	8/22/2013	8:50	bdl		nd		bdl			35
41	M08	8/26/2013	8:50	bdl		nd		bdl			46
76	M08	9/19/2013	9:00								
6	M10	8/15/2013	9:30			nd		bdl			3.1
18	M10	8/20/2013	9:45			nd		1884	765		4.5
19	M10	8/20/2013	14:32								
33	M10	8/22/2013	9:10			nd		3645	354		2.7
34	M10	8/22/2013	11:51								
35	M10	8/22/2013	13:35								
42	M10	8/26/2013	9:30			nd		3485	513		1.7
7	M30	8/15/2013	9:10								
36	M30	8/22/2013	9:35								
43	M30	8/26/2013	10:05								
8	M31	8/15/2013	8:42								
20	M31	8/20/2013	10:35								
21	M31	8/20/2013	14:55								
37	M31	8/22/2013	10:20								
44	M31	8/26/2013	10:30								
75	MBP	9/19/2013	8:50								
1	MCW12	8/13/2013	12:00	nd		nd		3135	663		4.8
3	MCW12	8/15/2013	8:00	nd		nd		3593	489		54

No.	ID	Date	Time	Human	sd	Dog	sd	Bird	sd	sCAF	CAF
10	MCW12	8/20/2013	7:35	nd		nd		DNQ			52
11	MCW12	8/20/2013	14:05								
24	MCW12	8/22/2013	7:20	nd		nd		9896	1589		1
25	MCW12	8/22/2013	11:30								
26	MCW12	8/22/2013	13:40								
39	MCW12	8/26/2013	7:50	nd		nd		3350	684		3.2
2	MCW14B	8/13/2013	11:15	nd		nd		bdl			24
45	MCW14B	8/29/2013	13:20	nd		nd		DNQ			41
55	MCW14B	9/5/2013	10:20	nd		nd		2740	954		36
64	MCW14B	9/18/2013	11:42	nd		nd		4196	912		25
77	MCW14B	9/24/2013	11:45	nd		nd		3331	1442		21
89	MCW14B	9/26/2013	11:50	nd		nd		2260	1306		18
38	REC	8/22/2013	10:20	nd		bdl		3228	1187		13
62	REC	9/5/2013	11:00	nd		nd		bdl			4.6
96	REC	9/26/2013	8:45	nd		nd		nd			1.5
50	TL01	8/29/2013	10:55	nd		bdl		2679	455		66
61	TL01	9/5/2013	9:50	bdl		4199	921	DNQ			59
70	TL01	9/18/2013	8:52	bdl		2659	1422	4556	679		88
83	TL01	9/24/2013	8:58	nd		DNQ		2487	336		69
91	TL01	9/26/2013	11:05	nd		22616	2689	1962	662		50
51	TL02	8/29/2013	11:30	1534	256	DNQ		bdl			49
71	TL02	9/18/2013	10:42	DNQ		19958	3667	bdl			31
84	TL02	9/24/2013	11:15	412	135	bdl		bdl			4
92	TL02	9/26/2013	10:20	DNQ		391577	53151	bdl			26
52	TL03	8/29/2013	10:25	DNQ		bdl		bdl			140
72	TL03	9/18/2013	10:23	nd		bdl		bdl			2900
85	TL03	9/24/2013	10:48	nd		nd		bdl			110
93	TL03	9/26/2013	10:10	nd		27619	8020	bdl			57
53	TL07	8/29/2013	12:07	nd		nd		DNQ			25
73	TL07	9/18/2013	9:22	nd		nd		DNQ			9.5
86	TL07	9/24/2013	9:47	nd		nd		bdl			4.1
94	TL07	9/26/2013	9:45	nd		nd		bdl			1.1
54	TL09	8/29/2013	12:35	nd		nd		DNQ			8
74	TL09	9/18/2013	9:45	nd		nd		bdl			4.7
87	TL09	9/24/2013	10:10	nd		bdl		bdl			4.6
95	TL09	9/26/2013	9:22	nd		bdl		2316	616		7.8
98	TL20	9/26/2013	10:45	nd		nd		nd			

No.	ID	Date	Time	sCOT	COT	sCARB	CARB	sSUCR	SUCR	SC	pH	T
9	DP	8/15/2013	9:50							1383	8.82	22.9
22	DP	8/20/2013	10:55							1500	8.8	24.2
23	FB	8/20/2013	11:00	<	0.59	<	0.08	<	5	na	na	na
63	FB	9/5/2013	11:05	<	0.59	<	0.08	<	5	na	na	na
88	FB	9/24/2013	12:00	<	0.59	<	0.08	<	5	na	na	na
97	FB	9/26/2013	10:40							na	na	na
46	L3	8/29/2013	12:50		14		6.6		3700	2610	7.11	21.7
56	L3	9/5/2013	9:30		9		3.8		1100	2213	7.1	22
65	L3	9/18/2013	11:20		7.8		4.8		770	2483	6.95	21.4
78	L3	9/24/2013	10:25		4.9		5		1100	2580	7.07	20.8
90	L3	9/26/2013	11:28		9.2		6.4		1500	2580	7.03	19.9
47	L5	8/29/2013	12:25		4		1		150	1391	8.34	26.3
57	L5	9/5/2013	8:05		11		1		630	1634	8.3	23.2
66	L5	9/18/2013	9:50		13		0.08		150	2295	8.03	23.1
79	L5	9/24/2013	9:45		2.7		0.08		120	2241	8.36	23
48	L6	8/29/2013	12:00		37		19		3900	1541	8.2	25.2
58	L6	9/5/2013	8:30		14		5		2800	1247	8.3	na
67	L6	9/18/2013	9:30		16		11		1500	1619	8.15	21.5
80	L6	9/24/2013	10:05		6.7		14		2400	1869	8.23	22.3
49	L8	8/29/2013	11:15		16		35		7600	1369	7.86	25.6
59	L8	9/5/2013	9:10		15		10		4800	1249	8	24.2
68	L8	9/18/2013	8:45		31		18		2800	1056	7.85	21.4
81	L8	9/24/2013	9:20		10		21		3800	1339	8.04	21.7
60	L9	9/5/2013	8:45		22		1		250	415.3	8.3	23.2
69	L9	9/18/2013	9:10		20		0.08-1		340	779	8.19	21.8
82	L9	9/24/2013	8:50		16		0.66		370	780	8.24	21.8
4	M01	8/15/2013	10:50							1620	7.58	22.5
12	M01	8/20/2013	8:00							744	8.01	21.1
27	M01	8/22/2013	7:35							954	8.14	21.1
13	M02	8/20/2013	8:35		34		1.7		210	883	8.05	21.1
14	M02	8/20/2013	14:08							850		
28	M02	8/22/2013	7:55		12		1		640	664	8.19	20.1
15	M05	8/20/2013	9:05		21		1.3		540	997	7.95	21
29	M05	8/22/2013	8:20		16		1.4		980	955	8.05	21
40	M05	8/26/2013	8:25		34		1.1		170	725	7.99	20.5
16	M05b	8/20/2013	14:12							3688		
30	M05b	8/22/2013	11:42							3646		
31	M05b	8/22/2013	13:30							4105		
5	M08	8/15/2013	10:10		9.6		1.6		570	2470	8.07	19.6
17	M08	8/20/2013	9:30		6.9		1.7		580	2090	7.99	19.4
32	M08	8/22/2013	8:50		8.7		1.4		810	2041	8	19.1
41	M08	8/26/2013	8:50		9.1		1.5		410	1741	8.06	18.4
76	M08	9/19/2013	9:00									
6	M10	8/15/2013	9:30		2		6.4		3400	4764	7.91	19
18	M10	8/20/2013	9:45		2.1		6.8		3700	5118	8	18.8
19	M10	8/20/2013	14:32							5020		
33	M10	8/22/2013	9:10		2		6.5		3800	5074	7.98	18.1
34	M10	8/22/2013	11:51							4633		
35	M10	8/22/2013	13:35							5050		
42	M10	8/26/2013	9:30		2.2		6.5		4600	5290	8	17.7
7	M30	8/15/2013	9:10							4212	7.73	18
36	M30	8/22/2013	9:35							4483	7.7	17.6
43	M30	8/26/2013	10:05							4627	7.54	16.8
8	M31	8/15/2013	8:42							3864	7.59	18
20	M31	8/20/2013	10:35							4063	7.77	18.6
21	M31	8/20/2013	14:55							4390		
37	M31	8/22/2013	10:20							4041	7.86	18.6
44	M31	8/26/2013	10:30							4287	7.77	18
75	MBP	9/19/2013	8:50									
1	MCW12	8/13/2013	12:00		2		1		220	na	na	na
3	MCW12	8/15/2013	8:00		16		1.5		560	1676	7.53	19.2

No.	ID	Date	Time	sCOT	COT	sCARB	CARB	sSUCR	SUCR	SC	pH	T
10	MCW12	8/20/2013	7:35		8.1		1.6		900	1919	7.61	18.9
11	MCW12	8/20/2013	14:05							2419		
24	MCW12	8/22/2013	7:20		2.4		1.1		220	3035	7.4	18.1
25	MCW12	8/22/2013	11:30							2965		
26	MCW12	8/22/2013	13:40							2911		
39	MCW12	8/26/2013	7:50		2.2		1		130	2819	7.75	17
2	MCW14B	8/13/2013	11:15		29		4.2		2200	2651	7.75	17.6
45	MCW14B	8/29/2013	13:20		11		4		2500	2616	7.82	19.8
55	MCW14B	9/5/2013	10:20		12		4.7		2400	2691	7.8	20.6
64	MCW14B	9/18/2013	11:42		12		7.6		1400	2640	7.66	17.7
77	MCW14B	9/24/2013	11:45		5.9		6.7		1800	2562	7.65	17
89	MCW14B	9/26/2013	11:50		6.2		4.6		1000	2542	7.69	16.2
38	REC	8/22/2013	10:20		8.2		37		31000			
62	REC	9/5/2013	11:00		15		49		6100	na	na	na
96	REC	9/26/2013	8:45		7.3		81		13000	1136	7.37	24.9
50	TL01	8/29/2013	10:55		18		4		2500	na	7.2	20.4
61	TL01	9/5/2013	9:50		20		2		1200	2968	7.3	20.5
70	TL01	9/18/2013	8:52		30		3.3		860	na	7.21	18.6
83	TL01	9/24/2013	8:58		14		2.2		600	2956	7.31	17.1
91	TL01	9/26/2013	11:05		9.6		6.6		1600	2804	2.44	17.9
51	TL02	8/29/2013	11:30		6		1		210	na	7.6	24
71	TL02	9/18/2013	10:42		12		0.08		120	1858	7.91	22.9
84	TL02	9/24/2013	11:15		0.59		0.08		20	2069	7.95	23.3
92	TL02	9/26/2013	10:20		8.1		0.08		98	1697	7.85	20.9
52	TL03	8/29/2013	10:25		12		1		93	?	?	?
72	TL03	9/18/2013	10:23		130		1.2		1500	832	7.92	23
85	TL03	9/24/2013	10:48		51		3		680	1701	7.92	23.2
93	TL03	9/26/2013	10:10		23		1.8		370	2672	na	22.2
53	TL07	8/29/2013	12:07		3.6		1		62	na	na	20.2
73	TL07	9/18/2013	9:22		7.3		0.08		150	na	7.94	17.2
86	TL07	9/24/2013	9:47		3.1		0.08		81	2793	7.92	15.9
94	TL07	9/26/2013	9:45		2.3		0.08		83	2656	7.96	15.3
54	TL09	8/29/2013	12:35		3.7		1		95	na	7.9	20.5
74	TL09	9/18/2013	9:45		7		0.08-1		180	1338	7.9	16.4
87	TL09	9/24/2013	10:10		2.4		0.08		120	2877	7.85	15.5
95	TL09	9/26/2013	9:22		2.1		0.08		94	2836	7.85	15
98	TL20	9/26/2013	10:45							na	na	na

No.	ID	Date	Time	DO (%)	Notes		
9	DP	8/15/2013	9:50	90.1			
22	DP	8/20/2013	10:55	75			
23	FB	8/20/2013	11:00	na	DI for chemicals, DNA grade water for HF183		
63	FB	9/5/2013	11:05	na	DI for chemicals, DNA grade water for HF183		
88	FB	9/24/2013	12:00	na	DI for chemicals, no blank for HF183		
97	FB	9/26/2013	10:40	na	DI for chemicals, DNA grade water for HF183		
46	L3	8/29/2013	12:50	62.8			
56	L3	9/5/2013	9:30	67.4			
65	L3	9/18/2013	11:20	45.8			
78	L3	9/24/2013	10:25	45.4			
90	L3	9/26/2013	11:28	52.8			
47	L5	8/29/2013	12:25	90.7			
57	L5	9/5/2013	8:05	128.1			
66	L5	9/18/2013	9:50	82.5			
79	L5	9/24/2013	9:45	97.5			
48	L6	8/29/2013	12:00	92.6			
58	L6	9/5/2013	8:30	121.8			
67	L6	9/18/2013	9:30	86.3			
80	L6	9/24/2013	10:05	81.5			
49	L8	8/29/2013	11:15	69.7			
59	L8	9/5/2013	9:10	104.5			
68	L8	9/18/2013	8:45	81.3			
81	L8	9/24/2013	9:20	78.6			
60	L9	9/5/2013	8:45	118.5			
69	L9	9/18/2013	9:10	84.5			
82	L9	9/24/2013	8:50	84.5			
4	M01	8/15/2013	10:50	83.5			
12	M01	8/20/2013	8:00	154			
27	M01	8/22/2013	7:35	156			
13	M02	8/20/2013	8:35	105			
14	M02	8/20/2013	14:08				
28	M02	8/22/2013	7:55	140			
15	M05	8/20/2013	9:05	156			
29	M05	8/22/2013	8:20	114			
40	M05	8/26/2013	8:25	82			
16	M05b	8/20/2013	14:12				
30	M05b	8/22/2013	11:42				
31	M05b	8/22/2013	13:30				
5	M08	8/15/2013	10:10	67.7			
17	M08	8/20/2013	9:30	68			
32	M08	8/22/2013	8:50	85			
41	M08	8/26/2013	8:50	57			
76	M08	9/19/2013	9:00		Ducks downstream, sediment at M8 stirred up		
6	M10	8/15/2013	9:30	69.4			
18	M10	8/20/2013	9:45	105			
19	M10	8/20/2013	14:32				
33	M10	8/22/2013	9:10	79			
34	M10	8/22/2013	11:51				
35	M10	8/22/2013	13:35				
42	M10	8/26/2013	9:30	78			
7	M30	8/15/2013	9:10	55.8			
36	M30	8/22/2013	9:35	56			
43	M30	8/26/2013	10:05	61			
8	M31	8/15/2013	8:42	64.2			
20	M31	8/20/2013	10:35	108			
21	M31	8/20/2013	14:55				
37	M31	8/22/2013	10:20	83			
44	M31	8/26/2013	10:30	57			
75	MBP	9/19/2013	8:50				
1	MCW12	8/13/2013	12:00	na	Sampled upstream of M2		
3	MCW12	8/15/2013	8:00	42.4			

No.	ID	Date	Time	DO (%)	Notes		
10	MCW12	8/20/2013	7:35	176			
11	MCW12	8/20/2013	14:05				
24	MCW12	8/22/2013	7:20	189			
25	MCW12	8/22/2013	11:30				
26	MCW12	8/22/2013	13:40				
39	MCW12	8/26/2013	7:50	23			
2	MCW14B	8/13/2013	11:15	62.3			
45	MCW14B	8/29/2013	13:20	67.2			
55	MCW14B	9/5/2013	10:20	57.2			
64	MCW14B	9/18/2013	11:42	52.3	Ducks present, sediment stirred up		
77	MCW14B	9/24/2013	11:45	53.2	5 ducks downstream, sediment stirred up		
89	MCW14B	9/26/2013	11:50	60.3	no ducks, no sediment stirred up (clear water)		
38	REC	8/22/2013	10:20				
62	REC	9/5/2013	11:00	na			
96	REC	9/26/2013	8:45	91.9	slightly yellow colored (in bucket)		
50	TL01	8/29/2013	10:55	26.3			
61	TL01	9/5/2013	9:50	37.1			
70	TL01	9/18/2013	8:52	38.3			
83	TL01	9/24/2013	8:58	27.6			
91	TL01	9/26/2013	11:05	26.8			
51	TL02	8/29/2013	11:30	80			
71	TL02	9/18/2013	10:42	81.4			
84	TL02	9/24/2013	11:15	68.8			
92	TL02	9/26/2013	10:20	89.8			
52	TL03	8/29/2013	10:25	?			
72	TL03	9/18/2013	10:23	85.5			
85	TL03	9/24/2013	10:48	69.2			
93	TL03	9/26/2013	10:10	92.5			
53	TL07	8/29/2013	12:07	61.7			
73	TL07	9/18/2013	9:22	84.9			
86	TL07	9/24/2013	9:47	65.4			
94	TL07	9/26/2013	9:45	81.5			
54	TL09	8/29/2013	12:35	74.4			
74	TL09	9/18/2013	9:45	76.7			
87	TL09	9/24/2013	10:10	60.4			
95	TL09	9/26/2013	9:22	74.7			
98	TL20	9/26/2013	10:45	na	Line blank, using DI after rinsing line with DI (also DI for HF183)		