Southern California
Stormwater Monitoring Coalition
Unified Approach to Stormwater Monitoring

Program Inventory and Workplan

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Executive Summary

In this report, we provide a workplan for developing a unified approach to stormwater monitoring (UASM) in southern California. We have also included an updated inventory of the Municipal Separate Storm Sewer System (MS4) monitoring programs maintained by the stormwater permittees within the Los Angeles, Santa Ana, and San Diego Regional Water Quality Control Boards.

The inventory reviewed 7 National Pollutant Discharge Elimination System (NPDES) permits, 4 annual reports, and 39 monitoring plans, including enhanced watershed management plans (EWMPs), coordinated integrated monitoring plans (CIMPs), or water quality improvement plans (WQIPs). Based on the review, we identified eight standardized monitoring questions for addressing the priority management objectives common to all MS4 monitoring programs. The eight standardized monitoring questions are the following:

Q1. What pollutants are associated with the stormwater runoff?

Q2. What are the sources of the identified pollutant(s)?

Q3. What are the sources (and magnitudes) of illicit discharge/illegal connections?

Q4. How effective the BMPs are for reducing flow and contaminant concentrations?

Q5. If (and how) the stormwater is influencing the quality of receiving water?

Q6. What is the overall health of receiving water?

Q7. If (and what) receiving water needs management actions based on its overall health?

Q8. How effective are the current water quality management plans?

Designing consistent monitoring elements, a core component of a standardized MS4 monitoring framework, is the key to ensure that the above-mentioned standardized monitoring objectives are met. The MS4 monitoring elements can be classified into four broad categories: design and planning, field techniques for data collection, laboratory methods, and reporting. The details of the monitoring elements (e.g., qualifying storm events, sampling frequency, data analyses techniques, etc.), influences the efficacy of a monitoring program for answering each monitoring question. We review the EWMPs and WQIPs to identify the similarities and dissimilarities across the monitoring programs in terms of the monitoring element details. Based on the inventory of the monitoring elements and their linkage to the standardized monitoring questions, we recommend a list of monitoring elements to be standardized to answer each monitoring question (Table Ex-1).

Based on the inventory analyses, we identify some specific knowledge gaps that need to be addressed for standardizing each monitoring element. The knowledge gaps are summarized below:

a) Standardize first-flush selection criteria
b) Standardize sampling site screening while planning for MS4 monitoring

c) Standardize field-sampling procedures
d) Standardize laboratory analytical methods
e) Standardize data analyses and reporting format

A workplan was developed to address each knowledge gap, then produce the UASM guidance. The recommended workplan is a critical pathway to standardized MS4 monitoring in southern California. The workplan can be used as a scope of work for the next step in the UASM process.

Table Ex-1: Linkage between the standardized monitoring questions and the monitoring elements based on the monitoring inventory of MS4 programs throughout southern California

Standardized Monitoring Question	**Storm event selection**	**Sampling frequency**	**Field sampling procedure**	**Flow measurement**	**Outfall selection**	**Outfall description**	**Laboratory methods & reporting limits**	**Data analyses**
Q1. What pollutants are associated with stormwater runoff?	**x**		**x**		**x**		**x**	
Q2. What are the sources of the identified pollutant(s)?	**x**	**x**				**x**	**x**	
Q3. If (and how) stormwater is influencing the quality of receiving water?		**x**	**x**	**x**			**x**	**x**
Q4. What are the sources (and magnitudes) of illicit discharge/illegal connections?					**x**	**x**	**x**	**x**
Q5. How effective the BMPs are for reducing flow and contaminant concentrations?	**x**			**x**	**x**		**x**	**x**
Q6. What is the overall health of receiving water?		**x**						**x**
Q7. If (and what) receiving water needs management actions based on its overall health?		**x**			**x**			**x**
Q8. How effective are the current water quality management plans?	**x**	**x**	**x**	**x**	**x**		**x**	**x**

1. Introduction

1.1 Background

Under the National Pollutant Discharge Elimination System (NPDES) Municipal Separate Storm Sewer System (MS4) Permit, stormwater dischargers in southern California are required to develop and maintain an urban runoff monitoring and reporting program (MRP). The primary objectives of such programs are to monitor, document, and report the volume of urban runoff, runoff quality, pollutant loads for various contaminants, the source of the contaminants, and the physicochemical and biological impacts of MS4 discharge on the receiving water.

The large municipalities develop watershed management plans incorporating the MRP requirements and submit to the respective Regional Water Quality Control Boards (RWQCB). Such watershed management plans are called enhanced watershed management plans (EWMPs) or water quality improvement plans (WQIPs). In some cases, watershed management plans are supplemented with a coordinated integrated monitoring program (CIMP). The monitoring requirements that have been codified in these EWMP/WQIP/CIMPs vary, with each RWQCB setting requirements that reflect the continuing evolution of stormwater science, as well as that accommodate the unique challenges facing individual watersheds.

Because urban runoff monitoring requirements differ from permit to permit, it has become prohibitive to perform a regional assessment of stormwater and receiving water quality. Over the past decade, monitoring requirements have evolved to the point that there is considerable variability in terms of monitoring objectives, sampling design, frequency, laboratory analyses, and reporting. Given the significant success of Stormwater Monitoring Coalition (SMC)—an organization of stormwater management agencies and RWQCBs in southern California—in bringing standardization to other facets of stormwater compliance monitoring, the SMC is seeking to develop standardized, best-practices designs for urban runoff monitoring programs that are grounded in the latest science. All SMC members will benefit greatly from understanding how to optimally set up and conduct standardized MS4 monitoring programs, as well as being able to aggregate MS4 monitoring data to form a high-quality, regional data set. Additionally, the SMC sees opportunities to leverage these regional MS4 data sets to inform performance evaluation of stormwater best management practices (BMPs) for runoff capture, reduction, and treatment.

1.2 History of Standardized Monitoring in Southern California

The SMC has made significant progress in recent years in the development of standardized water-quality monitoring programs across southern California that have helped managers compile a comprehensive regional snapshots of condition, evaluate BMP effectiveness, and prioritize waterbodies for management intervention. The SMC's Regional Watershed Monitoring Program, which was conceptualized in 2007 and launched in 2009, has successfully integrated elements from several individual watershed monitoring programs to create a large-scale, comprehensive, bioassessment-based monitoring program that spans more than 7,000 stream-kilometers of southern California's coastal streams and rivers. More recently, the SMC developed a laboratory guidance document for increasing the uniformity and reproducibility of aquatic toxicity test results among the region's stormwater management agencies.

In the past, the SMC also has invested in bringing standardization to MS4 urban runoff monitoring programs across the region. In 2004, the SMC published a model monitoring document that describes a framework for implementing regionally consistent approaches for status and trend monitoring of receiving waterbodies. The document was immediately used to help bring best-practices standardization to the hallmark features of compliance monitoring programs across southern California.

The scope and approach to MS4 monitoring has evolved considerably since 2004. In 2012, the SMC conducted a follow-up survey for assessing the level of standardization of various MS4 programs across the region. The survey, plus a subsequent workshop convened by the SMC, revealed that despite the SMC's standardization efforts in 2004, monitoring requirements had evolved so much that there was minimal similarity among the MS4 monitoring programs currently in use by SMC member agencies. The workshop participants, consisting of both stormwater regulators and dischargers, made several recommendations and expressed support for developing an updated guidance document that will enable SMC members to bring best-practices standardization to the current scope and range of MS4 monitoring program activities.

1.3 Objective of this document

This document is intended to serve as the first step toward establishing a unified, standardized approach to stormwater monitoring (UASM) in southern California. This document presents an updated inventory of all of the major MS4 monitoring approaches and NPDES permit requirements that are currently in place across the region. Similarities and dissimilarities among various stormwater agencies and RWQCBs are chronicled, and a recommended series of steps has been put forth to move forward with the standardization project (see UASM workplan, Appendix C).

1.4 Organization of the document

This document is organized in four sections. The first section (Section 2 & Appendix A) describes the methodologies and approaches followed in writing this document. This section also discusses the primary elements of a MS4 monitoring programs. The monitoring elements include monitoring objectives, sampling location selection criteria, sampling frequency, sampling techniques for increased effectiveness and representativeness, list of minimum target analytes and methods, and data analyses techniques. A list of standardized monitoring questions is provided in this section based on the review of the management questions that various stormwater agencies are trying to answer. The second section (Section 3 & Appendix B) provides an inventory of current MS4 monitoring practice in southern California: discussed for each monitoring elements. In this section, we also identify the monitoring elements that should be standardized to answer the standardized monitoring questions more effectively. The third section (Section 4) discusses possible strategies for standardizing the monitoring elements. The brief workplan for developing the UASM guidance document is presented under the Appendix C.

2. Methodology, monitoring elements, and monitoring objectives

2.1 Methodology for inventory development

The inventory of the MS4 monitoring has been developed by reviewing the NPDES permits submitted to and approved by three RWQCBs, e.g., Los Angeles, Santa Ana, and San Diego regional boards. In addition, watershed management plans and stormwater monitoring plans developed by the SMC member agencies and their co-permittees have been reviewed. The documents are analyzed to compare MS4 monitoring approach, objectives, and core monitoring elements across the SMC member agencies.

A total of 7 NPDES permits and 39 monitoring plans have been reviewed for core monitoring questions: the details of the monitoring elements within (Appendix A). NPDES permittees include Riverside County (RC), San Bernardino County (SBC), Orange County (OC), City of Long Beach (CLB), Los Angeles County (LAC), San Diego County (SDC), and Ventura County (VC). The list of monitoring plans and associated jurisdiction areas are listed in Table 1.

2.2 Standardized monitoring objectives

Any MS4 monitoring program should be tailored to specific management questions. While the individual programs may have their own set of objectives based on their immediate need and potential challenges, the common goal of any MS4 monitoring remains the same: ensuring safe stormwater discharge with minimal impact on receiving water quality. Therefore, it is rational to follow a standard monitoring approach to meet the minimum MS4 monitoring requirements set by NPDES permits. Identifying a set of common management questions and corresponding monitoring objectives is the first step in this process.

Defining a set of management questions for all SMC member agencies is a critical step for establishing a unified approach for stormwater monitoring in southern California. A question-driven monitoring framework improves the efficiency of the monitoring efforts in the following ways: a) it clearly demonstrates the success of monitoring programs by evaluating whether the data collected by the program can answer the defined monitoring questions. b) it facilitates transformation of the monitoring data into information; c) it eliminates the risk of collecting redundant data as well as the problem of missing data; d) it improves the communication among various stakeholders associated with MS4 monitoring efforts. Therefore, the proposed standardized monitoring effort in southern California would be most useful if driven by a common set of management questions to be answered by MS4 monitoring activities.

The priority monitoring objectives of the SMC member agencies, as presented in the appendix B, should serve as a basis for deciding on the standardized management questions. Additionally, the standardized questions should address the permit requirements in the region and be agreed upon by the stormwater agencies, both by the regulators and dischargers. The answers to the questions should greatly inform the status, trend, and challenges for outfall discharge and receiving water quality in the region. While these questions could be the common platform to carry out MS4 monitoring in the region, such questions must not discourage member agencies to have additional individual objectives to be accomplished by their monitoring efforts. Considering these factors, the standardized MS4 monitoring program in southern California should be able to answer the following questions:

Q1. What pollutants are associated with the stormwater runoff?

Q2. What are the sources of the identified pollutant(s)?

Q3. What are the sources (and magnitudes) of illicit discharge/illegal connections?

Q4. How effective the BMPs are for reducing flow and contaminant concentrations?

Q5. If (and how) the stormwater is influencing the quality of receiving water?

Q6. What is the overall health of receiving water?

Q7. If (and what) receiving water needs management actions based on its overall health?

Q8. How effective are the current water quality management plans?

Among the eight abovementioned questions, the first two questions are associated with stormwater outfall monitoring. These questions are key to stormwater quality characterization, common and emerging contaminants listing, and contaminants source tracking. Answers to these questions should be documented both at the site-specific and watershed scale. In addition, monitoring efforts should incorporate analyses at the both temporal and spatial scale to understand the status and trend of the stormwater quality. Once the level of contamination and the sources are determined, managers may carry out special studies, including source identification followed by source reduction efforts. Such efforts may include effective BMP implementation to reduce the severity of the level of contaminants at the stormwater outfall.

The third question relates to both stormwater and non-stormwater outfall monitoring and informs investigations for illicit discharge or illegal connection. Monitoring efforts designed for answering this question would help finding illicit discharges, identifying their sources, and devising management actions. Monitoring efforts followed by the management actions would help determine the effectiveness of actions taken and additional steps necessary to eliminate prohibited discharges.

The fourth question helps gathering data on the effects of BMP implementation on the stormwater quantity and quality at the outfall. Such assessment while primarily relevant to wet weather discharge, however, may involve dry weather monitoring data. Note that, answering this question under core monitoring should not substitute any special studies related to BMP performance evaluation, including BMP effectiveness monitoring. Investigating this question would not require any additional outfall monitoring efforts. However, a comprehensive documentation of land use and BMP implementation, related to the drainage area of an outfall, would be needed.

Providing information on the quality of receiving water is the primary focus of the management questions five to seven. The success of stormwater management effort should be measured by protection of the receiving water quality for beneficial use. Any efficient MS4 monitoring program should be able to readily describe the health of the receiving water bodies and answer whether stormwater discharge is significantly impacting their water quality: in terms of both recreational and habitat water quality objectives. The receiving water quality monitoring data would be the primary tool to assess the overall health of receiving water. Moreover, a side by side comparison of the receiving water quality monitoring data with the stormwater outfall monitoring data would elucidate the influence of stormwater discharge on the receiving water quality. Such assessment can be carried out based on the water quality standards for the intended receiving water use, targeted effluent concentrations based on other management objectives, including total maximum daily load, or any other criteria set by the water quality managers. If stormwater discharge appears not to be a significant contributor to receiving water quality degradation, managers may conduct special studies, including causal assessment to identify other sources impairing receiving water health.

Overall, the MS4 monitoring data should be able to quantitatively answer how effective the current watershed management plans are to protect receiving water quality for beneficial uses. The trend monitoring for the receiving water quality and the runoff quality at the outfall could be an effective way to determine if the implemented management actions are having a desired impact on the water quality. Such trend monitoring either can be short-term (monthly) or long-term (yearly or bi-yearly) or both. Short-term monitoring would inform whether the set milestones for long-term compliance strategies, according to reasonable assurance analysis for instance, are likely to be met. Such evaluation of watershed management plans is critical for a successful adaptive management approach which requires continuous evaluation of the effectiveness of current management practices.

2.3 MS4 monitoring elements

The monitoring elements are the core components of a MS4 monitoring framework. These elements ensure the objectives of a monitoring plan are met. Monitoring elements can be associated with planning monitoring efforts, sample collection and field measurement procedures, laboratory analytical methods, data analyses, and reporting. Decisions addressed by various monitoring elements include, but are not limited to, the following:

a) What storm events qualify for mobilizing sample collection efforts?
b) What sites to select for collecting stormwater samples?
c) What is the best procedure for collecting field-sample, e.g., number, type, duration?
d) What stormwater contaminants should be monitored in the collected water samples?
e) How many storms per season should be monitored for representative data?
f) What constitutes best practice for data management and analyses?
g) How to demonstrate the impact of stormwater management on the receiving water quality?

The answers to these questions guide the overall success of a MS4 monitoring program. Such success should be measured by the ability of the monitoring program to address the specific management questions or monitoring objectives.

2.4 Linkage between the monitoring objectives and monitoring elements

The key to answering the monitoring questions with reasonable accuracy is a comprehensive planning for the MS4 monitoring activities, including storm event and site selection, field sampling procedure, laboratory analytical methods, and data analyses. Note that, not all monitoring elements are equally important to standardize to accurately answer a certain monitoring question. Table 3 relates the above-mentioned eight monitoring questions to corresponding relevant monitoring questions. The current state of these monitoring elements and the need for standardization (if any) are discussed in the following section.

3. Potential monitoring elements for standardization

3.1 Background

The MS4 monitoring elements can be classified into four broad categories: design and planning; field techniques for data collection, laboratory methods, and reporting. The robustness of the monitoring framework, e.g., extent of data collection effort, reliability of the data collection, accuracy of the data analyses, and reporting influences the efficacy of a monitoring program for answering a certain monitoring question.

This section would provide an overview of current MS4 monitoring practices, followed by various SMC member agencies, in terms of these monitoring elements. Based on the inventory of the stormwater monitoring programs and the standardized monitoring objectives, recommendations are provided on whether a certain monitoring element should be standardized.

3.2 First flush and storm end criterion

The "first flush" is commonly described as a phenomenon that causes a significantly higher concentration of pollutants at the beginning of a storm event compared to the rest of the storm event. For geographical regions like southern California, an additional phenomena similar to the first flush is known to occur which is called a "seasonal first flush". This phenomenon refers to the pollutant build up during long dry periods and their release during the first storm event of the wet season. Therefore, "what storm event to monitor?" is an important question to consider when deciding on a monitoring plan to address "seasonal first flush".

The monitoring programs specifically designed to characterize (seasonal) first flush may inform the management questions related to the stormwater quality and pollutant sources: Q1 and Q2. Not accounting for the first flush discharge may cause potential bias in total pollutant load calculation from stormwater discharge. However, the first flush may or may not occur depending on the drainage characteristics of a watershed and pollutant sources. The first flush is more likely to occur in a smaller watershed with more mobile, pollutant sources which are limited in supply. However, the effects of watershed characteristics and the type of pollutants on the occurrence of first flush phenomena is yet to be understood.

In addition to the first flush consideration, selecting an appropriate storm end criterion ensures the representativeness of the collected sample during MS4 monitoring. Such selection essentially involve deciding on how long the sample collection effort would last after a sampling event has initiated. The event-mean concentration (EMC) and mass emission can be greatly influenced by the duration of sampling event, especially in an urbanized watershed with best management practices (BMP). The removal efficiency of stormwater BMPs is likely to vary based on the influent pollutant load (for example, initial storm samples vs. subsequent samples) and hydraulic loading (shorter storm event vs. persistent storm event). As a result, the pollutant load coming at the outfall would vary depending on the duration of sampling event.

The Table 4 provides a snapshot of first flush requirement and storm end criteria across stormwater programs in southern California. It appears that all programs recommend monitoring the first storm event of the season. The sampling trigger for the first flush is described as 70%

probability of 0.25-inch rain except for Santa Ana region which does not specify the requirement. While, this indicates a seasonal first flush requirement for majority of the programs, it is not clear if any of the programs collect first flush samples for individual qualifying storm events. For storm end criteria, majority of the programs suggest sample collection for the duration of entire storm or 24 hours, whichever is shorter. However, some programs do not specify sampling duration in their monitoring plans.

We recommend the standardization of first flush and storm end criteria to inform MS4 monitoring programs in this region: especially in answering the first and second monitoring questions. A challenge for setting such standard criteria is the variation in watershed (i.e., time of concentration, peak flow) or pollutant (i.e., priority pollutants) across the watersheds in southern California. Therefore, instead of coming up with a stringent value for first flush and storm end duration, developing a relationship between hydrologic parameters of a watershed and first flush criteria could be a better approach for such standardization.

3.3 Sampling frequency

The sampling frequency, i.e., the number of storm events to be sampled per sampling station within a season is an important parameter. The sampling frequency determines the breadth or the representativeness of the data available for the statistical and modeling exercise that are performed on the MS4 monitoring data. Such analyses are key to accurately answer the management questions set as MS4 monitoring objectives. Especially, questions 2-4 requires a wider scale, representative MS4 monitoring data. Increasing the number of sampled storm events makes the MS4 monitoring data more representative, however, at the expense of higher financial burden. Therefore, a trade-off between the cost of investment and perceived benefit is required to choose an optimum sampling frequency.

The Figure 1 shows the number of times dry weather and wet weather samples are collected at various outfall stations in the Los Angeles, San Diego, and Santa Ana region. Table 4 provides more details on every program listed under each of the regions. It appears from the inventory that most of the sites are sampled twice per year both during wet and dry weather. However, in San Diego region, many sites are sampled only once. On the other hand, some sites in the Los Angeles region follows a tiered approach. During the first year, these sites are sampled 4 times and the frequency can be reduced to 2 times per year based on the data obtained from first year monitoring.

We recommend determining the optimum number of storm events to be sampled that ensures the representativeness of the runoff/receiving water quality of a certain site. However, given the semi-arid weather of southern California, the sampling frequency or the number of qualifying storm event could be limited by the total number of storm over a water-year. Once determined, that number should be used as the standard sampling frequency for a given sampling site under a given stormwater program. The standard sampling frequency would minimize the uncertainty in answering multiple monitoring questions, including questions Q1, Q3, Q5, Q8. By reducing the temporal variance in runoff quality due to the antecedent conditions, size of the storm event, storm duration, etc, repeat sampling would ensure more accurate description of pollutant load, more reliable trend analyses, and better estimate of BMP performance.

3.4 Outfall screening

“Where to sample” is an important question to consider when designing a MS4 monitoring program. While “when to sample (first flush and storm end criteria)” and “how many times to sample” (sampling frequency)” are relevant questions to answer, collected samples are unlikely to be representative of the watershed without appropriate sections of sampling locations. The criteria for outfall screening would depend on the specific management question a monitoring program is designed to answer. Such screening criteria along with the nature of the watershed would dictate how many outfalls are required to monitor. Therefore, a careful selection of outfalls may reduce number of samples required to collect in a watershed without sacrificing the level of “representativeness” of the gathered data.

Following are 27 different criteria mentioned in various watershed management plans for selecting sampling sites: for dry weather and wet weather monitoring. Table 5 relates every program to the stated outfall selection criteria.

Wet Weather:

1) Representative land use
2) Safe and easy access; can deploy sampling equipment
3) Representativeness and linkage with receiving water
4) Feasibility and reliability of flow measurements.
5) Larger drainage area than other sites evaluated
6) One outfall per major drainage area
7) Possibility of sub-basin drainage area
8) Linkage to downstream receiving water quality monitoring location
9) LSPC modeling results from LCC metals TMDL
10) Ability to isolate major portion of the watershed
11) Ability to use auto sampling equipment
12) Population density
13) Traffic density
14) Age of the infrastructure
15) Good representation of the watershed
16) At least one site per co-permittee within the permit management area
17) Public property
18) Do not receive runoff from other municipalities

Dry weather

19) Non-stormwater flow status
20) Historical monitoring data; supplement long-term data set and long-term trend monitoring
21) Flow rate
22) Surrounding land use/potential sources/threat to receiving water quality
23) Outfall discharge status (transient, no-flow, persistent)
24) Representative flow duration, pollutant loading
25) Proximity to the receiving water monitoring sites
26) Containing discharge attributed to illicit discharge per dry season
27) Controllability

The details of the outfall selection criteria vary not only between dry and wet weather monitoring, but also between projects or programs. A majority of the program has chosen “representative land use” as a primary criterion for selecting wet weather sites followed by safe/easy access to sampling capabilities. In contrast, such criteria were not documented well for selecting dry weather sites except for San Diego region. Historical monitoring data, flow rate, and surrounding land use appear to be the mostly used criteria for San Diego. Note that, according to the most updated information, outfall screening for dry weather monitoring is ongoing for LA region. However, the corresponding EWMPs did not describe what criteria were being used for the screening process.

We suggest standardizing the minimum criteria for selecting the dry-weather and wet-weather outfall to help answering multiple monitoring questions, including Q1, Q2, Q4, Q5, Q7, Q8. For example, whether stormwater discharge is influencing the health of the receiving water would be determined by the linkage between outfall location, associated drainage area, and the receiving water. Similarly, strategic selection of an outfall location may delineate the efficacy of a certain stormwater control measure, i.e., BMP, without extensive on-site monitoring of the BMP.

3.5 Outfall description

While a detailed description of an outfall may not directly enhance the MS4 monitoring data quality, it provides a context of the data collected at the selected outfall. Outfall descriptions may include geographical coordinates of the outfall site, the size and shape of the outfall, the build or materials of the outfall, land use description of the drainage area associated with the outfall, and description of any linkage of the outfall with a receiving water along with the intended beneficial use of the receiving water.

The Table 6 shows the inventory of total of 442 outfalls are monitored across 39 different programs. These outfalls can be categorized as dry weather and wet weather outfall: 235 dry weather, 6 wet weather, and 201 wet and dry weather sampling sites. Information about size of the outfalls are only available for 115 sites. About 75% of the program have not specified the size or type of their outfalls. Among the reported sites, most of the outfalls are made of concrete with a dimension ranging from 8 inches to 315 inches. Additionally, some outfalls are made of corrugated metal pipes or earthen channels.

We strongly recommend establishing a data standard for describing the sampling outfalls for wet-weather and dry-weather monitoring. Such descriptions should include extensive information about the outfall which may aid in answering the standardized monitoring questions related to data analyses: Q2, Q4, and Q8. Outfall description may also help answering additional monitoring questions for adaptive stormwater management. For example, having historical information on land use change in the drainage area would inform the effect of land use change on the stormwater quality and contamination source. On the other hand, size and shape of the outfall would readily provide insight on planning for sampling collection effort.

3.6 Field-sampling and Flow measurement

While only a continuous measurement of stormwater runoff can provide a complete picture of the variation in flow and contaminant concentration during a storm event, such continuous measurement is impractical due to resource, e.g., time, equipment, and labor, limitation. The field sampling procedure and flow measurement techniques for MS4 monitoring should be adequately illustrative of natural runoff event. Using appropriate sampling techniques and accurate flow measurements are critical for answering all the standardized management questions presented earlier.

Designing the field sampling procedure involves two key questions: a) how many samples to be collected per storm event? and b) what would be the approach for sample collection (e.g., in-situ, on-site, grab or automatic)? While answers to both questions are critical for ensuring the effectiveness and the accuracy of the monitoring practice, answer to one influence the other. The number of required samples per storm events depends on the chosen sampling approach. The sampling approach needs to be adjusted for the constituents that are targeted for monitoring. Therefore, a combination of approaches may need to be used for monitoring a wide range of contaminants in stormwater runoff.

The Tables 7 and 8, respectively, summarizes the current wet weather and dry weather sampling practices in various MS4 monitoring programs in southern California. It appears that most of the programs use composite samples (collect by automatic samplers) for wet weather monitoring with exceptions for some contaminants, including bacteria and oil and grease. However, details like how many samples are collected per storm events, how the compositing are done (flow-weighted vs. time-weighted) are not mentioned in the EWMP/WQIPs. In contrast, grab samples are commonly used for dry weather monitoring, however volume of the grab samples are not mentioned. At least one program recommends preparing time-weighted composites from multiple grab samples collected over a period. Out of the 39 programs, 6 programs have not provided any wet weather sampling details and 14 programs have not discussed their dry weather sampling approach.

In addition to collecting samples for measuring contaminant concentration, measurement or estimation of flow is required to assess total pollutant load discharged through an outfall site. While total flow can be estimated using rainfall amount and drainage characteristics, actual flow rate is required for designing flow-weighted composite sampling technique. Flow measurements can be performed using primary, e.g., weir or flume, or secondary, e.g., floats or transducers, devices or a combination of both devices. Sampling location, desirable accuracy, likelihood of turbulence, and the range of expected flow rate influence what flow-measurement device would be appropriate.

The flow-measurement procedures are invariably missing in EWMP/WQIPs that are reviewed to develop the MS4 monitoring inventory. Only 7 programs mentioned their flow-measurement technique for wet weather monitoring and 3 programs mentioned the procedure for dry weather monitoring. Table 6 and 7 summarizes the techniques suggested by various programs according to their most updated EWMP/WQIP. Some provided a suite of options ranging from rainfall-runoff estimation method to using ISCO auto-sampler for flow measurement. The San Diego region explicitly mentioned that the chose flow-measurement technique would depend on the co-permittee's discretion. As apparent from the table, flow measurement techniques are likely to vary between dry weather and wet weather events. Dry weather approaches include stopwatch-bucket, float, and Marsh-McBirney flowmeter.

We suggest standardizing various aspects of field-sampling, including sampling approach, optimum number of samples, sampling duration, and flow measurement. Developing a standardized approach for field-sampling would ensure comparability of water quality data across different programs in the region. A documented standardized approach would may also increase the certainty of the statistical analyses of the data due to better representativeness of collected stormwater/receiving water sample. Standardized field-sampling procedure should constitute the best practice for sample collection and flow measurement in the field supported by scientific studies.

3.7 Analytes, analytical methods, and reporting limits

Stormwater contaminants can be categorized as conventional parameters, metals, inorganic constituents, and organics. A critical element of monitoring program is to decide which analytes to monitor, what laboratory method to be used for determining analyte value/concentration, and what would be the reporting limits for individual contaminants category. These decisions directly influence the ability to answer the first two monitoring questions with some indirect consequence on the accuracy of the rest of the monitoring questions.

We reviewed the MS4 monitoring data from three stormwater agencies, VC, OC, and SDC, for 2015-16 season: both for dry and wet weather samples. The goal was to compare the list of monitored water quality parameter, analytical methods, and reporting limits across these agencies. Table 9 shows 20 conventional parameters that are monitored under all three programs. In addition to these parameters, volatile suspended solids (VSS) and total petroleum hydrocarbon as oil are monitored by the Ventura and Orange counties; and coliphage is monitored only by the Orange County. In general, field and laboratory methods and reporting limits used for investigating these parameters are similar across the agencies.

Table 10 and 11 show the metal, inorganic, and organic constituents that are monitored by all three agencies. In addition to the metals listed in the Table 10, following constituents are monitored by individual agencies: Orange and San Diego Counties monitor for Cr, Fe, Mg, Mn; Orange County monitors for B, Co, Hg, Mo, Sn, V, Sr. The list of additional organics constituents monitored by individual agencies are long. For example, Orange County MS4 monitoring program monitors 180 additional constituents besides the ones mentioned in Table 10. These numbers are 44 and 79 for San Diego and Venture County, respectively. Moreover, while there is a significant overlap among the agencies regarding the analytical methods for these constituents, their reporting limits not only varies among the agencies but also within the same agency depending on the sampling location and date.

We recommend developing a list of criteria to select what constituents should be monitored as a part of an MS4 and receiving water monitoring program. Given the constituents list for every agency is different, such criteria would help to prepare a common list of priority contaminants to be monitored to inform the standardized monitoring questions, especially questions Q1, Q2, and Q6. Also, it is critical to develop a guidance on what reporting limits to be used for the chosen constituents. Note that, developing such standardized list of constituents or reporting limits is meant to act as a consensus on minimum monitoring requirement. Individual agencies should monitor additional constituents based on the additional management questions they might have as a part of their monitoring program.

3.8 Methods for data analysis

The final goal of designing a MS4 monitoring program is to answer the monitoring questions with a reasonable accuracy. Stormwater managers take advantage of various data analysis tools that help transforming data into information. The purposes of such analyses may include, but not limited to, comparing to water quality effluent limit or TMDL objectives, BMP effectiveness assessment, trend analysis, or validation of models. These purposes would dictate what technique should be used to analyze the monitoring data. Table 12 relates some example data analysis approach to answer the eight standardized management questions.

Although watershed management plans for individual programs provide guidance on the items to be included into annual reports, detailed data analyses techniques are not available in those plans. A review of past annual reports indicates that the existing data analyses techniques for MS4 monitoring program mostly focus on answering 5 questions described in the model monitoring document. However, not every monitoring plan uses quantitative techniques to answer all five questions. In general, the data analyses are centered on ensuring compliance and trend monitoring.

We recommend standardizing the data analyses techniques to reliably answer the monitoring questions. Standardizing data analyses technique would entail identifying the best data analyses approaches for answering individual monitoring questions and adopting those as standard techniques. Standardized data analyses would not only facilitate a vast regional database but also allow for comparing among various watershed management plans: in terms of what works and what not. For example, there are several techniques are available to estimate the effectiveness of a certain stormwater BMP to remove a certain contaminant based on a given set of influent and effluent concentrations for several storm events. These techniques include but not limited to percent removal, reference watershed method, and effluent probability method. If different methods are used to calculate for a set of BMPs, comparing their effectiveness during a storm event would be inaccurate. Therefore, using consistent (and the most effective) data analyses procedures is key to reliably compare among various stormwater control measures and/or watershed management plans.

4. Synthesis and next steps

MS4 monitoring programs maintained by the SMC member agencies are driven by NPDES permit requirements. While considerable similarities exist among various monitoring programs regarding their core objectives, there are inconsistencies in how those objectives are met through the monitoring efforts. Except for antecedent conditions for qualifying storms, no monitoring element is identical across all the agencies. Therefore, standardizing these monitoring elements to answer a set of common set of monitoring questions could inform the data comparability and regional water quality assessment methods.

Standardization of individual monitoring elements can be performed in one of the following three ways: a) a majority-driven approach where the procedure followed by the majority SMC member becomes the standard; b) result-driven approach where every procedure in the inventory is compared and tested in the field and the one with best the result is chosen; c) guidance-based approach where a decision support tool is developed to identify the best approach based on the given watershed and storm characteristics.

The first approach is the easiest to follow, however, there is a lack of scientific justification to do so. In contrast, the result-driven approach could be research-based and backed by experimental data. Replicating such results throughout the region for some of the monitoring elements, for example first flush criteria, could be challenging because of the other variables involved in the process, e.g., size of the watershed, storm frequency and duration. Therefore, we expect a combination of the result-driven and guidance-based approach to be followed to standardize the monitoring elements for the proposed UASM.

Regardless of the chosen approach, the paucity of scientific information and regional studies is a common barrier for suggesting detailed standardized protocol for the MS4 monitoring elements. While a few studies investigated some of the monitoring elements, e.g., number of storm events per station or number of samples per storm, these studies are outdated because of the recent change in MS4 monitoring requirements. Besides, studies on other types of monitoring elements, e.g., BMP effectiveness assessment or outfall selection criteria, are non-existent for southern California.

Therefore, research is needed to establish the best practices for MS4 data collection, data analyses, and data management to reliably answer the standardized monitoring questions. Given the resource constrains and legal framework under which these agencies operate, developing an effective monitoring guidance document with detailed instructions on optimum monitoring activities would be ideal for all stakeholders. This guidance document can be used as the minimum requirements for MS4 monitoring and reporting programs for all SMC member agencies.

The UASM guidance document development research should utilize a combination of lab and field-studies, review of the historical data, and statistical analysis. Based on the eight standardized monitoring questions, the following information should be collected:

- ✓ What watershed characteristics result in (seasonal) first-flush phenomenon in a watershed?
- ✓ What stormwater contaminants demonstrate first-flush phenomenon during their release from pollutant sources in a watershed?
- ✓ What factors to consider when selecting an outfall for dry weather monitoring?
- ✓ How many storms should be monitored per water year?
- ✓ What should be the minimum sampling frequently per site and optimum sampling duration per sampling event?
- ✓ What organic contaminants should be in the priority list for every MS4 program?
- ✓ How to best use MS4 monitoring results to evaluate gradual improvement of stormwater quality?
- ✓ How to best evaluate the effectiveness of watershed management plans?
- ✓ What standardized measure to use for describing overall health of receiving water?
- ✓ How to integrate MS4 monitoring results with reasonable assurance analyses for adaptive stormwater management?

The Appendix C describes a workplan designed to gather the above-mentioned information.

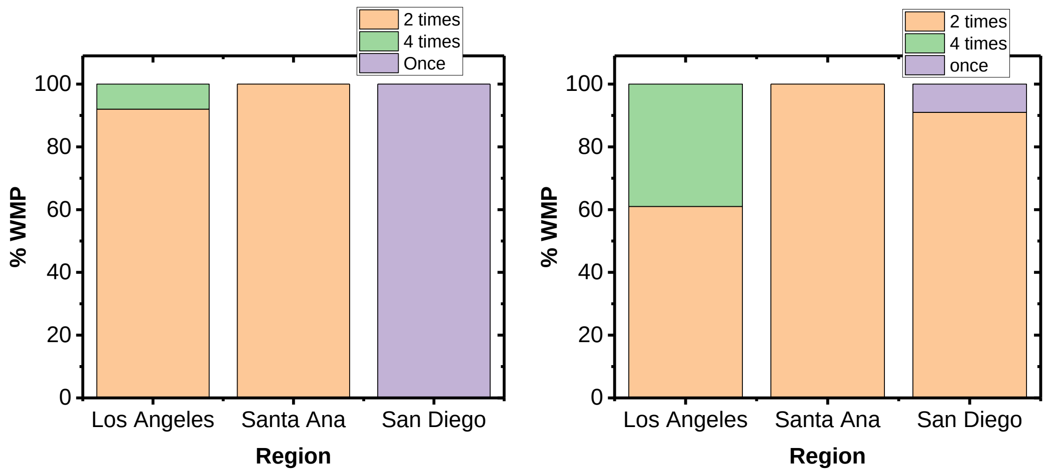

Figure 1: Dry weather (left) and wet weather (right) sampling frequency (per station/year) for MS4 monitoring in different regions of southern California

Appendix A: Documents reviewed for developing the inventory of MS4 monitoring in southern California

Permits:

1. National Pollutant Discharge Elimination System (NPDES) Permit and Waste Discharge Requirements for Discharges from The Municipal Separate Storm Sewer Systems (Ms4s) Draining the Watersheds Within the San Diego Region: Order No. R9-2013-0001; NPDES No. CAS0109266

2. National Pollutant Discharge Elimination System (NPDES) Permit and Waste Discharge Requirements for The San Bernardino County Flood Control District" The County of San Bernardino, and The Incorporated Cities of San Bernardino County Within the Santa Ana Region: Order No. R8-2010-0036; NPDES No. CAS618036

3. Waste Discharge Requirements for Municipal Separate Storm Sewer System (Ms4) Discharges Within the Coastal Watersheds of Los Angeles County, Except Those Originating from The City of Long Beach Ms4: Order No. R4-2012-0175; NPDES Permit No. CAS004001

4. Waste Discharge Requirements for Municipal Separate Storm Sewer System Discharges from The City of Long Beach: Order No. R4-2014-0024; NPDES Permit No. CAS004003

5. Waste Discharge Requirements for the County of Orange, Orange County Flood Control District and the Incorporated Cities of Orange County within the Santa Ana Region Areawide Urban Storm Water Runoff Orange County: Order No. R8-2009-0030; NPDES No. CAS618030

6. Monitoring and Reporting Program for Riverside County Flood Control and Water Conservation District, The County of Riverside and the Cities of Riverside County Within the Santa Ana Region AREA-WIDE Urban Storm Water Runoff Management Program: Order No. R8-2010-0033; NPDES No. CAS618033

7. Waste Discharge Requirements for Storm Water (Wet Weather) And Non-Storm Water (Dry Weather) Discharges from The Municipal Separate Storm Sewer Systems Within

the Ventura County Watershed Protection District, County of Ventura and the Incorporated Cities Therein: Order No. R4-2010-0108; NPDES Permit No. CAS004002

Annual Reports:

1. Ventura Countywide Stormwater Quality Management Program: 2015-2016 Annual Report
2. Orange County 2015-16 San Diego Region Transitional Monitoring and Assessment Report
3. San Bernardino County Areawide Stormwater Program Annual Report: Fiscal Year July 2015 to June 2016
4. City of Long Beach Stormwater Monitoring Report 2006/2007

Enhanced Watershed Management Plan/ Water Quality Improvement Plan/ Integrated Watershed Management Plan/ Coordinated Integrated Monitoring Plan:

A full list is available in Table 1

Table 1: Scope of the review of MS4 monitoring inventory

Region	No. of programs	Jurisdiction	Area
Los Angeles	26	Alamitos Bay/Los Cerritos Channel Group	37.5
		Ballona Creek	123
		Beach Cities Watershed Management Group	31
		Dominguez Channel Watershed Management Area Group	79
		East San Gabriel Valley Watershed Management Area	38
		El Monte	-
		Gardena	5.9
		Irwindale	9.6
		La Habra Heights	6.2
		Long Beach Inner and Outer Harbor, and eastern San Pedro Bay	-
		Los Cerritos Channel Watershed	27.7
		Lower Long Beach Bays estuaries and coastal San Pedro beaches	10.9
		Lower Los Angeles River	43.7
		Lower San Gabriel River	78.5
		Malibu Creek Watershed	109
		Marina del Rey	2.2
		North Santa Monica Bay Coastal Watersheds	86
		Palos Verdes Peninsula EWMP Agencies	
		Rio Hondo/San Gabriel River Water Quality Group	41
		Santa Monica Bay Watershed Jurisdiction 7	1.65
		Santa Monica Bay Watershed Jurisdictions 2 & 3	39
		Upper Los Angeles River	377
		Upper Los Angeles River, Upper Reach 2	22.2
		Upper San Gabriel River	96
		Upper Santa Clara River Watershed	190
		Walnut	3.48
Santa Ana	2	Riverside county, Santa Ana Region	-
		San Bernardino	620
San Diego	11	Carlsbad	211
		Los Penasquitos	94
		Mission Bay	64
		Riverside County, Santa Margarita Region	-
		San Diego Bay	444
		San Diego River	434
		San Dieguito River	346
		San Luis Rey	562
		Santa Margarita River	741
		South Orange County	259
		Tijuana	467

Appendix B: Overview of monitoring questions posed by various permits and programs

Even though all the permittees have core 5 management questions in mind, total 16 different goals have been mentioned in the permits reviewed. Following are the goals:

1) Define water quality status, trends, and pollutants of concerns (RC, SBC, OC)
2) Identify stormwater pollutants
    a) Characterize pollutants associated with urban runoff (OC, RC, SBC, LAC, CLB, VC)
    b) Characterize stormwater discharge (SDC)
3) Assess the contribution of stormwater to receiving water quality
    a) Influence of urban land use on water quality and identify water quality problems associated with urban runoff (OC, RC, SBC)
    b) Chemical, physical, and biological impacts to receiving water by MS4 (SDC, LAC, CLB, SDC, VC)
4) Identify other sources (e.g., atmospheric deposition, contaminated sediment) of pollutants in runoff (RC, SBC, OC)
5) Identify and prohibit illicit discharge (RC, SBC, OC, SDC)
6) Identify receiving water that needs additional actions for TMDL compliance (all permittees)
7) Determine mass loading rates for different urban land use categories (OC)
8) Determine runoff pollutant concentrations and loads at the source level (e.g., near a golf course or restaurants) (OC, RC)
9) Evaluate effectiveness of BMP (OC, RC, SBC, SDC) or pollutant control technologies (LAC, CLB, VC)
10) Evaluate cost and benefits of proposed stormwater quality control programs and share with the stakeholders, including public (OC, RC, SBC)
11) Develop and support an effective runoff management plan (RC, SBC)
12) Analyze and interpret collected data to determine the impact of urban runoff on receiving water and/or validate relevant water quality models (RC)
13) Identify and permit or prohibit illegal connections (RC, SBC)
14) Evaluate the effectiveness of water quality management plan (SDC, RC)
15) Identify the source(s) of a specific pollutant (SDC, CLB, LAC)
16) Assess the overall health of receiving water (SDC)

The monitoring goal or objectives mentioned in the monitoring plans primarily stem from corresponding permit requirements. However, in some cases EWMPs have more specific goals or objectives in mind. The stormwater program objectives, stormwater outfall monitoring objectives, and non-stormwater outfall monitoring objectives mentioned across 39 EWMPs/WQIPs are summarized below. Table 2 provides a detailed inventory of these objectives related to the specific WQIP/EWMP/CIMPs.

Stormwater Program Objectives:

1. Assess the chemical, physical, and biological impacts of discharges from the MS4 on receiving waters.
2. Assess compliance with receiving water limitations (RWLs) and water quality-based effluent limitations (WQBELs) established to implement Total Maximum Daily Load (TMDL) wet weather and dry weather waste load allocations (WLAs)
3. Characterize pollutant loads in MS4 discharges
4. Identify sources of pollutants in MS4 discharges
5. Measure and improve the effectiveness of pollutant controls implemented under the Permit

Stormwater Outfall Monitoring Objectives:

1. Determine the quality of stormwater discharge relative to municipal action levels
2. Determine whether stormwater discharge is in compliance with applicable stormwater WQBELs derived from TMDL waste load allocations (WLAs)
3. Determine whether the discharge causes or contributes to an exceedance of receiving water limitations
4. Identify pollutants in storm water discharges
5. Guide pollutant source identification efforts
6. Determine the relative contribution of MS4 outfalls to priority water quality conditions during wet weather
7. Investigate how discharge concentrations, loads, and flows change over time at representative MS4 outfalls
8. Determine the effectiveness of water quality improvement strategies associated with the pathogen health risk HPWQC

Non-stormwater Outfall Monitoring Objectives:

1. Determine whether a discharge is in compliance with applicable non-stormwater WQBELs derived from TMDL WLAs
2. Determine whether a discharge exceeds non-stormwater action levels
3. Determine whether a discharge contributes to or causes an exceedance of receiving water limitations
4. Assist in identifying illicit discharges
5. Determine the relative contribution of MS4 outfalls to priority water quality conditions during dry weather
6. Determine the sources of persistent non-stormwater flows
7. Inform the prioritization of outfall retrofits and feasibility of planned outfall capture strategies associated with the unnatural water balance and flow regime HPWQC

Table 2: MS4 monitoring objectives as described in watershed management plans developed by various MS4 monitoring programs

Region	Program	Program objective	Stormwater outfall monitoring objective	Non-stormwater outfall Monitoring objective
Los Angeles	Alamitos Bay/Los Cerritos Channel Group	NM	1,2,3	1,2,3,4
	Ballona Creek	NM	1,2,3	1,2,3,4
	Beach Cities Watershed Management Group	NM	2,4,5	3,4
	Dominguez Channel Watershed Management Area Group	NM	1,2,3	1,2,4
	East San Gabriel Valley Watershed Management Area	NM	1,2,3	1,2,3,4
	El Monte	NM	1,2,3	NM
	Gardena	NM	1,2,3	NM
	Irwindale	NM	NM	NM
	La Habra Heights	1,2,3,4,5	NM	NM
	Long Beach Inner and Outer Harbor, and eastern San Pedro Bay	NM	NM	NM
	Los Cerritos Channel Watershed	1,2,3,4,5	1,2,3	1,2,3,4
	Lower Long Beach Bays estuaries and coastal San Pedro beaches	NM	1,2,3	1,2,3,4
	Lower Los Angeles River	NM	NM	1,2,3,4
	Lower San Gabriel River	NM	NM	NM
	Malibu Creek Watershed	1,2,3,4,5	1,2,3	1,2,3,4
	Marina del Rey	NM	1,2,3	1,2,3,4
	North Santa Monica Bay Coastal Watersheds	NM	NM	1,2,3
	Palos Verdes Peninsula EWMP Agencies	1,2,3,4,5	1,2,3	NM
	Rio Hondo/San Gabriel River Water Quality Group	1,2,3,4,5	1,2,3	1,2,3,4
	Santa Monica Bay Watershed Jurisdiction 7	NM	1,2,3	1,2,3,4
	Santa Monica Bay Watershed Jurisdictions 2 & 3	NM	1,2,3	1,2,3,4
	Upper Los Angeles River	NM	1,2,3	1,2,3,4
	Upper Los Angeles River, Upper Reach 2	NM	1,2,3	1,2,3,4
	Upper San Gabriel River	NM	1,2,3	1,2,3,4
	Upper Santa Clara River Watershed	1,2,3,4,5	1,2,3	1,2,3,4
	Walnut	1,2,3,4,5	2	1
	Riverside county, Santa Ana Region	NM	NM	NM
	San Bernardino	NM	NM	NM
San Diego	Carlsbad	NM	2,4,5	3,4
	Los Penasquitos	NM	1,6,7	
	Mission Bay	NM	1,6,7	2,4
	Riverside County, Santa Margarita Region	NM	1,3,5,6	NM
	San Diego Bay	NM	1,3,6,7	3
	San Diego River	NM	2,3	3
	San Dieguito River	NM	1,2,4,5,6,7	2,4
	San Luis Rey	NM	2,4,5	2,4

	Santa Margarita River	NM	NM	NM
	South Orange County	NM	2,3,4,5,6,7	2,3,4,5,7
	Tijuana	NM	1,5,6	2,5,7

NM = Not mentioned

Table 3: Relevant monitoring elements with individual monitoring questions

Core Monitoring Question	**Storm event selection**	**Sampling frequency**	**Field sampling procedure**	**Flow measurement**	**Outfall selection**	**Outfall description**	**Laboratory methods & reporting limits**	**Data analyses**
Q1. What pollutants are associated with stormwater runoff?	x		x		x		x	
Q2. What are the sources of the identified pollutant(s)?	x	x				x	x	
Q3. If (and how) stormwater is influencing the quality of receiving water?		x	x	x			x	x
Q4. What are the sources (and magnitudes) of illicit discharge/illegal connections?					x	x	x	x
Q5. How effective the BMPs are for reducing flow and contaminant concentrations?	x			x	x		x	x
Q6. What is the overall health of receiving water?		x						x
Q7. If (and what) receiving water needs management actions based on its overall health?		x			x			x
Q8. How effective are the current water quality management plans?	x	x	x	x	x		x	x

Table 4: Criteria as described by different programs for sampling trigger, frequency, and duration related to MS4 monitoring

Region	Program	Sampling frequency Per station/year		First flush requirement	Storm end criteria	Qualifying storm	
		Wet	Dry			Antecedent condition	Sampling trigger after first flush
Los Angeles	Alamitos Bay/Los Cerritos Channel Group	3	4	No	24 h or SD whichever is shorter	Yes	SAFF
	Ballona Creek	3	2	Yes	24 h or SD whichever is shorter	Yes	SAFF
	Beach Cities Watershed Management Group	3	2	Yes	24 h or SD whichever is shorter	Yes	SAFF
	Dominguez Channel Watershed Management Area Group	3	2	Yes	24 h or SD whichever is shorter	Yes	0.1-0.5 inch In 6-12 h
	East San Gabriel Valley Watershed Management Area	3	2	Yes	NS	Yes	SAFF; 0.1-0.5 inch In 6-12 h
	El Monte	3	2-4	Yes	24 h or SD whichever is shorter	Yes	>1 inch with 70% probability
	Gardena	3	2-4	Yes	24 h or SD whichever is shorter	Yes	>0.1 inch
	Irwindale	3	2-4	Yes	24 h or SD whichever is shorter	Yes	>0.1 inch
	La Habra Heights	3	2-4	Yes	24 h or SD whichever is shorter	Yes	NS
	Long Beach Inner and Outer Harbor, and eastern San Pedro Bay	3	2-4	Yes	24 h or SD whichever is shorter	Yes	>1 inch per day
	Los Cerritos Channel Watershed	3	2	No	24 h or SD whichever is shorter	Yes	NS
	Lower Long Beach Bays estuaries and coastal San Pedro beaches	3	2-4	Yes*	NS	Yes	>0.25 inch with 70% probability
	Lower Los Angeles River	3	2	No	NS	Yes	>0.25 inch rain
	Lower San Gabriel River	4	2	No	NS	Yes	>0.25 inch rain
	Malibu Creek Watershed	3	2	Yes		Yes	NS
	Marina del Rey	3-4	2	Yes	SD if 3<SD<24 min 3 h, max 24 h	Yes	SAFF

Region	Program	Sampling frequency Per station/year		First flush requirement	Storm end criteria	Qualifying storm	
		Wet	Dry			Antecedent condition	Sampling trigger after first flush
	North Santa Monica Bay Coastal Watersheds	3	2	Yes	NS	Yes	SAFF
	Palos Verdes Peninsula EWMP Agencies	3	4	Yes	3 h or SD whichever is shorter	Yes	SAFF
	Rio Hondo/San Gabriel River Water Quality Group	3	2	Yes	24 h or SD whichever is shorter	Yes	SAFF; >0.15 inch in 6 h
	Santa Monica Bay Watershed Jurisdiction 7	3	2	Yes	24 h or SD whichever is shorter	Yes	SAFF
	Santa Monica Bay Watershed Jurisdictions 2 & 3	3	2	Yes	24 h or SD whichever is shorter	Yes	0.1-0.5 inch In 6-12 h
	Upper Los Angeles River	3	3-4	Yes	24 h or SD whichever is shorter	Yes	0.1-0.5 inch In 6-12 h
	Upper Los Angeles River, Upper Reach 2	3P, 1R	2	Yes	24 h or SD whichever is shorter	Yes	6 inch depth
	Upper San Gabriel River	3	2	Yes	24 h or SD whichever is shorter	Yes	SAFF, 20% base flow in receiving water
	Upper Santa Clara River Watershed	3	2	Yes	24 h or SD whichever is shorter	Yes	>1 inch rain with 70% probability
	Walnut	3	2-4	Yes	24 h or SD whichever is shorter	Yes	>260 cfs flow at USGS station
	Riverside county, Santa Ana Region	3	2	Yes, NS	NS	Yes	>0.3 inch in 6 h and/or >0.5 inch in 24 h (60% probability)
	San Bernardino	3	2	Yes, NS	NS	Yes	>0.25 inch
San Diego	Carlsbad	1	2	No		NS	>0.1 inch
	Los Penasquitos	1	2	No	NS	Yes	NS
	Mission Bay	1	2	No	NS	Yes	>0.1 inch
	Riverside County, Santa Margarita Region	1	1	No	24 h or SD whichever is shorter	Yes	>0.3 inch in 6 h and/or >0.5 inch in 24 h (60% probability)
	San Diego Bay	1	2	No	24 h or SD whichever is shorter	Yes	>0.1 inch

Region	Program	Sampling frequency Per station/year		First flush requirement	Storm end criteria	Qualifying storm	
		Wet	Dry			Antecedent condition	Sampling trigger after first flush
	San Diego River	1	2	No	24 h or SD whichever is shorter	Yes	>0.1 inch
	San Dieguito River	1	2	No	NS	Yes	>0.1 inch
	San Luis Rey	1	2	No	24 h or SD whichever is shorter	NS	>0.1 inch
	Santa Margarita River	1	2	No	24 h or SD whichever is shorter	NS	>0.1 inch
	South Orange County	1	2	No	NS	NS	NS
	Tijuana	1	2	No	24 h or SD whichever is shorter	Yes	>0.1 inch

Yes=>=70% probability of 0.25 in precipitation
Yes*=>=50% probability of 0.2 in precipitation
Yes, NS= First viable storm requirement, but specifics not mentioned

Antecedent dry period: 72 h with <0.1 inches rain (mentioned for receiving water, not for outfalls)

SD = storm duration

SAFF = same requirement as first flush

Table 5: Criteria for screening suitable sites for stormwater and non-stormwater outfalls

Region	Program	Outfall selection criteria	
		Wet	Dry
Los Angeles	Alamitos Bay/Los Cerritos Channel Group	1, 9,10	NM
	Ballona Creek	1,2,11	NM
	Beach Cities Watershed Management Group	1	NM
	Dominguez Channel Watershed Management Area Group	1,2,4,8	NM
	East San Gabriel Valley Watershed Management Area	1,2,17	NM
	El Monte	1,4,6,18	NM
	Gardena	1	NM
	Irwindale	1,6	NM
	La Habra Heights	1,2	26
	Long Beach Inner and Outer Harbor, and eastern San Pedro Bay	1	NM
	Los Cerritos Channel Watershed	1,9,10	20,21,22
	Lower Long Beach Bays estuaries and coastal San Pedro beaches	1,7,20WD	NM
	Lower Los Angeles River	NM	NM
	Lower San Gabriel River	15	
	Malibu Creek Watershed	NM	NM
	Marina del Rey	1,2,11	NM
	North Santa Monica Bay Coastal Watersheds	1,2,3,4	NDWS
	Palos Verdes Peninsula EWMP Agencies	1	NM
	Rio Hondo/San Gabriel River Water Quality Group	1,5	NM
	Santa Monica Bay Watershed Jurisdiction 7	NM	NM
	Santa Monica Bay Watershed Jurisdictions 2 & 3	1	NM
	Upper Los Angeles River	1,6	NM
	Upper Los Angeles River, Upper Reach 2	NM	NM
	Upper San Gabriel River	1,2,5	NM
	Upper Santa Clara River Watershed	NM,WD	NM,WD
	Walnut	1,2,6,13	NM
Santa Ana	Riverside county, Santa Ana Region	NM,WD	NM,WD
	San Bernardino	15,24,25WD	NM,WD
San Diego	Carlsbad	1,16	NM
	Los Penasquitos	1	20,21,22
	Mission Bay	1	20,22,27
	Riverside County, Santa Margarita Region	1,5,12,13,14WD	
	San Diego Bay	1	20,21,22,27
	San Diego River	1	19,22
	San Dieguito River	1,16	19,22
	San Luis Rey	1,16	22
	Santa Margarita River	NM	NM
	South Orange County	1	23
	Tijuana	1	NM

NM = Not mentioned; WD = Both wet and dry weather outfall

Table 6: Information available in the EWMP/CIMP/WQIP for the selected wet and dry weather outfalls in different programs

Program	Total no. of outfalls		Location given	Land use given	Outfall size		Outfall type	
	Wet	Dry			Wet	Dry	Wet	Dry
Alamitos Bay/Los Cerritos Channel Group	1	4	1W	1W	NM	4D	NM	RCP, CMP, RCB
Ballona Creek	3	TBD	3W	3W	3W	TBD	RCB, RCP	TBD
Beach Cities Watershed Management Group	3	TBD	3W	3W	NM	TBD	RM, RCC	TBD
Dominguez Channel Watershed Management Area Group	6	TBD	6W	6W	NM	TBD	NM	TBD
East San Gabriel Valley Watershed Management Area	4	TBD	4W	4W	4W	TBD	RCP, RCB	TBD
El Monte	2	TBD	2W		NM		RCP	TBD
Gardena	2	2	2W	NM	2W	NM	RCB	NM
Irwindale	3	TBD	2W		NM		RCB	TBD
La Habra Heights	2	1	2W	1W	NM	NM	NM	NM
Long Beach Inner and Outer Harbor, and eastern San Pedro Bay	2	TBD	2W	2W	NM	TBD	NM	TBD
Los Cerritos Channel Watershed	4	TBD	4W	4W	NM	TBD	NM	TBD
Lower Long Beach Bays estuaries and coastal San Pedro beaches	2	2TBD	2W	NM	NM	TBD	NM	TBD
Lower Los Angeles River	4	TBD	4W	4W	NM	TBD	NM	TBD
Lower San Gabriel River	3	TBD	3W	3W	NM	TBD	NM	TBD
Malibu Creek Watershed	4	TBD	4W	4W	4W	TBD	RCP	TBD
Marina del Rey	5	TBD	5W	5W	NM	TBD	NM	TBD
North Santa Monica Bay Coastal Watersheds	2	TBD	2W	2W	NM	TBD	NM	TBD
Palos Verdes Peninsula EWMP Agencies	3	TBD	3W	3W	NM	TBD	RM	TBD
Rio Hondo/San Gabriel River Water Quality Group	5	TBD	5W	5W	5W	TBD	RCP, RCB	TBD
Santa Monica Bay Watershed Jurisdiction 7	1	TBD	1W	4W	4W	TBD	RCP	TBD
Santa Monica Bay Watershed Jurisdictions 2 & 3	4	TBD	4W	4W	4W	TBD	RCB, RCP, RCC	TBD
Upper Los Angeles River	12	TBD	12W	12W	12W	TBD	Rectangular	TBD
Upper Los Angeles River, Upper Reach 2	1P, 6R	TBD	6W	6W	NM	TBD	RM	TBD

Upper San Gabriel River	6	TBD	6W	6W	6W	TBD	RCB, RCP	TBD
Upper Santa Clara River Watershed	6	6	6WD	6WD	6WD	TBD	RCB, RCP	TBD
Walnut	2	2TBD	2WD	2WD	2WD	TBD	RCP	TBD
Riverside county, Santa Ana Region	7	7	7W	NM	NM	NM	NM	NM
San Bernardino	3	3P;7-9R	3WD	NM	NM	NM	NM	NM
Carlsbad	8	38	3W, 38D	NM	NM	38D	NM	RCC, RCB CMP, OC, CNG, EC
Los Penasquitos	5	11	5W	5W	NM	NM	NM	NM
Mission Bay	5	5	4W, 5D	4W,5D	NM	NM	NM	NM
Riverside County, Santa Margarita Region	7	7	7WD	NM	NM	NM	NM	NM
San Diego Bay	9	26	9W,26D	NM	NM	NM	NM	NM
San Diego River	5	25	5W,25D	NM	NM	NM	NM	NM
San Dieguito River	6	13	6W,13D	6W,13D	NM	NM	NM	NM
San Luis Rey	5	12	5W,12D	5W,12D	NM	12D	NM	CMP, RCP
Santa Margarita River	38	30	38W,30D	38W,30D	NM	NM	NM	NM
South Orange County	14	51	14W,51D	NM	NM	NM	NM	NM
Tijuana	5	11	5W,11D	5W,3D	5W	3D	RCP, outfall	Pipe, outfall

TBD = To be decided; NM = Not mentioned; W = Wet weather outfall; D = dry weather oufall; RCC: Reinforced concrete channel; RCP: RC pipe; CMP: Corrugated metal Pipe; EC: Earthen channel; CNG: Curb and Gutter; RM: Round manhole

Table 7: Details of field sampling and flow-measurement techniques for wet weather outfall monitoring

Watershed	Sampling method	Flow measurement details	
		Measured?	Method
Alamitos Bay/Los Cerritos Channel Group	CNS excepting bacteria, oil & grease	NM	-
Ballona Creek	CNS excepting bacteria, oil & grease	NM	-
Beach Cities Watershed Management Group	CNS	NM	-
Dominguez Channel Watershed Management Area Group	CNS	NM	-
East San Gabriel Valley Watershed Management Area	CNS excepting bacteria, oil & grease	Yes	NS
El Monte	CFW or CTW	Yes	Time required to fill a container of known volume
Gardena	CNS	NM	-
Irwindale	CNS	NM	-
La Habra Heights	CNS	NM	-
Long Beach Inner and Outer Harbor, and eastern San Pedro Bay	CFW excepting bacteria, oil& grease, cyanide, VOC	Yes	ISCO flowmeter, bubbler, submerged pressure transducer
Los Cerritos Channel Watershed	CNS	NM	-
Lower Long Beach Bays estuaries and coastal San Pedro beaches	CNS	NM	-
Lower Los Angeles River	CNS	NM	-
Lower San Gabriel River	NM	NM	-
Malibu Creek Watershed	NM	NM	-
Marina del Rey	CFW excepting bacteria, oil & grease	NM	-
North Santa Monica Bay Coastal Watersheds	NM	NM	-
Palos Verdes Peninsula EWMP Agencies	CNS excepting bacteria, oil & grease, PAH, VOC, cyanide, phenol	Yes	Automated flowmeter, manual measuring device; or rainfall-runoff relationship
Rio Hondo/San Gabriel River Water Quality Group	CNS excepting bacteria, oil & grease	NM	-
Santa Monica Bay Watershed Jurisdiction 7	CNS	NM	-
Santa Monica Bay Watershed Jurisdictions 2 & 3	CNS	NM	-

Watershed	Sampling method	Flow measurement details	
		Measured?	Method
Upper Los Angeles River	NM	NM	-
Upper Los Angeles River, Upper Reach 2	**CNS**	NM	-
Upper San Gabriel River	CNS excepting bacteria, oil & grease	NM	-
Upper Santa Clara River Watershed	NM	NM	-
Walnut	CNS	NM	-
Riverside county, Santa Ana Region	CNS excepting bacteria	NM	-
San Bernardino	Grab	NM	-
Carlsbad	CNS excepting bacteria, conventional parameters	NM	-
Los Penasquitos	CNS excepting bacteria, conventional parameters	NM	-
Mission Bay	Grab	Yes	Data from USGS station, USEPA guidance document or co-permittee discretion
San Diego Bay	CNS excepting bacteria, environmental parameter	Yes	USEPA guidance document or co-permittee discretion
San Diego River	CNS excepting bacteria, environmental parameter	Yes	Data from USGS station, USEPA guidance document or co-permittee discretion
San Dieguito River	Grab and composite	NM	-
San Luis Rey	CNS excepting bacteria, environmental parameter	NM	-
Santa Margarita River	NM	NM	-
South Orange County	NM	NM	-
Tijuana	Grab and composite	Yes	USEPA guidance document

NM = Not mentioned; CNS = Composite, but details not specified ; CFW = Composite, flow-weighted; CTW = Composite, time-weighted

Table 8: Details of field sampling and flow-measurement techniques for dry weather outfall monitoring

Watershed	Sampling method	Flow measurement details	
		Measured?	Method
Alamitos Bay/Los Cerritos Channel Group	NM	NM	-
Ballona Creek	Grab	NM	-
Beach Cities Watershed Management Group	Grab	NM	-
Dominguez Channel Watershed Management Area Group	Grab and composite	NM	-
East San Gabriel Valley Watershed Management Area	Grab	NM	-
El Monte	Grab and CNS	NM	-
Gardena	Composite excepting bacteria	NM	-
Irwindale	Grab	NM	-
La Habra Heights	Grab	NM	-
Long Beach Inner and Outer Harbor, and eastern San Pedro Bay	Grab taken from a vessel	NM	-
Lower Long Beach Bays estuaries and coastal San Pedro beaches	NM	NM	-
Lower Los Angeles River	NM	NM	-
Lower San Gabriel River	NM	NM	-
Malibu Creek Watershed	NM	NM	-
Marina del Rey	NM	NM	-
North Santa Monica Bay Coastal Watersheds	NM	NM	-
Palos Verdes Peninsula EWMP Agencies	Grab	NM	-
Rio Hondo/San Gabriel River Water Quality Group	NM	NM	-
Santa Monica Bay Watershed Jurisdiction 7	Grab	NM	-
Santa Monica Bay Watershed Jurisdictions 2 & 3	Grab	NM	-
Upper Los Angeles River	NM	Yes	Marsh-McBirney method
Upper Los Angeles River, Upper Reach 2	NM	NM	-
Upper San Gabriel River	NM	NM	-
Walnut	C: 3 grab samples collected 15 min interval	NM	-
San Bernardino	Grab and composite	Yes	Float method
Carlsbad	Grab	NM	-
Los Penasquitos	NM	NM	-
Mission Bay	Grab	NM	-

Watershed	Sampling method	Flow measurement details	
		Measured?	Method
San Diego Bay	Grab	NM	-
San Diego River	Grab	NM	-
San Dieguito River	Grab	NM	-
San Luis Rey	Grab	NM	-
Santa Margarita River	NM	NM	-
South Orange County	NM	NM	-
Tijuana	Grab	Yes	Float method; bucket and stopwatch method

NM = Not mentioned; CNS = Composite, but details not specified

Table 9: Conventional parameters monitored under all three stormwater programs and analytical methods

Parameter	Ventura County	Orange County	San Diego County
Alkalinity as CaC03	SM 2320 B	-	SM 2320 B
Ammonia N	EPA 350.1	EPA 350.1	EPA 350.1, FieldMeasure, SM 4500-NH3
BOD	SM 5210 B	EPA 405.1	EPA 405.1, SM 5210 B
Chemical Oxygen Demand	EPA 410.4	EPA 410.4	EPA 410.4
E. coli	MMO-MUG, SM 9223 B	EPA 1603, colilert	SM 9223 B
Enterococcus(Idexx)	Enterolert, SM 9230 D	IDEXX Enterolert, EPA 1600	Enterolert, EPA 1600, EPA 1600, SM 9230 B
Fecal coliform	SM 9221 E	MF (APHA 9222 D)	SM 9221 B
Hardness as $CaCO_3$	EPA 200.7	SM 2340B	EPA 200.7, SM 2340
NO_3-N	EPA 353.2	EPA 353.2	EPA 353.2, SM 4500-NO3 E
pH	Field Measure	150.1, EPA 9045, NA	Field Measure
Phosphorus As P	EPA 365.1	EPA 365.3, NA	EPA 365.1, EPA 365.3, Hach Method 8190, SM 4500-P C
Salinity	Field Measure	Field Measure	Field Measure
Settleable Solids		SM 2540F	
Specific Conductivity	Field Measure	EPA 120.1	Field Measure, SM 2510 B
TDS	SM 2540 C	EPA 160.1	SM 2540 C
Temperature	Field Measure	Field Measure	Field Measure
TKN	EPA 351.2	EPA 351.2	ASTM 1426-93BM, EPA 351.2, SM 4500-N C
Total coliform	MMO-MUG, SM 9223 B	MF (APHA 9222 B)	SM 9221 B
TSS	SM 2540 D	SM 2540D	SM 2540 D
Turbidity	EPA 180.1, Field Meter	EPA 180.1	EPA 180.1, Field Measure, SM 2130 B

Table 10: Metallic and inorganic constituents monitored under all three stormwater programs and analytical methods

Parameter	Orange County	Ventura County	San Diego
Ag	EPA 6020, EPA 200.8, EPA 1640	EPA 200.8	EPA 200.7, EPA 200.8, EPA 6020
Al	EPA 200.8	EPA 200.8	EPA 200.8, EPA 6010C, EPA 6020
As	EPA 6020, EPA 1640, EPA 200.8	EPA 200.8	EPA 200.8, EPA 6010C, EPA 6020
Ba	EPA 6020, EPA 200.8	EPA 200.8	EPA 6020
Be	EPA 6020, EPA 1640, EPA 200.8	EPA 200.8	EPA 6020
Ca	EPA 200.7	EPA 200.7	EPA 200.7
Cd	EPA 6020, EPA 1640, EPA 200.8	EPA 200.8	EPA 200.7, EPA 200.8, EPA 6010C, EPA 6020
Cl	EPA 325.3	EPA 300.0	EPA 300.0, SM 4500-Cl C
Cu	EPA 6020, 200.8, EPA 1640, EPA 200.8	EPA 200.8	EPA 200.7, EPA 6010C, EPA 6020
F	EPA 625, 8270, EPA 8270D	EPA 300.0	EPA 625, EPA 8270C
K	EPA 200.7	EPA 200.7	EPA 200.7
Na	EPA 200.7, EPA 200.8	EPA 200.7	EPA 200.7
Ni	EPA 6020, EPA 1640, EPA 200.8	EPA 200.8	EPA 200.7, EPA 200.8, EPA 6010C, EPA 6020
Pb	EPA 6020, EPA 1640, EPA 200.8	EPA 200.8	EPA 200.7, EPA 200.8, EPA 200.8, SM 3113 B
Se	EPA 6020, EPA 1640, EPA 200.8	EPA 200.8	EPA 200.7, EPA 200.8, EPA 6020
SO_4	EPA 300	EPA 300.0	EPA 300.0, SM 4500-SO4 E
Tl	EPA 6020, EPA 1640, EPA 200.8	EPA 200.8	EPA 200.8
Zn	EPA 6020, EPA 1640, EPA 200.8	EPA 200.8	EPA 200.7, EPA 6010C, EPA 6020

Table 11: Organic constituents monitored under all three stormwater programs and analytical methods

Constituent	Orange County	San Diego County	Ventura County
2,4'-DDD	EPA 625, Dry Weight, EPA 8270C, EPA 8270D	CAS SOP SOC-PESTMS2, EPA 608, EPA 8081A	EPA 608
2,4'-DDE	EPA 625, Dry Weight, EPA 8270C, EPA 8270D	CAS SOP SOC-PESTMS2, EPA 608	EPA 608
2,4'-DDT	EPA 625, Dry Weight, EPA 8270C, EPA 8270D	CAS SOP SOC-PESTMS2, EPA 608	EPA 608
4,4'-DDD	EPA 625, EPA 8270C, EPA 8270D	CAS SOP SOC-PESTMS2, EPA 608, EPA 8081A	EPA 608
4,4'-DDT	EPA 625, EPA 8270C, EPA 8270D	CAS SOP SOC-PESTMS2, EPA 608	EPA 608
Acenaphthene	EPA 625, EPA 8270D	EPA 625, EPA 8270C, EPA 8270C, EPA 8270D	EPA 625, EPA 8270C
Acenaphthylene	EPA 625	EPA 625, EPA 8270C, EPA 8270D	EPA 625, EPA 8270C
Aldrin	EPA 625, EPA 8270D	CAS SOP SOC-PESTMS2, EPA 8081A	EPA 608
Allethrin	EPA 8270C, EPA 8270C	EPA 625M, EPA 8270D, GCMS-NCI-SIM	-
Anthracene	EPA 625, EPA 8270D	EPA 625M, EPA 8270D, GCMS-NCI-SIM	EPA 625, EPA 8270C
Azinphos methyl (Guthion)	EPA 525.2	EPA 625M	EPA 525.2m
Benzo (A) Anthracene	8270	EPA 625, EPA 8270C, EPA 8270D	EPA 625, EPA 8270C
Benzo (A) Pyrene	8270	EPA 625, EPA 8270C, EPA 8270D	EPA 525.2, EPA 625, EPA 8270C
Benzo (K) Fluoranthene	8270	EPA 625, EPA 8270C, EPA 8270D	EPA 625, EPA 8270C
Benzo(b)Fluoranthene	8270	EPA 625, EPA 8270C, EPA 8270D	EPA 625, EPA 8270C
Benzo(e)pyrene	8270	EPA 625, EPA 8270C, EPA 8270D	EPA 625, EPA 8270C
Bolstar	EPA 525.2	EPA 625M	EPA 525.2m
Chlordane	Dry Weight	EPA 8081A	EPA 608
Chlorpyrifos	EPA 525.2	CAS SOP SOC-PESTMS2, EPA 625M, EPA 8081M, EPA 8141A, EPA 8141B	EPA 525.2m
Chrysene	EPA 625, EPA 8270D	EPA 625, EPA 8270C, EPA 8270D	EPA 625, EPA 8270C
Coumaphos	EPA 525.2	EPA 625M	EPA 525.2m
Demeton-o	EPA 525.2	EPA 625M	EPA 525.2m
Demeton-s	EPA 525.2	EPA 625M	EPA 525.2m
Diazinon	EPA 525.2	EPA 625M, EPA 8081M, EPA 8141A, EPA 8141B	EPA 525.2
Dichlorvos	EPA 525.2	EPA 625M	EPA 525.2m
Dieldrin	EPA 625, Dry Weight, EPA 8270C	CAS SOP SOC-PESTMS2, EPA 8081A	EPA 608
Dimethoate	EPA 525.2	EPA 625M	EPA 525.2

Dimethyl Phthalate	EPA 625	EPA 625, EPA 8270C, EPA 8270D	EPA 625
Endosulfan sulfate	EPA 625, EPA 8270C	CAS SOP SOC-PESTMS2, EPA 8081A	EPA 608
Endosulfan-I	EPA 625, EPA 8270C	CAS SOP SOC-PESTMS2, EPA 8081A	EPA 608
Endosulfan-II	EPA 625, EPA 625	CAS SOP SOC-PESTMS2, EPA 8081A	EPA 608
Endrin	EPA 625, Dry Weight, EPA 8270C	CAS SOP SOC-PESTMS2, EPA 8081A	EPA 608
Endrin Aldehyde	EPA 625, Dry Weight, EPA 8270C	CAS SOP SOC-PESTMS2, EPA 8081A	EPA 608
Fenthion	EPA 525.2	EPA 625M	EPA 525.2m
Heptachlor	Dry Weight, EPA 8270C, EPA 625	CAS SOP SOC-PESTMS2, EPA 8081A	EPA 608
Heptachlor Epoxide	Dry Weight, EPA 8270C, EPA 625	CAS SOP SOC-PESTMS2, EPA 8081A	EPA 608
Indeno[1,2,3-c,d]pyrene	EPA 625	EPA 625, EPA 8270C, EPA 8270C SIM, EPA 8270D SIM	EPA 625, EPA 8270C
Merphos	EPA 525.2	EPA 625M	EPA 525.2m
Methoxychlor	Dry Weight, EPA 8270C, EPA 625	CAS SOP SOC-PESTMS2, EPA 8081A	EPA 525.2
Mevinphos	EPA 525.2	EPA 625M	EPA 525.2m
Mirex	Dry Weight, EPA 8270C, EPA 625	CAS SOP SOC-PESTMS2	EPA 608
Naled	EPA 525.2	EPA 625M	EPA 525.2m
Naphthalene	EPA 625, 8270, EPA 8270D	EPA 625, EPA 8270C, EPA 8270C SIM, EPA 8270D SIM	EPA 625, EPA 8270C
Nitrobenzene	EPA 625	EPA 8270C	EPA 625
Pentachlorophenol	EPA 625, EPA 8151	EPA 625, EPA 8270C	EPA 515.3, EPA 625, EPA 8270C
Phenanthrene	EPA 625, EPA 8270D	EPA 625M-NCI, EPA 8270D_NCI, EPA 8270M_NCI	EPA 625, EPA 8270C
Phenol	EPA 625	EPA 8270C	EPA 625, EPA 8270C
Phorate	EPA 525.2	EPA 625M	EPA 525.2m
Pyrene	EPA 625, EPA 8270D	EPA 625, EPA 8270C, EPA 8270C SIM, EPA 8270D SIM	EPA 625, EPA 8270C
Tokuthion	EPA 525.2	EPA 625M	EPA 525.2m
Toxaphene	EPA 625, Dry Weight, EPA 8270C	EPA 8081A	EPA 608
Trichloronate	EPA 525.2	EPA 625M	EPA 525.2m

Table 12: Possible data analysis techniques to answer specific monitoring questions

Core Monitoring Question	**Data Analyses**
Q1. What pollutants are associated with stormwater runoff?	Comparison to water quality criteria
Q2. What are the sources of the identified pollutant(s)?	Frequency/persistence analyses/ source tracking
Q3. If (and how) stormwater is influencing the quality of receiving water?	Pollutant load & temporal trend analyses
Q4. What are the sources (and magnitudes) of illicit discharge/illegal connections?	Source tracking
Q5. How effective the BMPs are for reducing flow and contaminant concentrations?	BMP effectiveness assessment
Q6. What is the overall health of receiving water?	Persistence analyses/ Regional water quality index
Q7. If (and what) receiving water needs management actions based on its overall health?	Pollutant load analyses: TMDL/MAL
Q8. How effective are the current water quality management plans?	Validation of models & trend analyses

Appendix C: Workplan for Creating a Standardized Monitoring Guidance Document

Introduction

A review of MS4 monitoring programs in southern California indicates similarities among SMC member agencies in terms of monitoring objectives. However, considerable differences exist in terms of the details of monitoring elements. Standardizing these monitoring elements, based on a list of standardized monitoring questions, is key to a unified approach for standardized MS4 monitoring (UASM) in the region. A detailed analysis of the monitoring questions, inventory of existing monitoring methods and designs, and rationale for recommended standardization is described in this Technical Report. This Workplan describes the efforts required to improve monitoring effectiveness and develop a UASM for all Southern California Stormwater Monitoring Coalition members.

Problem Statement

Detailed investigation into the following five monitoring elements are needed to improve the effectiveness and standardization of MS4 monitoring in the Southern California Region:

1. Standardize first-flush selection criteria
2. Develop a guideline on how to select sampling sites while planning for MS4 monitoring
3. Standardize field-sampling procedure
4. Standardize laboratory analytical methods
5. Standardize data analyses and reporting format

Tasks:

The contractor shall use a combination of lab and field-studies, review of the historical data, and/or statistical analysis to gather required information for answering eight standardized monitoring questions

1) Standardize first-flush selection criteria

The goal of this task is to investigate what watershed characteristics result in (seasonal) first-flush phenomenon in a watershed. Such investigation should incorporate first-flush strength analyses for priority contaminants. The strength analyses should be designed to determine what stormwater contaminants demonstrate first-flush phenomenon during their release from pollutant sources in a watershed. The outcome of this analysis will dictate which sites are susceptible to first flush and should be selected for first flush monitoring.

Deliverables:

a) A ranking of pollutants for first-flush consideration
b) Correlation matrix for watershed characteristics-first flush prevalence
c) Of the existing watersheds being monitored, which should be monitored for first flush

2) Develop a guideline on how to select sampling sites while planning for MS4 monitoring

Identify the set of criteria that can be used to select outfall sites for dry weather monitoring. In addition, already established wet weather outfall screening criteria should be examined to assign relative significance for each criterion listed. Based on the list of the criteria, an equitable number of dry and wet weather outfalls should be specified for each MS4 monitoring program.

Deliverables:

a) Standardized list of selection criteria for dry weather outfall monitoring
b) Standardized list of selection criteria for wet weather outfall monitoring

3) Standardize field-sampling procedure

Field-sampling procedures focus on monitoring design details such as deciding how many storms should be monitored, how frequently each site should be monitored, what the duration of each sampling event is, and what type of samples should be collected. This task will provide decision support tools for each of these monitoring design details. Activities under this task should specify the minimum requirements for the UASM in southern California.

Deliverables:

a) A statistical tool based on power analysis that determines the optimum number of storm events per year at each station
b) Statistical analysis of the effects of sampling duration on the representativeness of stormwater samples
c) A decision support tool to standardize the optimum number of samples for both flow and time-weighted composite samples

4) Standardize laboratory analytical methods

Develop a guideline for standardizing chemical analyses, including conventional parameters, metals, inorganic, and organic constituents. Especially, from the wide range of organic contaminants that the SMC member agencies monitor, a subset of organics should be identified that represent the quality of stormwater and non-stormwater runoff in the region.

Deliverables:

a) A priority list for contaminants that needs to be monitored in every MS4 program
b) A list of optional contaminants that needs to be monitored at selected locations, and what criteria will be used to select these optional contaminants
c) Uniform reporting limits for individual analytical methods

5) Standardize data analyses and reporting format

Develop a standard framework for monitoring and assessing the effectiveness of the MS4 program, including the performance of BMPs, describing the health of the receiving water, and quantifying the effects of runoff on receiving water quality. Moreover, a comprehensive guideline should be established on how to use MS4 monitoring results to evaluate gradual improvement of stormwater quality per reasonable assurance analyses and modify watershed improvement plans as needed by adaptive management.

Deliverables:

a) A standard operating protocol to evaluate the effectiveness of watershed management plans
b) A standard operating protocol for monitoring BMP effectiveness for stormwater capture and treatment
c) An interactive database that standardizes comparisons between receiving water quality and stormwater quality, then identifies the outfalls immediately upstream that could be degrading receiving water quality
d) A standardized measure for describing overall health of receiving water
e) A guideline to integrate MS4 monitoring results with reasonable assurance analyses for adaptive stormwater management

Budget and Schedule:

TBD

Proposal Submittal Instructions:

TBD