Appendix J – San Diego Region Bacteria TMDLs Supporting Technical Information

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Appendix J.1 – San Diego Region Bacteria TMDLs Supporting Documentation White Paper #1

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Total Maximum Daily Loads for Indicator Bacteria, Project I – Twenty Beaches and Creeks in the San Diego Region (Including Tecolote Creek) White Paper #1:

Justification for shifting the focus of the TMDL compliance actions to identifying, prioritizing, and abating human waste inputs to receiving waters

INTRODUCTION:

In 2010, the San Diego Water Board adopted a Bacteria TMDL to address twenty waterbodies in southern Orange and San Diego Counties identified as impaired by fecal indicator bacteria. The Bacteria TMDL was developed in response to data indicating that water quality at the creeks and beaches covered under the TMDL routinely exceeded water quality objectives (WQOs) for fecal indicator bacteria (FIB). WQOs for FIB have been set at levels assumed to ensure safe conditions for recreators (swimmers, surfers, etc.). However, FIB are only indicators rather than direct measures of pathogens. The use of indicators as the sole compliance metric for the TMDL introduces uncertainty into assessing true health risks associated with water contact recreation. The TMDL does not distinguish between different sources of FIB that may pose widely varying risk to water recreators. Although the additional information supporting the recommendations discussed in the white papers was completed primarily to support the 2014 Triennial Review of the Beaches and Creeks Bacteria TMDL, the information is also applicable to the Baby Beach in Dana Point Harbor and Shelter Island Shoreline Park Bacteria TMDL.

Sources of indicator bacteria are ubiquitous and can include natural sources such as feces from aquatic and terrestrial wildlife and persistent environmental sources of bacteria, as well as human sources such as sewer line leaks and breaks, improperly functioning septic systems, outdoor defecation by humans, and illegal sewage disposal from boats along the coastline or RVs in the urban environment. The 2012 USEPA Recreational Water Quality Criteria (RWQC) and other recent scientific studies indicate that human sources of indicator bacteria are much more likely to contain human illness-causing pathogens and are therefore more indicative of human health risk than other natural sources of FIB.

Solutions to reduce or eliminate all sources of FIB from beaches and creeks involve costly programs, including capital projects such as diversions of flows from stormwater conveyances to sanitary sewers for treatment and structural stormwater best management practices (BMPs). Implementation of these solutions could involve large expenditures of taxpayer dollars that are not likely to substantially reduce risk of illness to swimmers and surfers.

Therefore, TMDL revisions are needed to incorporate a regulatory approach that more effectively targets human health risk. This can be accomplished by revising the TMDL to 1) prioritize implementation actions that reduce loads from human waste sources more clearly linked to human health impacts, and 2) more fully incorporate all relevant parties responsible for controlling discharges from human waste sources.

JUSTIFICATION:

Changes to the TMDL to focus compliance actions on addressing human sources of fecal bacteria are justified and necessary for the following reasons:

- The TMDL needs to **focus on the sources with the highest risk to human health**: recent science shows that human sources of fecal bacteria pose a higher health risk than other sources and addressing human sources is likely to reduce human health risk below USEPA recommended risk levels.

- Human waste markers are **prevalent in Southern California coastal watersheds**: recent studies in Southern California have shown that DNA markers indicative of human waste (HF183) are prevalent in coastal watersheds and ubiquitous after wet weather events.
- **Reducing human sources has been shown to be effective** at reducing HF183 levels: the City of San Diego's Morena Drain Tiger Team has found that abating human sources can be effective at reducing HF183 levels, a prevalent human waste marker in Southern California coastal waters.
- Economic studies have shown that reducing human waste inputs is the **most effective use of limited resources** to protect human health at water bodies impaired for primary recreational use.
- A focus on human sources of fecal bacteria to address health risk is **consistent with recent strategic resolutions put forth by San Diego Water Board**:
    - The Practical Vision, Resolution No. R9-2013-0153, a planning tool to guide focusing limited resources on the highest regional priorities, and
    - The Key Beneficial Uses and Key Areas report, Resolution No. R9-2017-0030, identifying key beneficial use categories and the areas most important to each category to inform strategic decisions.

Recent scientific research shows that fecal waste from humans poses a higher risk to human health than other sources of fecal bacteria

Research from the USEPA in support of the 2012 RWQC indicates that the source of fecal contamination is an important factor in understanding the human health risk associated with recreational waters. Most notably, the potential human health risk from human versus non-human sources can vary (Schoen and Ashbolt, 2010; Soller et al., 2010b). Exposure to waters contaminated with non-human fecal sources generally poses a reduced risk of infection to recreators when compared to human fecal sources (Soller et al., 2014; Harwood et al 2014).

Research has used quantitative microbial risk assessment (QMRA) to quantify the differential risks by source type (Soller et al., 2015, Schoen and Ashbolt, 2010; Soller et al., 2010a, Soller et al., 2010b, Schoen et al., 2011). The predominant finding of these risk assessment research efforts is the following: the level of risk at a site depends on the relative strength of human fecal sources, with mixtures dominated by non-human sources having substantially lower risks. Risks in waters dominated by non-human sources are generally below the USEPA benchmark of 32 excess gastrointestinal illnesses per 1,000 exposures.

Studies have incorporated measurement of host-associated DNA markers, in addition to measurement of traditional FIB (*E. coli* and enterococci), to better assess the contribution from fecal pollution of human origin. A study by Dr. Alexandria Boehm from Stanford University and colleagues (Boehm et al., 2015) used QMRA to calculate the relationship of human-associated molecular markers and risk of contracting a swimming-related illness. They found human health risk increases as the levels of human-associated markers increase in water impacted by raw sewage; therefore, reducing human sources of fecal contamination within the TMDL waterbodies will likely substantially reduce risk to human health during water recreation.

Additional information on the risk posed by specific non-human sources, and the risk posed by different types of human sources (e.g. sewage vs. transient populations) is provided in Section 4 of the TMDL Technical report.

Recent studies in Southern California have shown that DNA markers indicative of human waste (HF183) are prevalent in coastal watersheds and ubiquitous after wet weather events

The Surfer Health Study (SHS) was completed by the Southern California Coastal Water Research Project (SCCWRP) in 2016 to investigate health risks associated with surfing under various winter conditions in the San Diego area, as well as the relationship between water quality and illness risk (SCCWRP, 2016). The SHS involved a symptomatic survey of surfers across San Diego beaches after entering the water during dry and wet weather conditions during the wet weather season. In addition, at two beaches (Tourmaline Surfing Park and Ocean Beach) additional water quality data were collected at the beach and in the stormwater discharge, including FIB concentrations, human pathogen concentrations, and DNA markers for different fecal sources for the duration of the SHS. The human source marker HF183 is a DNA fragment present in a bacterium specific to human fecal matter, which allows one to distinguish between human fecal contamination and FIB from other sources. The SHS found that the presence of HF183 was detected in nearly every sample from stormwater discharges during wet weather in the region surveyed. Furthermore, the high frequency of HF183 coincided with a high frequency of detection of human-specific pathogens such as Norovirus in the same discharges.

A study published through SCCWRP's Southern California Bight 2013 (Bight '13) Regional Monitoring program entitled *Regional assessment of human fecal contamination in southern California coastal drainages* supports on a regional level what the SHS found for the two San Diego watersheds. The study examined dry and wet weather samples analyzed for HF183 from coastal drainages throughout southern California and found that HF183 is frequently present in these drainages, and is particularly ubiquitous and detected at especially high concentrations after rain events.

Given the greater health risk associated with human sources of fecal contamination, and the evidence supporting the presence of human fecal contamination in San Diego-area urban discharges, particularly during wet weather, implementation actions to abate human fecal sources are crucial to protecting water contact recreation beneficial uses at local beaches. As discussed in the Opposing Viewpoints section below, evidence also suggests that human fecal contamination from sources without specific implementation requirements in the current TMDL, such as sewer and septic systems, may be a major source of human fecal inputs to receiving waters.

Early implementation efforts, such as the City of San Diego's Morena Drain Tiger Team, have found that abating human sources can be effective at reducing HF183 levels.

In response to elevated HF183 levels, municipalities in San Diego County have begun investigations and remediation of identified sources of HF183. The results of the investigations have shown that sources of elevated HF183 are often addressed through strategies that are different from those implemented to address FIB. When targeting FIB to meet objectives, municipalities often focus on capturing and treating volumes of stormwater using large structural stormwater management measures or multiple small measures such as "green streets" to reduce FIB concentrations. Addressing identified human sources has been found to require different strategies.

For example, the City of San Diego has mobilized a team of people with expertise spanning multiple agencies within the City to address identified human waste sources that would not likely be addressed through traditional structural stormwater management measures. The City's "Tiger Team" conducted source identification work in areas with high HF183 levels and discovered a multitude of sources, including illegal RV and sanitary services dumping, broken laterals that allowed raw sewage to infiltrate into the stormwater conveyance system, broken irrigation lines that washed sewage wastes from the broken lateral further downstream, and illegal discharges, such as wash water, from commercial facilities. When these sources were addressed, subsequent monitoring showed HF183 concentrations to be significantly reduced. As an example, in one area identified based on monitoring data, a source of human fecal pollution is suspected to have been a broken private sewer lateral from a local fast food restaurant. This source was identified and repaired in May 2016. After the repair of the lateral, FIB and HF183 results decreased in concentration.

Several human waste sources, such as the private laterals and illegal dumping, would not likely have been intercepted by traditional structural stormwater BMPs. Additionally, several of these sources require cooperation and coordination with stormwater and wastewater collection system departments, which now only occur under a traditional stormwater management strategy on occasion to address illicit discharges.

Targeting human waste sources is more likely to reduce human health risk, even though it is a time consuming and resource intensive effort. Focusing the TMDL compliance actions on human waste sources will result in implementation actions most likely to reduce human health risk and foster coordination among the various agencies necessary to address these sources.

The Bacteria TMDL Cost-Benefit Analysis identified addressing human sources as the most cost effective TMDL compliance scenario.

The San Diego Bacteria TMDL Cost-Benefit Analysis (CBA) Report from October 2017 was produced to evaluate the costs and benefits of a range of scenarios and implementation methods for achieving the wet weather targets in the Bacteria TMDL (Environmental Incentives and ECONorthwest, 2017). The scenarios explored variations on the following: implementation of traditional stormwater best management practices (BMPs) targeting FIB, changing the Bacteria TMDL compliance schedule, targeting human waste sources of bacteria, and reducing bacteria through stream restoration. The study found that targeting human waste sources was the most cost-effective method to reduce health risk and protect water recreation opportunities. Additionally, the projected number of avoided infectious illnesses per million dollars invested for targeting human sources was more than ten times higher than implementing stormwater BMPs. The findings of the CBA reflect the benefits and reduction in human health risk from addressing human fecal sources, and show that addressing these sources will be the most effective investment toward avoiding illnesses in swimmers and surfers.

The additional required source investigation monitoring and source abatement efforts required by the proposed TMDL revisions will nevertheless require a significant investment of time and resources. Additional monitoring will require acquisition of necessary access permits, intragency cooridation, and more labor hours. However these resources will be more efficiently directed towards risk mitigation by targeting human sources.

A focus on human health risk is consistent with recent strategic resolutions put forth by San Diego Water Board.

The San Diego Water Board adopted the Practical Vision (Resolution No. R9-2013-0153) in November 2013 to establish a framework for the Board to establish strategic priorities and work in the most effective manner with available resources through collaboration with stakeholders. A major goal of the Practical Vision is to ensure that funding, staff, and other resources are put to the best use to achieve meaningful environmental outcomes. Research on the influence of human waste sources on human health risk, and the success of early implementation efforts show that focusing TMDL compliance and implementation on addressing human sources of bacteria are a more effective way to achieve meaningful environmental outcomes, i.e. improvement of human health, than the current TMDL approach. Furthermore the CBA findings confirm that of the options currently under consideration, this approach is the best allocation of funds for the benefits achieved.

Following the strategy of focusing efforts for the greatest positive environmental impact, the San Diego Water Board adopted the Key Beneficial Uses and Key Areas resolution (Resolution R9-2017-0030) identifying beneficial use categories that are most critical to protecting human and environmental health in the San Diego region and areas where protection of key beneficial uses is most important. The resolution and staff report identify recreation as a key beneficial use and human health as primary concern for water contact recreation. Thus, focusing the TMDL on human waste sources shown to pose the greatest threat to human health is consistent with the San Diego Water Board's regional priorities. Furthermore, the Key Beneficial Uses and Key Areas report acknowledges that human sources of human pathogens are of particular concern regarding risk to human health.

HOW THIS APROACH DIFFERS FROM THE CURRENT TMDL

Implementation and compliance actions in the current TMDL are focused on reducing FIB loads from stormwater conveyance systems that may intercept, by chance, some of the human waste sources. The current TMDL does not distinguish between the potential health impacts from exposure to different sources of fecal contamination. The use of FIB to assess health risk introduces uncertainties concerning actual conditions and danger to human health, as indicator bacteria encompass a wide variety of sources that pose varying threats of illness to humans. As previously discussed, human sources of fecal contamination are more likely to be indicative of illness risk. Therefore, making the distinction between high risk human sources and other sources of fecal contamination will allow TMDL responsible parties to more effectively address the most significant threats to human illness at impaired beaches. Changes to the TMDL will also allow for consideration of alternatives to large capital investments in projects that address sources of bacteria that do not pose a high risk to human health and may not address sources causing human health risk. Not changing the TMDL would support an approach prioritizing reducing FIB loads over reducing human health risk, which is inconsistent with the risk-based foundation of the 2012 RWQC, and, given the scientific evidence supporting the efficacy of addressing human sources at reducing human health risk, is also inconsistent with the focus on meaningful environmental outcomes in the Practical Vision.

The current Bacteria TMDL also assumes that there is no contribution to bacteria loading from sources such as exfiltration from sanitary sewers and septic systems based on other regulatory provisions prohibiting waste discharge from these systems. However, as discussed in the

Opposing Viewpoints and Responses section below, recent studies and implementation efforts have found that these systems are contributing to bacteria loading and may be significant contributors to human health risk. Correcting assumptions that discharge prohibitions imply zero discharge will allow these high risk human waste sources to be addressed by focusing TMDL implementation on abatement of human sources. The new approach to TMDL implementation will also provide a mechanism for stormwater agencies to collaborate with sanitation agencies to address bacteria loads from these systems. Currently, almost all required load reduction in the Bacteria TMDL is the responsibility of MS4s.

OPPOSING VIEWPOINTS AND RESPONSES

Sewer and septic systems are already prohibited from discharging waste, so appropriate regulatory actions have already been required.

Although discharge prohibitions are in place for sewer and septic systems, data increasingly suggest that the existing prohibitions and wasteload allocations of zero in the TMDL may not be effective at preventing these bacteria inputs from reaching receiving waters, and that these sources are likely contributors to beneficial use impairments. Additionally, in order to successfully address these sources, sanitation agencies should be required to participate in TMDL monitoring efforts, especially when tracking exceedances upstream.

To accompany the CBA, Brown and Caldwell published an exploratory report to characterize various sources of human fecal bacteria (Brown and Caldwell, 2017). The report used inspection records from San Diego and Orange County to estimate the average number of defects that may contribute to exfiltration per linear foot of pipe, the average exfiltration rate per defect per inch diameter, and the average total daily volume of leaked sewage. The study also examined information on leaking septic systems and data on sanitary sewer overflows and private lateral spills from the Regional Board. The exploratory study found that these systems are likely a significant source of human fecal contamination in most watersheds covered under the TMDL.

The following are summary of findings cited in Section 4 of the TMDL technical report, and from the Brown and Caldwell report on the contribution of sewer and septic systems to bacteria loading rates:

- A SCCWRP study conducted during dry weather used an intensive, 30-hour study of bacterial water quality and a simultaneous rhodamine dye test of the local collection system and microbial source tracking (MST) to investigate the potential contribution of FIB from collection systems to San Juan Creek and Doheny State Beach. The rhodamine dye tracer results indicated the wastewater collection system near the beach was leaking and MST results in seawater were consistent with a diffuse source of human fecal material (Layton et al., 2015). In addition, MST results from storm drain discharge sampling suggest that sewage infiltration into storm drains may be occurring (Layton et al., 2015).
- Information reported to the California Integrated Water Quality System (CIWQS) indicates that, between March 2007 and April 2016, 1,752 SSOs occurred within the area encompassed by the TMDL, accounting for approximately 37 million gallons spilled. Of these, 37 million gallons, approximately 30 million gallons reached nearby surface waters.

- The San Diego Union Tribute reported that San Diego County was the fourth largest grouping of septic systems in California in 2005, with approximately 80,000 systems.
- According to the Brown and Caldwell report, the failure rate of septic systems is 0.7% over the course of a year with an average rate of untreated septic discharge at 153 gallons per day per failed system.

Studies have not shown exactly where human waste is coming from; therefore, human fecal sources cannot be effectively addressed.

As the TMDL's previous focus on FIB has not encouraged resources to be focused on human sources, TMDL responsible parties in coordination with leading scientists are actively improving methods to identify and abate human sources. MS4 permittees have proposed a study as part of SCCWRP's Southern California Bight 2018 Regional Monitoring Program (Bight '18) to investigate sewer exfiltration rates as well as addressing human waste contributions from septic systems and homeless encampments. In addition, individual permittees have initiated their own source identification monitoring and abatement efforts. For example, the County of San Diego has initiated monitoring downstream of known septic areas to compare HF183 and bacteria loads and concentrations to areas with sewer systems.

As discussed in the Justification section, early source investigation efforts, such as those conducted by the City of San Diego's "Tiger Team," have been successful at identifying and abating sources of human waste. By coordinating with multiple City departments, the City was successful at identifying significant sources of human waste in the drainages investigated, and abatements of these sources resulted in reductions of HF183 levels. It also should be noted that some of the sources identified, including a leaking private sewer lateral from a fast food restaurant, would not have been addressed by traditional stormwater BMPs. Focusing efforts on human fecal sources has not only been shown to be effective to identify specific sources, but also provides a unique and necessary opportunity for interagency coordination to target these sources in a way that may be infeasible for a stormwater agency alone.

Human waste reduction efforts should be performed in addition to, rather than instead of, stormwater-based compliance measures to reduce fecal indicator bacteria.

The CBA examined the costs and benefits of targeting human waste sources compared to stormwater BMP implementation and determined that specifically targeting human sources was the most efficient way to invest limited resources to reduce human health risk in recreational waters. This supports the consistency of this approach with the goals of the Practical Vision to focus limited resources where they will be most effective. As discussed above, stormwater management measures targeted at FIB may not address many human sources of bacteria. Unless installed downstream of the specific pipe where dumping, cross-connections or other diverse sources are found, stormwater management measures would not capture or address these high risk sources. There is limited data about stormwater BMP performance and reliability in reducing FIB levels. Additionally, treatment of FIB in stormwater is often not technically feasible, requiring capture and infiltration or reuse of large volumes of stormwater. Infiltration can be challenging to implement in many parts of the San Diego region due to local geologic constraints. However, co-permittees are proposing to implement the TMDL through a phased schedule, which would initially focus actions on abating human sources, at high recreational use areas[1]. If illness risk is still present above recommended levels after the initial phases of implementation, additional actions, such as stormwater BMPs, may be considered as part of later phases. Additionally, co-permittees will continue to implement existing programs that address a suite of constituents, including FIB. Continued compliance monitoring at beaches throughout the first phase of implementation will be used to assess the efficacy of human source abatement actions and will provide information to evaluate the revised TMDL and inform modifications for later phases of implementation.

It is unclear who is responsible for addressing transient encampments.

Transient populations are potentially significant sources of human fecal contamination to local watersheds; however, specific studies have not been conducted to quantify the impact. Homelessness is a multi-dimensional social issue well beyond the capacity of a stormwater, flood control, or sanitation agency to manage effectively and appropriately on its own. Furthermore, water quality issues caused by homelessness cannot be solved by one-time actions, as homeless populations can change and migrate over time and in response to encampment removal efforts. It is reasonable and appropriate to expect public agencies to address water quality impacts caused by homelessness when encampments are located on public property or within infrastructure that is owned and operated by those agencies. However, expectations about the long-term effectiveness of such efforts must be tempered by the complexities of this issue. Long-term solutions to address homelessness must necessarily involve broad societal discussions about affordable housing, mental health services, and civil liberties among many other considerations. At a minimum, any Water Board actions with bearing on the homelessness issue should be coordinated with the many stakeholders and agencies actively involved in developing policy in this area. All potential water quality mandates on homelessness should be considered within a much broader context.

[1] White Paper #3 discusses proposed revisions to the TMDL to move compliance points to areas of high recreational use intensity.

REFERENCES

Arnold, B.F., Schiff, K.C., Ercumen, A., Benjamin-Chung, J., Steele, J.A., Griffith, J.F., Steinberg, S.J., Smith, P., McGee, C.D., Wilson, R. and Nelsen, C., 2017. Acute Illness Among Surfers After Exposure to Seawater in Dry-and Wet-Weather Conditions. *American Journal of Epidemiology*, pp.1-10.

Boehm, A.B., Soller, J. and O. Shanks, 2015. Human-Associated Fecal Quantitative Polymerase Chain Reaction Measurements and Simulated Risk of Gastrointestinal Illness in Recreational Waters Contaminated with Raw Sewage. *Environmental Science & Technology Letters* 2(10): 270–275.

Brown and Caldwell, 2017. Technical Memorandum on Human Sources Scenario for San Diego County and South Orange County Watersheds. Prepared for the County of San Diego, Department of Public Works, Watershed Protection Program. July 21, 2017.

Environmental Incentives and ECONorthwest, 2017. Cost Benefit Analysis: San Diego Region Bacteria Total Maximum Daily Loads, Draft Report. July 2017.

Harwood V., Staley C., Badgley B.D., Borges K., Korajkic A. 2014. Microbial source tracking markers for detecting of fecal contamination in environmental waters: relationships between pathogens and human health outcomes. FEMS Microbiol. Rev 38: 1-40.

Layton B.A., M.R. Raith, and J.F. Griffith. 2015. Use of dye tracers and qPCR to identify human fecal contamination at Doheny State Beach, Dana Point, CA. Southern California Coastal Water Research Project. Technical Report 860. Costa Mesa, CA. April 2015.

SCCWRP, 2016. The Surfer Health Study: A Three-Year Study Examining Illness Rates Associated with Surfing During Wet Weather. Southern California Coastal Water Research Project. Technical Report 943. September 2016.

SCCWRP, 2017. Regional assessment of human fecal contamination in southern California coastal drainages. International Journal of Environmental Research and Public Health.

SDRWQCB, 2010. Revised Total Maximum Daily Loads for Indicator Bacteria Project I – Twenty Beaches and Creeks in the San Diego Region (Including Tecolote Creek), Technical Report. California Regional Water Quality Control Board, San Diego Region. Resolution No. R9-2010-0001

SDRWQCB, 2013. San Diego Water Board Practical Vision: A Strategic Plan. Resolution No. R9-2013-0153. November 1, 2013.

SDRWQCB, 2017. Key Beneficial Uses and Key Areas: Focusing on What is Most Important. Resolution No. R9-2017-0030. February 2017

Schoen, M.E., and Ashbolt, N.J., 2010. Assessing Pathogen Risk to Swimmers at Non-Sewage Impacted Recreational Beaches. *Environmental Science and Technology* 44(7): 2286-2291.

Schoen, M.E., Soller, J., Ashbolt, N. 2011. Evaluating the importance of faecal sources in human-impacted waters. Water Research 45: 2670-2680.

Soller, J.A., Bartrand, T., Ashbolt, N.J., Ravenscroft, J., Wade, T.J. 2010a. Estimating the Primary Etiologic Agents in Recreational Fresh Waters Impacted by Human Sources of Fecal Contamination. Water Research 44(16): 4736–4747.

Soller, J., Schoen, M.E., Bartrand, T., Ravenscroft, J., Wade, T.J. 2010b. Estimated Human Health Risks from Exposure to Recreational Waters Impacted by Human and Non-human Sources of Fecal Contamination. Water Research 44(16): 4674–4691.

Soller, J., Bartrand, T., Ravenscroft, J., Molina, M. Whelan, G., Schoen, M. and Ashbolt, N. 2015. Estimated human health risks from recreational exposures to stormwater runoff containing animal faecal material. Environmental Modeling & Software 72: 21-32.

Soller J., Schoen ME, Varghese A, Ichida AM, Boehm AB, Eftim S, Ashbolt NJ, Ravenscroft JE, 2014. Human health risk implications of multiple sources of faecal indicator bacteria in a recreational waterbody. Water Res. 2014 Dec 1; 66:254-64.

Soller, J.A., Schoen, M., Steele, J.A., Griffith, J.F. and Schiff, K.C. 2017. Incidence of gastrointestinal illness following wet weather recreational exposures: Harmonization of quantitative microbial risk assessment with at epidemiologic investigation of surfers. *Water Research, 121*:280-289.

USEPA, 2012. Recreational Water Quality Criteria. U.S. Environmental Protection Agency, Office of Water. Washington D.C. (EPA 820-F-12-058, 2012).

Appendix J.2 – San Diego Region Bacteria TMDLs Supporting Documentation White Paper #2

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Total Maximum Daily Loads for Indicator Bacteria, Project I – Twenty Beaches and Creeks in the San Diego Region (Including Tecolote Creek) White Paper #2:

Justification for a new alternative compliance pathway to reflect local study data and a focus on risk.

INTRODUCTION

Recent scientific advancements support TMDL revisions to incorporate alternative compliance pathways that use site-specific information on sources of fecal indicator bacteria (FIB) to evaluate the actual risk to the health of water contact recreators versus only a concentration or load of FIB. These additional proposed compliance pathways will allow resources to be focused on human sources of fecal bacteria which represent the highest risk to human health.

The San Diego Water Board adopted a Bacteria TMDL in 2010 to address twenty waterbodies in southern Orange and San Diego Counties identified as impaired by FIB. The Bacteria TMDL was developed in response to data indicating that water quality at the creeks and beaches covered under the TMDL routinely exceeded criteria for FIB protective of water contact recreation beneficial uses (swimming, surfing, etc.).

To protect recreators from the risk of water contact illness, Water Quality Objectives (WQOs) were developed based on FIB concentrations. However, FIB are only indicators of fecal contamination rather than direct measures of the pathogens which cause human illness, therefore FIB are not always reliable measures of the risk to human health. Recent studies have shown that not all sources of fecal contamination are equally likely to cause illness. It was found that human-sourced fecal contamination is the main cause of illness in humans as opposed to non-human sources such as wildlife or sediments FIB sources (Soller et al., 2015, Schoen and Ashbolt, 2010; Soller et al., 2010a, Soller et al., 2010b, Schoen et al., 2011). The 2010 TMDL is based on FIB WQOs, and therefore does not distinguish between different sources of FIB and makes the assumption that all FIB are equally likely to cause illness.

JUSTIFICATION:

There are multiple lines of evidence to justify a revision of the TMDL to focus on site-specific risk-based compliance approaches in addition to the traditional FIB compliance pathways. Lines of evidence include the following:

- Recent studies suggest that **site-specific risk may be different from USEPA criteria**, therefore, site-specific information is needed to best address risk in a specific area.
- Studies have shown that **alternative markers exist** that are better indicators of risk to human health than FIB levels in the San Diego Region.
- Emphasizing protection and reduction of human health risk (rather than solely focusing on reduction of FIB levels), will **incorporate the best-available science** and better protect human health.
- **Additional compliance pathways** are the best way to address risk by incorporating available site-specific information.

Recent studies suggest that site-specific risk may be different from USEPA criteria, therefore, site-specific information is needed to best address risk in a specific area.

Since the original 2010 TMDL was developed a number of important studies have come out demonstrating that site-specific risk to human health may be different in the San Diego Region from that assumed for the national criteria. The USEPA 2012 Recreational Water Quality Criteria (RWQC) were developed based on epidemiological studies that linked the health risk associated with recreational water use to concentrations of indicator bacteria. The RWQC recognized that conditions in some waterbodies or regions may vary from the waterbodies that formed the basis of the criteria. The waterbodies of the San Diego Region have different bacteria source conditions than the sites used for all but one of the USEPA epidemiological National Epidemiological and Envrionmental Assessment of Recreational Water (NEEAR) studies. Additionally, the criteria document recognized that FIB are indicators rather than direct measurements of risk to human health and that the sources of the FIB at a particular site could alter the human health risk. As a result, the criteria document included a discussion of methods that could be used to develop site-specific targets that reflect the local sources of fecal bacteria and environmental conditions of a site to best address risks to human health from water contact recreation.

All of the studies used as the basis for the RWQC were conducted during dry weather in the summer (SCCWRP, 2016) and most were in areas without distinct dry and wet seasons like those observed in Southern California. Additionally, the studies used to develop the RWQC were in locations with known sources of human fecal inputs, including treated wastewater discharges (Wade et al. 2008, 2006, 2010). The Surfer Health Study (SHS), conducted in the San Diego Region, provided an epidemiological study that reflected the conditions not captured by the studies used as the basis for the RWQC. The SHS was designed to investigate health risks associated with wet weather conditions in ocean locations primarily influenced by diffuse sources like urban runoff and not wastewater discharges, as well as the relationship between water quality and illness risk (SCCWRP, 2016). The SHS and other ancillary studies (e.g., Soller et. al, 2017) established a connection between recreator illness following water exposure during or immediately following wet weather events (but not dry weather events) and risk to human health via epidemiological and Quantitative Microbial Risk Assessments (QMRA)-based approaches in the study area. The results of the study demonstrated that the excess gastrointestinal illness risk for surfers exposed to wet weather was below the USEPA RWQC threshold (12 versus 32 excess gastrointestinal illnesses per 1,000 recreators) despite elevated FIB concentrations, likely due at least in part to the varying fecal sources and conditions from those studied as part of the RWQC development. Given these differences in observed illness risk, using site-specific information from the SHS to guide implementation and assess compliance will be more likely to support a reduction in human health risk at waterbodies in the San Diego Region.

Studies have shown that alternative markers exist that are better indicators of risk to human health.

FIB can result from both human and non-human fecal sources. The use of human markers can provide verification that high FIB concentrations are the result of high risk human sources to support effective implementation measures to reduce and eliminate high risk sources to improve the protection of water contact recreational beneficial uses.

In the RWQC, USEPA acknowledged that non-human sources may have different illness-enterococci relationships than human sources of fecal contamination (Soller et al. 2010b) and provided for the development of site-specific objectives using health risk (QMRA) models (U.S. EPA 2012a, b). The SHS confirmed results from other studies (Soller et al., 2015, Schoen and Ashbolt, 2010; Soller et al., 2010a, Soller et al., 2010b, Schoen et al., 2011) that a relationship between FIB only occurs when there is a well-defined source of human fecal contamination (SCCWRP, 2016). The SHS results also identified non-human sources that could contribute large loads of FIB to stormwater, but with a lower risk of illness for water contact activities (SCCWRP, 2016).

The SHS used HF183 to identify the presence of human fecal contamination as it is both sensitive and specific to human sources of fecal contamination (Boehm et al. 2013) and human sources are known to be more likely to cause illness to humans. The use of HF183 to support evaluation of compliance will provide a more site-specific way of evaluating risk than FIB alone. Additionally, subsequent analysis using the SHS QMRA model was able to develop thresholds of HF183 that corresponded to the risk of excess illness observed in the SHS (Appendix B of Technical Report). Use of the HF183 thresholds in the updated Bacteria TMDL will focus implementation efforts on mitigating human sources that will result in a public health benefit for water contact recreators.

Emphasizing protection and reduction of human health risk will encourage and incorporate the best-available science and better protect human health.

Allowing for compliance to be determined using studies developed based on established methods for assessing risk, such as epidemiology studies or human health risk models, will incentivize development of studies to directly assess human health risk and to develop implementation strategies that target human fecal sources to protect water contact recreators.

The goal of the revised TMDL is to reduce the risk of illness to water recreators, as opposed to being solely focused on reducing levels of FIB. As mentioned previously, the type of FIB source is the main driver of risk to human health and HF183 is a confirmed indicator for human sources for which a relationship to human health risk has been established through the SHS during wet weather. However, epidemiological studies and human health risk models such as QMRA provide direct measurements of human health risk to exposed populations. The methods to evaluate human health risk are based on well-established science which have been endorsed by USEPA (Soller et al., 2015, Schoen and Ashbolt, 2010; Soller et al., 2010a, Soller et al., 2010b, Schoen et al., 2011). While conducting these studies is expensive and time consuming, the direct measurement of risk provides a clear demonstration that water recreators are protected if the risk measurements are below USEPA established thresholds. The SHS is an example of this type of study and the results demonstrated that this exposure was below the RWQC established risk levels for surfers during wet weather across San Diego beaches.

Additional compliance pathways are the best way to address risk by incorporating available site-specific information.

The revised TMDL includes additional compliance pathways to provide better use of available new science and information. The SHS, as discussed above, provides a very useful source of region-specific information about the risk to human health from indicator bacteria. However, it is recognized that though comprehensive, the SHS has some uncertainties associated with it. As a result, rather than relying on the study to develop region-wide site-specific objectives, the TMDL proposes to use compliance pathways that use the information developed as part of the SHS to focus implementation efforts. The result is an approach that provides multiple compliance pathways to meet the RWQC depending on the level of information available for the waterbody.

The proposed additional compliance pathways allow for the best use of site-specific information in each watershed. A pathway for just using FIB to assess compliance is maintained to ensure that areas without site-specific HF183 or human health risk assessments are meeting objectives. However, two other pathways have been established that allow the use of information from the SHS, where applicable, to be used for assessing compliance. One pathway allows the use of HF183 to either confirm that elevated FIB levels are the result of high risk human sources or establish that non-human sources are the cause of elevated FIB. The other pathway allows for the demonstration that the human health risk from the SHS, or other similar studies, apply to a waterbody and are below the RWQC risk threshold of 32/1000 excess illnesses.

The use of additional compliance pathways allows the best available information at any given site to be used. This approach will also maintain consistency with the existing TMDL and SWRCB Bacteria Provisions while incorporating the use of site-specific information.

HOW THIS APPROACH DIFFERS FROM THE CURRENT TMDL

The 2010 TMDL is based on WQOs of fecal indicator bacteria which are not a direct measurement of the pathogens that can cause illness. Furthermore, the original TMDL included a single compliance pathway which required reductions in FIB loads. The revised implementation strategy will include three different pathways to compliance, one of which is the same as the original TMDL although with updated WQOs while the others allow the use of site-specific information if available as listed below:

- Pathway 1: FIB data (same as original TMDL with new FIB WQOs),
- Pathway 2: FIB data + human genetic marker HF183[1]
- Pathway 3: Epidemiologic or QMRA study

Pathways 2 and 3 represent new approaches based on site-specific best available science focused on identifying the risk to human health. Pathway 2 requires the use of the human marker, HF183[1] and FIB data to determine what proportion of the FIB concentration is from human fecal sources. Pathway 3 allows a site to be assessed directly for risk via an epidemiologic or QMRA study. Further discussion of the different compliance pathways can be found in Section 7 of the TMDL Technical Report.

Maintaining the current TMDL approach would preclude the use of site-specific information developed as part of the SHS. The result would be a continued focus on reducing FIB loads, regardless of the source. This approach would likely result in implementation actions that are not as protective of human health as could be achieved by incorporating additional compliance pathways that focus on abating human sources and reducing human health risk. Additionally,

[1] An equivalent human marker to HF183 may be used as molecular source tracking science develops and evolves.

maintaining the current TMDL approach would disincentive scientific studies to further evolve development of indicators that are more representative of human health protection than FIB in the San Diego Region.

OPPOSING VIEWPOINTS

The current TMDL should already be sufficiently protective of human health, adding a risk-based pathway is unnecessary.

New reports and studies have come out since the original 2010 Bacteria TMDL was developed which significantly alter our understanding of the risk to human health as a result of the source of bacteria exposure. Effective implementation actions and the Bacteria TMDL should be updated to reflect the current understanding of risk. For instance, recent studies have found that the level of risk at a site depends on the relative strength of human fecal sources, with mixtures dominated by non-human sources having substantially lower risks, and risks in waters dominated by non-human sources generally below the USEPA benchmark of 32 illnesses per 1,000 exposures (Soller et al., 2015, Schoen and Ashbolt, 2010; Soller et al., 2010a, Soller et al., 2010b, Schoen et al., 2011).

A study by Boehm and colleagues (Boehm et al., 2015) used QMRA to calculate the relationship between human-associated molecular markers and risk of contracting a swimming-related illness. The study found that human health risk increases as the levels of human-associated markers increase in waters impacted by raw sewage. While this study was focused on waterbodies affected by raw sewage, as opposed to the mixture of sources known to affect the San Diego region, the study finding supports that human sources of fecal contamination within the TMDL waterbodies could pose a risk to human health. More rapid, reliable and cost-effective methods have also become available to directly measure pathogens, host-associated DNA markers, and alternative indicators.

There has been an increased understanding of local conditions in the San Diego area based on MS4 Permittee implementation actions, monitoring, and special studies resulting in better understanding of natural background levels of indicator bacteria and direct measurement of health risks using epidemiological studies and QMRA.

Finally, the release of the 2012 USEPA RWQC established two risk levels protective of human health based on an extensive review of epidemiological studies, QMRA, and alternative indicators or methods. The current TMDL is not reflective of these risk levels or any of the recent studies and therefore will not provide adequate protection to recreators if unrevised.

The Basin Plan Amendment for the TMDL allows for the revision of the TMDL if sufficient data are collected to provide the basis for the modification. The examples of new information and studies that have been conducted since the 2010 TMDL are sufficient to provide the basis for a revision to the TMDL.

Site-specific information is unnecessary since the existing objectives should be protective of all areas.

The SHS provides the most relevant, local scientific information available about FIB levels and risk in the region during the winter season. The existing FIB WQOs do not reflect the most recent USEPA 2012 Recreational Water Quality Criteria and therefore need to be updated to be protective to an acceptable level of risk. However, even with the update of the FIB WQOs, site-specific information is critical to assess the actual risk level of a site since many areas have varying sources of FIB. Some sites may have excessive FIB concentrations from natural non-human sources which will not pose a threat to human health. The SHS demonstrated that conditions in the San Diego Region are different from the studies used to develop the RWQC which were mostly based on sites impacted by wastewater point sources. Site-specific information or approaches such as measurements of HF183 or QMRA will be able to determine the human health risk level better than a general FIB measurement, as demonstrated by the SHS. Furthermore, site-specific information will allow TMDL responsible parties to focus limited resources on the areas with the greatest human health risk.

The SHS results are not applicable to all watersheds.

The relationship between illness risk and ocean exposure during wet weather was established using health information gathered from people that surfed at beaches throughout the region north of Imperial Beach. As a result, the results indicating that human health risk is below USEPA thresholds are applicable throughout the SHS study area. Furthermore, the SHS data are more representative of local sources than national studies. The revised TMDL incorporates a compliance pathway that requires assessment of whether the bacteria sources and therefore risk, within a watershed are similar to the SHS through an EPA-established process to evaluate sources. Only after the FIB sources have been confirmed to be comparable to the SHS sites can epidemiological and QMRA data be applied to a specific site. In addition, the original compliance pathway of using FIB levels to determine compliance remains an option and in those cases the SHS will not be applied.

The revised TMDL recognizes the sources in a particular area may change over time causing higher levels of risk. The revised TMDL therefore includes requirements for sanitary surveys every 5 years, mandatory reassessments, and extensive monitoring all of which are designed to detect if source conditions change. The sanitary survey assessment process follows USEPA published guidelines and tools (e.g., the Marine Beach Sanitary Survey User Manual). If source conditions change, then a reevaluation of study findings will be triggered. In addition, the adaptive management program specifies methods for modifying or adding strategies to address any human sources of bacteria contributing to exceedances.

The SHS study only covered a short time during drought conditions and therefore may not be representative of typical conditions and risk levels.

The SHS covered two winter seasons from January to March 2014 and December 2014 to March 2015 and included 10 storm events of varying sizes and intensities resulting in a total of 33,377 days of observations. The second winter season (Oct. 2014 - Sept. 2015; 303 mm annual precipitation) fell within the long-term annual average rainfall (ca. 300-350 mm per year) as measured at the San Diego Airport. The TMDL includes separate wet and dry weather numeric targets and the SHS is only applied to the wet weather targets. Because the SHS focused on exposure and illness rates during and immediately following wet weather events when indicator bacteria concentrations are generally much higher than dry weather, there is enhanced confidence that the SHS results are indicative of water quality conditions that are protective of the primary contact recreation use. Despite the drier years during the time frame the SHS was conducted, the human marker HF183 was found throughout the rain events of coverage and therefore the SHS reflects various conditions when recreators were exposed to potential illness-causing pathogens.

The SHS is not representative of the risk and population exposure.

The SHS specifically targeted surfers as the test population as they engage in ocean immersion during wet weather events and therefore represent a high-risk population. At Southern California beaches, the majority of individuals who participate in water contact activities in the ocean during wet weather events are adults. Therefore, this population is relevant to San Diego beaches. Furthermore, dry weather gastrointestinal illness levels for surfers were similar to other dry weather epidemiology studies for water contact recreations. This suggests that surfers become ill at a similar rate to the general population during ocean recreational activities (SHS Study). Follow up observations of recreators at Ocean Beach during four storms in 2017 were made to confirm the assumption of the SHS that the surfers were the appropriate target population. Only 6.6% of the observed beach users were children <5 or elderly. Only 9% of the observed beach users participated in recreational activities that involved head immersion in the water and of those 82% were surfers, Of the individuals that that participated in likely head immersion activities 0.16% were in the 0-4 year age group, and 0.8% were in the 5-17 year old group for a total of 1% of the population under <18 years of age. These observations support that surfers are the most likely population of ocean recreators to be exposed during and immediately after storms.

Although not sampled directly, a follow up analysis to evaluate the potential effect of exposure to other high-risk populations such as children was conducted. This analysis replaced the incidental water ingestion (exposure) distribution for the general population (median 19 mL) to a children specific ingestion distribution (median 38 mL) based on recently published data (Dufour et al., 2017). This modification was input into the QMRA model and two scenarios were run - the first assuming the entire exposed population is children and the section assuming 25% of the exposed population is children (still an over-representation of that reported by San Diego County). Using conservative assumptions, the risk level was still less than the USEPA RWQC level (29 illnesses out of 1,000 recreators if all are children and 18-19 illnesses out of 1,000 recreators if including 25% children and 75% adults).

REFERENCES

Boehm, A.B., L.C. Van De Werfhorst, J.F. Griffith, P.A. Holden, J.A. Jay, O.C. Shanks, D. Wanga, S.B. Weisberg. 2013. Performance of forty-one microbial source tracking methods: A twenty-seven lab evaluation study. *Water Research* 47: 6812-6828

Boehm, A.B., Soller, J. and O. Shanks, 2015. Human-Associated Fecal Quantitative Polymerase Chain Reaction Measurements and Simulated Risk of Gastrointestinal Illness in Recreational Waters Contaminated with Raw Sewage. *Environmental Science & Technology Letters* 2(10): 270–275.

Dufour, A.P., Beymer, T., Cantu, R., Magnusun, M. and Wymer, L. 2017. Ingestion of swimming pool water by recreational swimmers. *Journal of Water and Health* (In Press).

Wade, T.J., E. Sams, K.P. Brenner, R. Haugland, E. Chern, M. Beach, et al. 2010. Rapidly measured indicators of recreational water quality and swimming-associated illness at marine beaches: a prospective cohort study. *Environ Health* 9: 66.

Wade, T.J., R.L. Calderon, K.P. Brenner, E. Sams, M. Beach, R. Haugland, et al. 2008. High sensitivity of children to swimming-associated gastrointestinal illness: results using a rapid assay of recreational water quality. *Epidemiology* 19: 375–383.

Wade, T.J., R.L. Calderon, E. Sams, M. Beach, K.P. Brenner, A.H. Williams, et al. 2006. Rapidly measured indicators of recreational water quality are predictive of swimming-associated gastrointestinal illness. *Environ Health Perspect* 114: 24–28.

SCCWRP, 2016. The Surfer Health Study: A Three-Year Study Examining Illness Rates Associated with Surfing During Wet Weather. Southern California Coastal Water Research Project. Technical Report 943. September 2016.

SDRWQCB, 2010. Revised Total Maximum Daily Loads for Indicator Bacteria Project I – Twenty Beaches and Creeks in the San Diego Region (Including Tecolote Creek), Technical Report. California Regional Water Quality Control Board, San Diego Region. Resolution No. R9-2010-0001.

Schoen, M.E., and Ashbolt, N.J., 2010. Assessing Pathogen Risk to Swimmers at Non-Sewage Impacted Recreational Beaches. *Environmental Science & Technology* 44(7): 2286-2291.

Schoen, M.E., Soller, J., Ashbolt, N. 2011. Evaluating the importance of faecal sources in human-impacted waters. *Water Research* 45: 2670-2680.

Soller, J.A., Bartrand, T., Ashbolt, N.J., Ravenscroft, J., Wade, T.J. 2010a. Estimating the Primary Etiologic Agents in Recreational Fresh waters Impacted by Human Sources of Fecal Contamination. *Water Research* 44(16): 4736–4747.

Soller, J., Schoen, M.E., Bartrand, T., Ravenscroft, J., Wade, T.J. 2010b. Estimated Human Health Risks from Exposure to Recreational Waters Impacted by Human and Non-human Sources of Fecal Contamination. *Water Research* 44(16): 4674–4691.

Soller, J., Bartrand, T., Ravenscroft, J., Molina, M. Whelan, G., Schoen, M. and Ashbolt, N. 2015. Estimated human health risks from recreational exposures to stormwater runoff containing animal faecal material. *Environmental Modeling & Software* 72: 21-32.

Soller, J.A., Schoen, M., Steele, J.A., Griffith, J.F. and Schiff, K.C. 2017. Incidence of gastrointestinal illness following wet weather recreational exposures: Harmonization of quantitative microbial risk assessment with an epidemiologic investigation of surfers. *Water Research* 121: 280-289.

SWRCB, 2017, Draft Staff Report, Including Substitute Environmental Documentation for Part 3 of the Water Quality Control Plan for Inland Surface Waters, Enclosed Bays, and Estuaries of California-Bacteria Provisions and a Water Quality Standards Variance Policy and Amendment to the Water Quality Control Plan for Ocean Waters of California-Bacteria Provisions and a Water Quality Standards Variance Policy. Draft Report. State Water Resources Control Board. June, 2017.

USEPA, 2012. Recreational Water Quality Criteria. U.S. Environmental Protection Agency, Office of Water. Washington D.C. (EPA 820-F-12-058, 2012).

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Appendix J.3 – San Diego Region Bacteria TMDLs Supporting Documentation White Paper #3

Total Maximum Daily Loads for Indicator Bacteria, Project I – Twenty Beaches and Creeks in the San Diego Region (Including Tecolote Creek) Reopener White Paper #3:

Justification for change in the TMDL compliance monitoring locations to locations where the most water contact recreation occurs

INTRODUCTION

In 2010, the San Diego Water Board adopted a Bacteria TMDL to address twenty waterbodies in southern Orange and San Diego Counties identified as impaired by fecal indicator bacteria (FIB). The Bacteria TMDL was developed in response to data indicating that water quality at the creeks and beaches covered under this TMDL was not safe for water contact recreation or non-water contact recreation beneficial uses according to exceedances of water quality objectives (WQOs) based on FIB concentrations. Swimming, surfing and other leisure activities at these beaches are an essential aspect of the lifestyle that residents enjoy and visitors to the San Diego Region seek. Numerous local businesses—surf shops and other retailers, hotels and restaurants—are also centered on recreational opportunities at beaches.

An essential component of implementation of the TMDL is water quality monitoring. Monitoring is needed to evaluate progress toward attainment of the TMDLs and protection of the recreational beneficial uses in the receiving waters. Current TMDL compliance monitoring in the impaired beaches and creeks includes MS4 NPDES permit monitoring locations and AB 411 monitoring locations at beaches, and, for creeks, one location at the mouth of the creek and one or more locations upstream of the mouth (usually at MS4 NPDES permit mass emissions stations) are required.

The revised TMDL uses a tiered monitoring structure. The first tier of the monitoring program will evaluate compliance with the TMDL at the beaches to capture the highest recreational use intensity locations. Subsequent tiers are geared towards assessment, identification and abatement of human waste sources upstream, followed by monitoring to assess efficacy of various abatement actions.

Receiving water compliance locations will be defined to be representative of human health risk of exposure, and thus will be chosen at high recreational use locations. For all listed beaches and creeks with a beach at the coastal mouth, compliance monitoring is now moved to the beach downstream of the outfall or creek discharge location. For unique cases where creeks do not have a beach downstream (e.g. Chollas Creek), monitoring will be conducted in the ocean at a location outside the mixing zone for the creek discharge or in the creek above the tidal prism as appropriate.

JUSTIFICATION

Changes to the TMDL to focus monitoring on locations with the highest recreation use intensities are justified and necessary for the following reasons:

- The TMDL **should consider recreational use intensity and exposure rate** as a component of human health risk, not just bacterial concentrations. This approach is supported by the USEPA 2012 Recreational Water Quality Criteria (RWQC).
- Monitoring at high recreational use intensity locations will be more consistent with the San Diego Regional Monitoring Framework and the Key Beneficial Uses and Key Areas

Resolution. Monitoring at popular beaches provide **more accurate information about beneficial use impacts**.

- Ocean waters are a **key area for the protection of water contact recreation** in the San Diego region. The San Diego Water Board's Key Beneficial Uses and Key Areas Resolution prioritizes beaches over other waterways to be safe to swim.
- Studies show that **point zero[1] locations are not representative of exposure**, due to general lack of recreational activities and rapid dilution moving away from those locations.

The TMDL should consider use intensity and exposure rate in addition to bacterial exposure concentrations as components of human health risk.

The ultimate goal of the TMDL is to protect the health of the beach going public. Many recent scientific studies[2], along with the 2012 RWQC, support implementation actions focused on reducing human fecal sources, rather than generally focusing on all bacteria loads, as a more efficient and effective way of protecting the health of water contact recreators.

As a result, TMDL revisions emphasize a focus on reducing human health risk over reducing indicator bacteria loads. To prioritize the potential of human health risk in different types of waterbodies, the recreational use intensity (the type of recreational use and the frequency at which a waterbody is being used for recreation), and the influence from human sources of fecal waste are assessed[2]. To more directly target human health risk, the proposed changes to the TMDL are designed to account for these two additional components of risk. This requires moving compliance monitoring locations to high-use beach areas to best assess risk to water recreators. **Figure 1** provides an overview of the use intensity and human source influence associated with different types of waterbodies regulated by these TMDLs, with the highest overall risk to human health (i.e., highest illness risk and highest exposure rates) in the top right corner of the figure, popular beaches in the summer.

Monitoring at high recreational use locations will be more consistent with the San Diego Regional Monitoring Framework and provide more accurate information about public health impacts.

The Regional Monitoring Framework complements modifications to the TMDL which focus on evaluating and reducing human health risk rather than focusing on simply quantifying bacteria loads in discharges. The San Diego Water Board adopted Resolution No. 2012-0069 in December 2012 endorsing the report entitled *A Framework for Monitoring and Assessment in the San Diego Region* (Regional Monitoring Framework). The Regional Monitoring Framework outlines an approach to shift monitoring from a discharge-oriented approach, focused on determining whether discharges are in compliance with regulatory requirements, to evaluating

[1] Point zero locations refer to position along the shoreline where freshwater surface flow enters the ocean.

[2] A summary of studies supporting implementation actions focused on reducing human fecal sources can be found in White Paper #1: Justification for shifting the focus of the TMDL compliance actions to identifying, prioritizing, and abating human waste inputs to receiving waters.

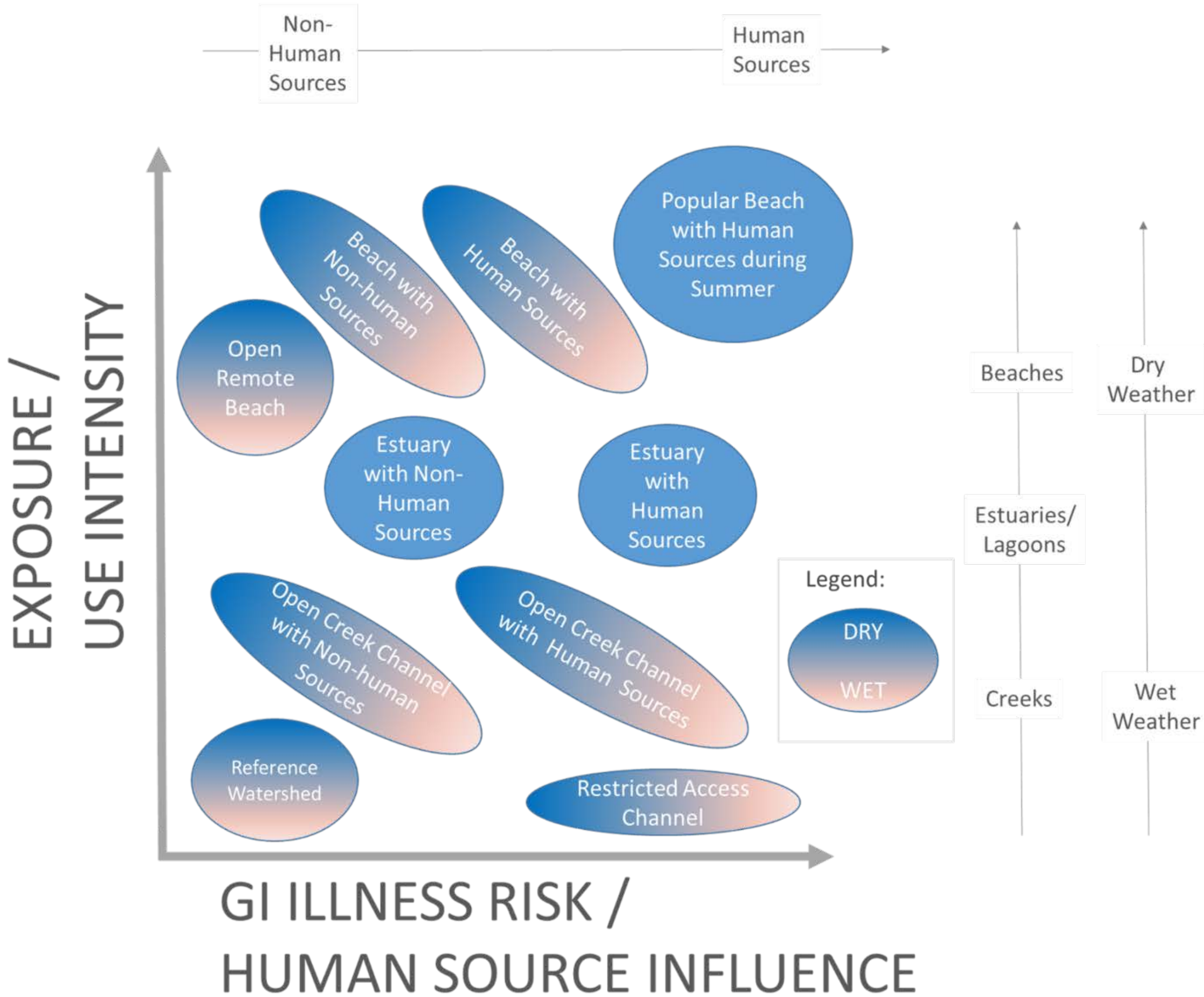

Figure 1. Recreational Use Intensity and Illness Risk by Waterbody Type

water body conditions. For unsatisfactory conditions, after the sources of stressors are identified, then monitoring evaluates the effectiveness of management actions to address those sources.

For consistency with the Regional Monitoring Framework, the first tier receiving water compliance monitoring is designed to answer monitoring questions related to receiving water conditions being protective of beneficial uses. For water contact recreation the question is: Is the water safe to swim? To answer this question, and inform the subsequent assessment and source identification process, monitoring must first occur where water contact recreation occurs. Therefore, monitoring data collected at high-use recreational beaches will be used to assess compliance with the TMDL and beneficial use impacts.

Ocean waters are a key area for the protection of water contact recreation in the San Diego region

The approach to selecting receiving water monitoring compliance locations is designed to focus on the key areas for the water contact beneficial use and is supported by a recently adopted Water Board resolution. This resolution (Resolution No. R9-2017-0030) supports the use of key beneficial uses and key areas for prioritization of Water Board efforts. Key beneficial uses are the beneficial uses that are most critical to protecting human and environmental health. Key areas are the places where protection and restoration of the chemical, physical, and biological integrity of waters is most important for a key beneficial use. The key beneficial use/key area concept allows for prioritization of the work that contributes most to protection and restoration of the integrity, or health, of waters. The Key Beneficial Uses and Key Areas (KBU and KA) report identifies recreation as a key beneficial use for the Water Board and the key waterbodies identified for water contact recreation were 1) Ocean 2) Mission Bay and 3) San Diego Bay and Dana Point Harbor. Streams and creeks are not included as a key area for water contact recreation. Additionally, the KBU and KA report states that recreation in creeks is mostly non-water contact recreation, and that aesthetic conditions of waterbodies are the primary concern for protecting beneficial uses. Potential applications of the key beneficial uses/key areas concept identified in the report include to "inform decisions about which beneficial uses, places & parameters to focus on in monitoring and assessment of the status & trends of water body conditions".

Observations in the San Diego Bacteria TMDL Cost-Benefit Analysis (CBA) Report from October 2017 also support the intensity of recreation at beaches in the region. According to the CBA, total beach attendance for the area covered by the TMDL approaches 150 million people annually, with peak water quality recreation occurring in the summer: 23.3% and 12.5% of summer beachgoers were swimmers and surfers, respectively.

Studies show that rapid dilution occurs with increasing distance from point zero locations, such as the Surfer Health Study conducted by the Southern California Coastal Water Research Project in 2016.

The Surfer Health Study evaluated dilution between upstream discharge and point of exposure, and determined that rapid dilution occurs with increasing distance from point zero locations. The Surfer Health Study mean dilution factors range from 25 to 150 with a median of 85, indicating that the concentrations observed at point zero monitoring locations are not representative of actual exposure. Therefore, monitoring locations are moved in the revised TMDL to be representative of concentrations in areas with the greatest exposure, in terms of number of recreators, exposure time, and degree of immersion in the ocean adjacent to popular recreation beaches.

This is especially the case during wet weather. Observations of beachgoers show that surfers are the predominant group of water contact users after wet weather events (MBI, 2017). As surfing occurs offshore in the surf zone (region where waves break before they reach shore), it can be concluded that water contact recreation is less likely to occur at point zero monitoring locations.

HOW THIS APPROACH DIFFERS FROM THE CURRENT TMDL

By factoring in recreational use intensity into selection of compliance monitoring locations, the new approach focuses on better answering the question of whether beneficial uses are being protected through evaluating receiving water compliance in locations where the beneficial use occurs. Furthermore, a goal of the TMDL reopener is to incorporate updated scientific studies that clearly indicate that focusing implementation strategies on the reduction of human sources of fecal bacteria rather than all sources of bacteria is the most effective way to protect beachgoer's health.

Through the new focus on reducing human health risk, the monitoring program proposed as part of the revised TMDL has been restructured into a tiered framework in the revised TMDL that provides a clear link between human source inputs upstream, abatement actions, and improved conditions for recreation. While the current TMDL includes direct compliance monitoring upstream in creeks, the revised TMDL includes requirements for actions based on findings from beach compliance monitoring, which will reduce human source inputs and improve water quality in the watershed as a whole, including in the creeks.

If the current TMDL approach is maintained, monitoring in creeks and discharges, as opposed to high recreational use areas, would drive the prioritization of implementation efforts. This approach is inconsistent with the Regional Monitoring Framework and Key Beneficial Uses document and would not reflect an assessment of the impacts to beneficial uses. The current TMDL approach could result in prioritizing implementation efforts on areas and conditions (e.g. high flows in creeks) that are not significantly impacting beneficial uses over identification of high risk conditions in the areas where beneficial uses are most likely to be impacted.

OPPOSING VIEWPOINTS AND RESPONSES

If compliance monitoring is conducted only at beaches, then water contact recreation in creeks is not being protected.

As previously discussed, the KBU and KA report states that recreation in creeks is mostly non-water contact recreation, and identifies aesthetic conditions of waterbodies as the primary concern for protecting non-water contact recreation. The new TMDL approach is consistent with the priorities identified in the KBU and KA report by focusing on reduction of human health risk in key areas for water contact recreation (i.e., ocean waters). Tying compliance to protection of key beneficial uses in key areas, along with the tiered monitoring structure and watershed based compliance actions, will allow TMDL responsible parties to direct resources to achieve significant water quality improvements where they are needed most, while continuing to protect the watersheds as a whole.

Furthermore, the tiered monitoring structure uses beach compliance monitoring as a trigger for implementation actions that will address the watershed as a whole. Therefore water quality in creeks will not be neglected. Monitoring data collected at high-use recreational locations will be used to assess compliance with the TMDL and will trigger assessment monitoring upstream if exceedances occur. Upstream monitoring will be aimed at assessing and eliminating high-risk human sources of bacteria. Source identification and abatement efforts will address human waste sources and protect recreation at all waterbodies, not just beaches.

Additionally, several different compliance pathways are included in the revised TMDL, includes a pathway that requires monitoring for HF183 in creeks and discharges. As HF183 is a human source marker, if this pathway is chosen, monitoring to assess human source influence and human health risk will occur directly in creeks.

Finally, the TMDL includes an assessment of the implementation approach to ensure it is protective of beneficial uses. If the assessment demonstrates that the approach is not protective of beneficial uses, modifications to the monitoring locations could be implemented after a TMDL reopener, including requiring creek monitoring.

If compliance monitoring locations are only at beaches then no data will be collected to support delisting 303(d) listed creeks.

Due to the structure of the new tiered implementation approach, it is unlikely that the listing status of creeks will change compliance actions for TMDL responsible parties. First, compliance monitoring at beaches with the new approach will support TMDL compliance for the watershed tributary to the beach, which will include compliance in creeks. Second, compliance actions, such as human waste source abatement, will be triggered by beach exceedances and the results of assessment and source identification monitoring. Therefore, although these compliance actions will be protective of water quality in creeks, they will not be tied to the listing status in the creeks. Third, although the objective of the TMDL program is to restore impaired waterbodies to compliance with water quality standards, based on precedent, it is unlikely that delisted waterbodies would be removed from the TMDL. Therefore, parties responsible for water quality in creeks will still be subject to TMDL requirements regardless of listing status.

This change to the TMDL reflects knowledge on improved approaches to protect beneficial uses gained after many of the water bodies were listed on the 303(d) list. The 303(d) list and TMDL program are ultimately tools to identify impairments of beneficial uses and contributions to those impairments. The revised TMDL reflects the San Diego Water Board Practical Vision and focuses implementation efforts to achieve the greatest environmental and societal benefit.

REFERENCES

Environmental Incentives and ECONorthwest, 2017. Cost Benefit Analysis: San Diego Region Bacteria Total Maximum Daily Loads, Draft Report. July 2017.

Michael Baker, International, 2017. Recreational Observations at Ocean Beach, San Diego after Rain Events. Prepared for the County of San Diego. September 5, 2017.

SCCWRP, 2016. The Surfer Health Study: A Three-Year Study Examining Illness Rates Associated with Surfing During Wet Weather. Southern California Coastal Water Research Project. Technical Report 943. September 2016.

SDRWQCB, 2010. Revised Total Maximum Daily Loads for Indicator Bacteria Project I – Twenty Beaches and Creeks in the San Diego Region (Including Tecolote Creek), Technical Report. California Regional Water Quality Control Board, San Diego Region. Resolution No. R9-2010-0001

SDRWQCB, 2012. A Framework for Monitoring and Assessment in the San Diego Region. November 2012

SDRWQCB, 2013. San Diego Water Board Practical Vision: A Strategic Plan. Resolution No. R9-2013-0153. November 1, 2013.

SDRWQCB, 2017. Key Beneficial Uses and Key Areas: Focusing on What is Most Important. Resolution No. R9-2017-0030 February 2017

Soller, J., Schoen, M.E., Bartrand, T., Ravenscroft, J., Wade, T.J. 2010. Estimated Human Health Risks from Exposure to Recreational Waters Impacted by Human and Non-human Sources of Fecal Contamination. Water Research 44(16): 4674–4691.

USEPA, 2012. Recreational Water Quality Criteria. U.S. Environmental Protection Agency, Office of Water. Washington D.C. (EPA 820-F-12-058, 2012).

Appendix J.4 – San Diego Region Bacteria TMDLs Supporting Documentation

White Paper #4

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Total Maximum Daily Loads for Indicator Bacteria, Project I – Twenty Beaches and Creeks in the San Diego Region (Including Tecolote Creek) Reopener White Paper #4:

Justification for extension of the compliance schedule.

INTRODUCTION

In 2010, the San Diego Water Board adopted a Bacteria TMDL to address twenty waterbodies in southern Orange and San Diego Counties identified as impaired by fecal indicator bacteria (FIB). The Bacteria TMDL was developed in response to data indicating that water quality at the creeks and beaches covered under the TMDL routinely exceeded water quality objectives (WQOs) for FIB. WQOs for FIB were set at levels assumed to ensure safe conditions for recreators (swimmers, surfers, etc.).

Since the 2010 TMDL was developed, scientific advances have found that FIB are not the best indicators for human health risk. The USEPA released updated Recreational Water Quality Criteria (RWQC) guidance in 2012 which employs a risk-based approach and developed WQOs for FIB that translate the risk levels into targets protective of human health (USEPA 2012). In addition, the knowledge of local conditions of human health risk and of FIB sources have increased due to local epidemiological and Quantitative Microbial Risk Assessment (QMRA) studies and targeted work by municipal separate storm sewer system (MS4) Permittees. Furthermore, a study by Dr. Alexandria Boehm from Stanford University and colleagues (Boehm et al., 2015) determined that the risk of illness increases as the levels of human-associated markers of raw sewage increase. Therefore, the source of FIB, particularly human-sourced FIB, is a better indicator of human health risk versus FIB concentrations alone.

The revised TMDL incorporates an approach that reflects the current regulatory situation (WQOs based on FIB) and science and management measures that more effectively target risk to human health. This is accomplished by incorporating revisions to the TMDL that support focusing on reducing FIB loads associated with human sources that have a clear link to human health impacts. This approach will reduce bacteria loads most associated with human health risk and provide a structure for incorporating additional science and information on human health risk before implementing actions to address non-human sources of bacteria. This approach also prioritizes waterbodies with the highest recreational use intensities, at which human fecal pathogens could cause a greater number of illnesses. The incorporation of a focus on human sources results in the need to modify the implementation approach to the TMDL, incorporate new responsible parties, and conduct significant investigative efforts to identify and mitigate human sources.

An extended compliance schedule is necessary to allow time to enact the new implementation approach focusing on human sources and new implementation requirements for the TMDL responsible parties. The 2010 TMDL compliance schedule required that dry weather and wet weather WQOs be met within 10 and 20 years, respectively, from the effective date of the TMDL with final compliance occurring in 2021 for dry weather and 2031 for wet weather. The revised TMDL proposes an extended compliance schedule to allow responsible parties the time needed to implement the new requirements. The proposed extended compliance schedule is as follows:

- Wet weather compliance would be reached within 20 years of incorporation of the TMDL revisions into applicable permits, not to exceed 25 years from the effective date of the TMDL revisions, and
- Dry weather compliance would be reached within 10 years of incorporation of the TMDL revisions into applicable permits, not to exceed 15 years from the effective date of the TMDL revisions.
- Should an integrated plan[1] be approved during the implementation period, the adopted integrated plan schedule would become the revised implementation schedule for the responsible agency with the approved plan.

The period of time selected for the compliance schedule extension is based on the existing TMDL compliance schedule of 10 years for dry weather and 20 years for wet weather when addressing multiple pollutants. The revised TMDL provisions, as discussed in the justification section below, essentially require a completely new implementation approach for the TMDL responsible parties (which explicitly incorporates new responsible parties) and include new targets and indicators for compliance. As a result, the proposed extension basically restarts the schedule as if this were a new TMDL and allows for the same amount of time as the previous TMDL to meet the final targets and allocations. The compliance schedule extension and inclusion of an option for adjusting the schedule for integrated planning will allow a robust application of the adaptive management approach and ensure that efforts to mitigate exposure of recreators to illness-causing pathogens are properly targeted, resulting in maximum protection of the REC-1 beneficial use.

JUSTIFICATION

Changes to the timeline for the compliance schedule are justified for the following reasons:

- The proposed TMDL revisions incorporate targets based on new WQOs that are **more stringent** (both in the risk level and bacteria concentration) than the original TMDL which requires more time to comply.
- The proposed TMDL revisions incorporate information on the **latest science** and modify the TMDL to focus on human sources of FIB requiring more time to allow for implementation requirements.
- The modified implementation requirements for the **MS4 dischargers include additional monitoring and source abatement obligations** which will take additional time to implement.
- Additional time is required for **sanitation agencies and others to assess areas of concern** and implement actions to address any identified infrastructure issues.
- Extending the compliance schedule will **allow responsible parties to reduce the annual cost burden** to more affordable levels.
- The proposed TMDL revisions focus on human sources and will require **increased coordination across various agencies and private property owners** in order to identify and address human sources and coordinate monitoring and reporting activities with new responsible parties.

[1] https://www.epa.gov/npdes/integrated-planning-municipal-stormwater-and-wastewater

- Additional time for compliance will allow **more targeted remediation of chronic problems** which require more complex solutions and/or actions from private citizens.

The TMDL revisions incorporate targets that are more stringent than the original TMDL which require more time to comply.

The 2010 TMDL established concentration-based numeric targets in receiving waters consistent with the Basin Plan WQOs that were based on the USEPA 1986 criteria (USEPA, 1986). Since the development of the 2010 TMDL, USEPA released the 2012 RWQC guidance and much effort has been invested in the San Diego Region and other areas to better understand the sources of bacteria, their impact on receiving waters, and how to effectively address impairments. As opposed to the previous water-quality based approach, the 2012 USEPA RWQC endorsed a risk-based approach by evaluating epidemiologic studies to establish two risk levels, both deemed protective of human health (32 or 36 excess gastrointestinal illnesses per 1,000 exposures). These risk levels can then be translated into targets that are protective of the risk to human health (USEPA, 2012).

The revised TMDL incorporates these recent advancements in our understanding of risk to set targets which are more stringent (both in regard to the risk level and bacteria concentration) than those included in the 2010 TMDL. The 2010 TMDL utilized FIB concentrations that correlate to those listed in the 1986 USEPA criteria and a risk level of 36 excess gastrointestinal illnesses per 1,000 recreators[2]. The revised TMDL updates the risk level to 32 excess illnesses, thus making the risk level more protective than the original TMDL. The revised targets for beaches (marine) are based on enterococci and the targets for creeks (fresh) are based on E. coli, with magnitudes that correspond to the risk level endorsed by the 2012 RWQC guidance and State Water Board Bacteria Provisions. In addition, a new compliance pathway has been added that utilizes the output of the Surfer Health Study (SHS). The SHS was completed by the Southern California Coastal Water Research Project (SCCWRP) in 2016 to investigate health risks associated with surfing under various winter conditions and the relationship between water quality and illness risk. As part of the study, the human health marker HF183 was linked to illness rates and the presence of human-sourced FIB. The revised TMDL includes a pathway that defines an HF183 threshold that corresponds with a more protective illness rate than the 2010 TMDL. Because these targets are more stringent than those previously set in the 2010 TMDL, more time is required to meet the new TMDL targets.

The proposed TMDL revisions incorporate information on the latest science and focus on human sources of FIB, representing significant modifications to the TMDL requiring more time for compliance.

Research from the USEPA in support of the 2012 RWQC indicated that the source of fecal contamination is an important factor in understanding the human health risk associated with recreational waters. Most notably, the potential risk from human versus non-human sources of FIB can vary (Schoen and Ashbolt, 2010; Soller et al., 2010b). A study by Jeffrey Soller and colleagues (Soller et al., 2010) used QMRA to establish the risk of contracting a swimming-related illness and exposure to waters impacted by gull, chicken, pig, cattle, or human fecal

[2] Appendix A to the 2012 RWQC report (Wymer, et. a., 2012) evaluated the illness risk of the 1986 USEPA criteria using the National Epidemiological and Environmental Assessment of Recreational (NEEAR) study program methodology, set forth by the USEPA in 2002, and determined that the 1986 criteria corresponded to an illness risk of 36 excess illnesses per 1,000 exposures.

contamination. The authors found human health risk is higher for exposure to recreational waters affected by human fecal bacteria; therefore, reducing human sources of fecal contamination within the TMDL waterbodies will likely substantially reduce risk to human health during water recreation.

A study published through SCCWRP's Southern California Bight 2013 (Bight '13) Regional Monitoring program entitled *Regional assessment of human fecal contamination in southern California coastal drainages* (SCCWRP, 2017) examined dry and wet weather samples analyzed for HF183 from coastal drainages throughout southern California. The study found that HF183 is frequently present in these drainages, and is particularly ubiquitous and detected at especially high concentrations after rain events. Targeted monitoring conducted as a follow-up to the SHS found HF183 concentrations at elevated levels throughout the San Diego River watershed (SCCWRP, 2016). As a result, it is likely that the revised TMDL approach will require a significant investment of time and money to investigate and abate human sources.

Given the greater health risk associated with human sources of fecal contamination, and the evidence supporting the presence of human fecal contamination in San Diego-area urban discharges, particularly during wet weather, implementation actions to abate human fecal sources are crucial to protecting water contact recreation beneficial uses at local beaches. Evidence also suggests that human fecal contamination from sources without specific implementation requirements in the current TMDL, such as sewer and septic systems, are a likely source of human fecal inputs to receiving waters (see Section 4 Source Analysis of the Technical Report for more information).

The revised TMDL focuses on human sources of FIB and requires significant modifications, including source identification monitoring and assessments to identify specific sources of human fecal bacteria affecting receiving waters and performance monitoring to demonstrate that human sources have been addressed. This change will require more time to identify sources and to coordinate with responsible parties in order to implement human source reduction actions. Time is also needed for responsible parties, such as MS4s and sanitary agencies, to develop coordinated monitoring programs to address new monitoring requirements.

The modified implementation requirements for the MS4 dischargers include additional monitoring and source abatement obligations that will take additional time to implement.

The revised compliance schedule reflects the extra time that will be required for MS4 dischargers to implement new monitoring and source abatement requirements in the revised TMDL. Under the revised TMDL a four-tiered monitoring approach will be implemented when exceedances of numeric targets are observed. The approach includes receiving water compliance monitoring, upstream assessment monitoring, source identification monitoring and assessment, and performance monitoring.

It is expected that these compliance actions, identified as a result of the source identification monitoring and assessments, will require additional time and resources to implement. Source investigation and abatement can be time intensive, as evidenced by follow-up work conducted as a result of the SHS. The SHS found elevated levels of HF183 in the monitored waterbodies. In response to the elevated HF183 levels, source investigations were conducted in two local drainage areas which showed some of the highest levels of HF183. The City of San Diego formed a cross-departmental group (Tiger Team) to investigate possible sources of fecal contamination and develop key investigation guidance for fecal contamination. This effort involved extensive sampling of various parameters at a number of different outlets during multiple months. Coordination across various City divisions and departments resulted in the identification of 10 possible origin sources for the human FIB, each of which needed to be investigated for a possible corrective action. Possible sources included illegal RV and sanitary services dumping, two broken laterals that allowed raw sewage to infiltrate into the stormwater conveyance system, broken irrigation lines that washed sewage wastes from the broken lateral further downstream, and illegal discharges such as wash water from commercial facilities. When these sources were addressed, subsequent monitoring showed HF183 concentrations to be significantly reduced.

The Tiger Team represents an example of the type of integrated program that is needed to effectively identify and target human sources of FIB in MS4 systems. Such programs are time and resource intensive, due to the addition of new sampling locations, permitting and safety measures, intragency coordination and other factors, and City staff estimate that approximately two similar source investigations and source abatements could be initiated each year based on the time necessary to complete the work in these recent efforts. However, this may vary based on the size of the drainage area, available resources, and other site specific conditions. Furthermore, even with additional resources, time is needed to conduct monitoring and source identification studies. While a MS4 is responsible for investigating and preventing discharges to and through their MS4, they are not solely responsible for discharges of human sources to the MS4 from septics, collection systems, private laterals, exfiltration from sanitary sewers, and transients which will require coordination with other agencies to address.

It is essential that more time be allowed for MS4 dischargers to implement the new requirements and ensure that the highest risk sites are prioritized to quickly remove the largest threats to human health. Additional time is required for sanitation agencies and private property owners in some cases (for septics and private laterals) to assess areas of concern and implement actions to address any identified infrastructure issues.

Due to the proposed focus on human sources, it is anticipated that addressing wastewater collection system infrastructure (and other sources) will be a component of the implementation actions required by the TMDL. For example, sanitary agencies did not have major obligations in the 2010 TMDL beyond complying with their Waste Discharge Requirements (WDRs) to prevent sanitary sewer overflows (SSOs). However, with the revised focus on human sources of FIB in the revised TMDL, sanitary agencies and others will need to be involved in the implementation and monitoring requirements of the revised TMDL and may be required to implement actions beyond prevention of SSOs if other sources associated with the collection system (e.g. exfiltration) are determined to be a source in some areas.

Under the original TMDL, sanitary agencies were responsible for complying with their WDRs by developing and implementing sanitary sewer system management plans and a monitoring and reporting plan to limit SSOs, but no specific actions were required to comply with the TMDL requirements. However, since the adoption of the TMDL, SSOs have continued to occur and have the potential to contaminate sediments and act as reservoirs of bacteria which can later be mobilized by storm events, resulting in elevated indicator bacteria concentrations in receiving waters. As a result, the revised TMDL will require more active participation by sanitary agencies in the TMDL to prevent and manage spills.

In addition to the focus on spill management, the revised TMDL will require sanitary agencies to also address any source issues that are identified through the new TMDL monitoring program. As mentioned previously, a four-tiered monitoring approach will be required for waterbodies not in compliance, including receiving water compliance monitoring, upstream assessment monitoring, source identification monitoring and assessment, and performance monitoring. The new focus on human sources of FIB has not been implemented before, therefore there are large uncertainties associated with the number of sanitary sewer sources, the potential cost of infrastructure replacements, and the time needed to abate sources of human sewage. It is possible that some of these sources will involve infrastructure repairs which could take significant time and resources to complete. As such, additional time is required for sanitation agencies and private property owners in some cases (for septics and private laterals) to assess areas of concern and implement actions to address newly identified infrastructure issues. Time is also needed to set up structures that allow sanitation agencies and others to coordinate monitoring and follow-up source identification and abatement efforts consistent with other responsible parties. Due to the significant new requirements for sanitation agencies that were not included in the 2010 TMDL, the extended schedule was selected to be consistent with the time allowed for compliance with requirements for other responsible parties in the 2010 TMDL.

Extending the compliance schedule will allow responsible parties to reduce the annual cost burden to more affordable levels.

The San Diego Bacteria TMDL Cost-Benefit Analysis (CBA) Report from October 2017 was produced to evaluate the costs and benefits of a range of scenarios and implementation methods for achieving the wet weather targets in the Bacteria TMDL (Environmental Incentives and ECONorthwest, 2017). The scenarios explored the following: implementation of traditional stormwater best management practices (BMPs) targeting FIB, changing the Bacteria TMDL compliance schedule, targeting human waste sources of bacteria, and reducing bacteria through stream restoration. In addition to targeting human sources, the CBA found that extending the wet weather compliance schedule is one of the most cost-effective scenarios because it resulted in reduced annual costs and achieved bacteria load reductions over a longer period of time. Additionally, an initial Financial Capability Assessment conducted in association with the CBA found that cost burden associated with the 2010 TMDL compliance schedule will likely exceed acceptable affordability thresholds, which USEPA defines as costs that exceed 2% of median household income. However, extending the time schedule will spread the cost of compliance over a longer period of time, thus reducing the annual cost per median household income and increase the affordability of compliance. Additionally, incorporating a mechanism to allow for the use of a schedule developed based on the USEPA integrated planning guidance would increase affordability, while also prioritizing coordinated projects that provide multiple benefits.

Time for increased coordination across various agencies will be required in order to identify and address human sources and coordinate monitoring and reporting activities with responsible parties.

The revised TMDL and focus on human sources requires that increased coordination occurs across various agencies and others in order to identify and address human sources and coordinate monitoring and reporting activities with new responsible parties.

For instance, the Tiger Team required coordination with individuals from two City departments (i.e., Transportation & Storm Water and the Public Utility Department) and resulted in the identification of ten separate potential origin sources requiring coordination with many private responsible parties. It is anticipated that multiple teams would need to be deployed to address identified sources that could involve multiple layers of coordination across agencies and jurisdictions. Such coordination is essential for the success of the program as evidenced by the positive abatement outcome achieved by the Tiger Team, however developing and maintaining such coordination efforts takes time and the proposed compliance extension will allow such successful coordination efforts to occur.

In addition, several human waste sources, such as private laterals, illegal dumping, RV/camper discharges, and leaking septic systems, would not likely have been intercepted by traditional structural stormwater BMPs and therefore will represent newly identified responsible parties. Some of these sources require outreach to private citizens that will take time to implement successfully. Additionally, several of these sources require cooperation and coordination with wastewater agencies that typically only occurs when addressing illicit discharges. Building relationships and setting up systems to maintain coordination with new responsible parties takes time and resources, but will be essential for the success of the TMDL.

Additional time for compliance will allow more targeted remediation of chronic problems

Chronic sources of human FIB may include slow leaking septic tanks, wastewater infrastructure issues, broken private sewer laterals, and illicit RV/camper discharges. Many of these sources will require time to undergo targeting monitoring and remediation in order to identify and remove the sources. Some of these sources may require systematic infrastructure changes which will need ample time to be properly vetted and evaluated.

The Tiger Team developed enhanced monitoring guidelines to identify such sources. The phases involved included (1) isolating different branches of the MS4 to determine extent of impacted area, (2) refining the boundary of the impacted area to identify potential sources, and (3) continuous investigation until the source of human fecal contamination was abated. Even with such targeted monitoring and use of human source indicators, it may take multiple years to fully identify and abate a chronic source. As such, an extended compliance timeframe is needed to ensure chronic human fecal contaminations are properly identified and abated.

HOW THIS APPROACH DIFFERS FROM THE CURRENT TMDL

Implementation and compliance actions in the current TMDL are focused on reducing FIB loads from stormwater conveyance systems that may intercept by chance some of the human waste sources. The current TMDL does not distinguish between the potential health impacts from exposure to different sources of fecal contamination. The use of FIB to assess health risk introduces uncertainties concerning actual conditions and danger to human health, as FIB encompass a wide variety of sources that pose varying threats of illness to humans. As previously discussed, human sources of fecal contamination are more likely to be indicative of illness risk. Therefore, making the distinction between high risk, human sources and other sources of fecal contamination will allow TMDL responsible parties to more effectively address the most significant threats to human illness at impaired beaches. Changes to the TMDL will also allow for consideration of alternatives to large capital investments in projects that address sources of bacteria that do not pose a high risk to human health and may not address sources causing human health risk. Not changing the TMDL would support an approach prioritizing reducing FIB loads over reducing human health risk, which is inconsistent with the risk-based foundation of the 2012 RWQC.

The current Bacteria TMDL also assumes that, due to other regulatory discharge prohibitions, there is no contribution to bacteria loading from sources such as exfiltration from sanitary sewers and septic systems. However, as discussed above, recent studies and implementation efforts have found that these systems are contributing to bacteria loading and may be significant contributors to human health risk. Correcting assumptions that discharge prohibitions imply zero discharge will allow these high risk human waste sources to be addressed by focusing TMDL implementation on abatement of human sources. The new approach to TMDL implementation will also provide a mechanism for stormwater agencies to collaborate with sanitation agencies to address bacteria loads from these systems. Currently, almost all required load reduction in the Bacteria TMDL is the responsibility of MS4s.

The 2010 TMDL compliance schedule requires that dry weather WQOs be met within 10 years from the effective date of the TMDL and wet weather WQOs be met within 20 years from the date of the TMDL. However, the 2010 TMDL did not explicitly evaluate the time and resources needed to address compliance. The proposed revisions to the TMDL incorporate new information that was unavailable at the time of the initial TMDL development and lay out explicit pathways to come into dry weather compliance within 10 years and wet weather compliance within 20 years of the integration of the requirements into applicable permits. The revisions also allow for modifications to the schedule if included in an approved integrated plan. Maintaining the current TMDL schedule will not facilitate meeting compliance objectives any faster as the major time limiting steps are monitoring and identification of sources, and ability to fund implementation actions. Furthermore, the revised TMDL incorporates provisions to prioritize high risk areas where there are higher rates of recreation along with prevalent human FIB markers. The proposed compliance extension accounts for the time required to coordinate and conduct such studies and bring sewer and septic systems into compliance.

OPPOSING VIEWPOINTS AND RESPONSES

The current TMDL schedule already provides ample time (20 years) to address bacteria, any extension of time will only put the public at risk by allowing them to be exposed to human waste for a longer period of time.

The updated implementation strategy includes using human source tracking methods to target the bacteria which represent the greatest risk to human health. These proposed methods will provide better protection of human health than those objectives and methods used in the original 2010 TMDL which only focused on FIB loads. For instance, studies have shown that the human health risk of illness increases as the levels of human-associated markers of raw sewage increase. Therefore, resources focused on reducing human-sourced FIB will result in faster decreases in human health risk than focusing on FIB loads alone. However, because these methods are new and resource intensive they require additional time to implement.

Currently, discharges from sewer or septic sources are not allowed and, therefore these sources are assumed to not contribute any bacteria to receiving waters. However, the application of new methods, such as human markers, indicates that in some cases there are discharges from leaking septic tanks and sewers that contribute to recreational waters. Complying with the original TMDL provisions will not address these high-risk sources. Using the tools proposed in the TMDL revisions will address these sources, but will require additional time to implement and use human markers to target the locations of such sources.

The extension for compliance will allow a more targeted implementation and will implement WQOs which are more protective of human health than those included in the existing TMDL. In addition, the revised TMDL approach also prioritizes waterbodies with the highest recreational use intensities, at which human fecal pathogens could cause a greater number of illnesses. Therefore, the revised time schedule will actually allow increased protection of human health as compared to the original compliance schedule.

The bacteria objectives are not new and have been around for a long time; why was the proposed approach not taken from the beginning?

Newly developed scientific advances have gone into the development of the proposed TMDL revisions that were not available prior to 2010 during the original TMDL development process (e.g., SCCWRP, 2016, Boehm et. al, 2015). By using them now, the revised TMDL will provide increased protection to human health via implementation of a risk-based approach to more directly target human health risk. Other Bacteria TMDLs (e.g., Los Angeles River; LARWQCB, 2010) include longer compliance timelines as bacteria exceedances are complex and present unique challenges to address. Therefore, utilizing these new scientific advances requires that the timeline is adjusted to ensure appropriate implementation which will result in a reduction in illness-causing bacteria.

REFERENCES

Boehm, A.B., Soller, J. and O. Shanks, 2015. Human-Associated Fecal Quantitative Polymerase Chain Reaction Measurements and Simulated Risk of Gastrointestinal Illness in Recreational Waters Contaminated with Raw Sewage. *Environmental Science & Technology Letters* 2(10): 270–275.

Environmental Incentives and ECONorthwest, 2017. Cost Benefit Analysis: San Diego Region Bacteria Total Maximum Daily Loads, Final Report. October 2017.

LARWQCB, 2010. Los Angeles River Watershed Bacteria Total Maximum Daily Load. Resolution R10-007.

SCCWRP, 2016. The Surfer Health Study: A Three-Year Study Examining Illness Rates Associated with Surfing During Wet Weather. Southern California Coastal Water Research Project. Technical Report 943. September 2016.

SCCWRP, 2017. Regional assessment of human fecal contamination in southern California coastal drainages. International Journal of Environmental Research and Public Health.

SDRWQCB, 2010. Revised Total Maximum Daily Loads for Indicator Bacteria Project I – Twenty Beaches and Creeks in the San Diego Region (Including Tecolote Creek), Technical Report. California Regional Water Quality Control Board, San Diego Region. Resolution No. R9-2010-0001.

Soller, J., Schoen, M.E., Bartrand, T., Ravenscroft, J., Wade, T.J. 2010. Estimated Human Health Risks from Exposure to Recreational Waters Impacted by Human and Non-human Sources of Fecal Contamination. *Water Research* 44(16): 4674–4691.

USEPA, 2012. Recreational Water Quality Criteria. U.S. Environmental Protection Agency, Office of Water. Washington D.C. (EPA 820-F-12-058, 2012).

Wymer, L, Wade, T., and Dufour, A. 2012. Translation of 1986 Criteria Risk to Equivalent Risk Levels for use with New Health Data Using Rapid Methods for Measuring Water Quality. U.S. Environmental Protection Agency, Office of Water. Washington D.C. (EPA 820-F-12-058, Appendix A, 2012).

U.S. EPA 1986. EPA's Ambient Water Quality Criteria for Bacteria – 1986. U.S. Environmental Protection Agency: Washington, DC. EPA440/5-84-002.

Appendix J.5 – San Diego Region Bacteria TMDLs
Draft TMDL Technical Report

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Revised Total Maximum Daily Loads for Indicator Bacteria for Beaches and Creeks in the San Diego Region

Draft Technical TMDL Report

September 11, 2017

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LIST OF ACRONYMS AND ABBREVIATIONS

BMPs	Best Management Practices
Caltrans	California Department of Transportation
CCR	California Code of Regulations
CIWQS	California Integrated Water Quality System
CFR	Code of Federal Regulations
CFU	Colony-forming units
CWA	Clean Water Act
EMCs	Event mean concentration
E. coli	*Escherichia coli*
FIB	Fecal indicator bacteria
GI	Gastrointestinal
GIS	Geographic Information System
GM	Geometric mean
LA	Load allocations
mL	Milliliter
MOS	Margin of safety
MPN	Most probable number
MS4	Municipal Separate Storm Sewer Systems
MST	Microbial source tracking
NEEAR	National Epidemiological and Environmental Assessment of Recreational water
NGI	NEEAR-GI illness
NPDES	National Pollutant Discharge and Elimination System
OWTS	Onsite wastewater treatment system
qPCR	Quantitative polymerase chain reaction
QMRA	Quantitative microbial risk assessment
REC-1	Water contact recreation
REC-2	Non-contact water recreation
Regional Board	California Regional Water Quality Control Board, San Diego Region
RWQC	Recreational water quality criteria
SCCWRP	Southern California Coastal Water Research Project
SHS	Surfer health study
SSO	Sanitary Sewer Overflows
STV	Statistical threshold value
State Water Board	State Water Resources Control Board
TMDL	Total Maximum Daily Load
TSM	Technical Support Materials
USEPA	United States Environmental Protection Agency
WDR	Waste discharge requirements
WLA	Wasteload allocation
WQIP	Water quality improvement plan
WQO	Water quality objective

1. Introduction

Safe swimming conditions are a top priority at San Diego Region beaches, which are a defining community and economic resource for the area. Swimming, surfing and other leisure activities at these beaches are essential aspects of the lifestyle that residents enjoy and visitors to the San Diego Region seek. Numerous local businesses—hotels, restaurants, surf shops, and other retailers—also rely heavily upon recreational opportunities at beaches. This highly desirable region has become increasingly urbanized, and with urbanization comes the potential for water quality impairment. Beach water quality is generally very good throughout the region during the dry summer months. An extensive network of storm drain diversions to the sanitary sewer system and various other measures have resulted in measurable improvements in beach water quality. Precipitation events during the winter season have been shown to contribute to elevated levels of fecal indicator bacteria (FIB) in the ocean, typically declining to pre-storm levels within three days. Water quality objectives (WQO) for FIB have been established to ensure safe conditions for recreation at these water bodies. However, the use of FIB to assess impacts introduces uncertainties concerning actual conditions and danger to human health. It is well established that FIB derive from a wide variety of sources, ranging from decaying organic matter to wildlife and pets to human waste, which pose varying threats of illness to humans. Traditional solutions to reduce or eliminate FIB from beaches can involve costly capital projects, including water diversions and structural stormwater best management practices (BMPs). Implementation of these stormwater-centric solutions could lead to large amounts of money spent addressing sources of FIB that are not likely to cause illness, which could be better spent targeting higher risk sources.

In 2010, the California Regional Water Quality Control Board, San Diego Region (San Diego Water Board) adopted Resolution No. R9-2010-0001, *A Resolution Amending the Water Quality Control Plan for the San Diego Basin (9)* to Incorporate Revised Total Maximum Daily Loads for Indicator Bacteria, Project I – Twenty Beaches and Creeks in the San Diego Region (Including Tecolote Creek), referred to herein as the Bacteria TMDL (RWQCB, 2010). The Bacteria TMDL addressed twenty waterbodies in southern Orange and San Diego Counties identified as impaired by FIB on the 2002 Clean Water Act (CWA) Section 303(d) List of Water Quality Limited Segments (20 303(d) list) adopted by the State Water Resources Control Board. The Bacteria TMDL underwent a lengthy stakeholder process, culminating in the adoption of a peer-reviewed TMDL technical report, and Basin Plan amendment.

Since the Bacteria TMDL was adopted, the Phase I Municipal Separate Storm Sewer System (MS4) permittees (Phase I MS4s and Caltrans) developed detailed implementation plans called Bacteria Load Reduction Plans (BLRPs) or Comprehensive Load Reduction Plans (CLRPs), which have since been incorporated into the Water Quality Improvement Plans (WQIPs) required by the MS4 Permit. In addition, the MS4 Permittees have initiated numerous implementation actions to reduce bacteria, collected water quality data to assess the extent of bacteria impairments in the region, and conducted a number of special studies to identify bacteria sources and potential risks. As a result, there is now a much better understanding about sources of bacteria, BMPs to mitigate bacteria loads, implementation costs, and regulations related to recreational water quality.

Within Section 11.2.6 of the TMDL Technical Report, the San Diego Water Board acknowledged that revisions to the TMDLs, wasteload allocations (WLAs), load allocations (LAs), implementation plan, and potentially to beneficial uses and water quality objectives may be warranted as TMDL implementation progresses, experience is gained, and new information is developed. The San Diego Water Board committed within the Bacteria TMDL to initiating a Basin Plan amendment project to revise requirements and/or provisions for implementing the TMDLs provided that three conditions are met:

1. Sufficient data are collected to provide the basis for the Basin Plan amendment.
2. A report is submitted to the San Diego Water Board documenting the findings from the collected data.
3. A request is submitted to the San Diego Water Board with specific revisions proposed to the Basin Plan and the documentation supporting the revisions.

In parallel, the state of the science and regulatory environment have evolved. This report leverages scientific advancements and newly available information and analyses conducted since 2010 to discuss revisions to the Bacteria TMDL that will more effectively and efficiently address pathogens to protect recreational beneficial use in the watersheds addressed by the TMDL.

Three main factors support reconsideration of the provisions and implementation requirements in the Bacteria TMDL. These include:

- ***Evolving Regulatory Landscape*** – In 2012, USEPA adopted new nationwide Recreational Water Quality Criteria (2012 RWQC)[1] reflecting its incorporation of the latest science and risk assessments in an effort to better protect public health. The Bacteria TMDL adopted in 2010 was based on indicator bacteria and regulatory thresholds that are no longer recommended in the 2012 RWQC. The 2012 RWQC provide two sets of recommended criteria, either of which USEPA has determined to be protective of REC-1 beneficial uses. The criteria also include guidance for developing alternative and site-specific water quality criteria, including epidemiological studies, Quantitative Microbial Risk Assessments (QMRA), and alternative indicators or methods. The 2012 RWQC are intended to guide states in developing water quality standards to protect swimmers from exposure to water that may present a risk to their health, with an emphasis on differing health risks posed by different types of bacteria sources. In addition, the State Water Board released a report titled *Part 3 of the Water Quality Control Plan for Inland Surface Waters, Enclosed Bays and Estuaries of California (ISWEBE Plan)—Bacteria Provisions and a Water Quality Standards Variance Policy, and an amendment to the Water Quality Control Plan for Ocean Waters of California (Ocean Plan)—Bacteria Provisions and a Water Quality Standards Variance Policy* (hereafter referred to as the Bacteria Provisions*)*. The Bacteria Provisions provide updated WQOs consistent with the USEPA's 2012 RWQC and recommend implementation provisions to control for bacteria including "reference system and natural sources exclusion approaches, high flow suspensions, seasonal suspensions, and a definition of the limited water contact recreation beneficial use" (SWRCB, 2017).
- ***Advances in Science*** – Since the adoption of the Bacteria TMDL, the science related to bacteria, pathogens, and human health risk has evolved substantially. With the advancements in understanding of FIB and pathogens, microbial source tracking, and risk assessments at the national and local levels, the state of the science has been advanced. More rapid, reliable and cost-effective methods have also become available to directly measure pathogens and alternative indicators.
- ***Increased Understanding of Local Conditions*** – Since the Bacteria TMDL was developed, the MS4 Permittees have implemented controls to reduce bacteria loading to waterbodies, collected data, updated modeling and planning tools, and conducted special studies to increase understanding of local and sub-regional conditions, sources, and risks. Most notably, local studies have more accurately quantified background levels of FIB and provided direct measurement of health risks using epidemiological studies and QMRA as recommended in the RWQC.

[1] USEPA, Office of Water, Recreational Water Quality Criteria. EPA 820-F-12-058, November 2012.

In addition to the advancements listed above, on May 13, 2015, the San Diego Water Board adopted Triennial Review priorities for the Basin Plan. Among its top priorities, the San Diego Water Board identified the need to evaluate the contact water recreation (REC-1) beneficial use and associated WQOs. As stated in the San Diego Water Board's Triennial Review Staff Report, the goal of implementing this priority project is to determine whether and to what extent data supports amending the REC-1 WQOs, implementation provisions for applicable TMDLs, or the TMDLs themselves.

Finally, the San Diego Water Board has put forth a Practical Vision to accomplish the following:

- Put resources into developing meaningful environmental outcomes and addressing priorities.
- Align with Healthy Waters prioritization process to protect areas that are key for the recreational beneficial uses.
- Allow resources to be focused on actions that will contribute most to protecting public health.
- Incorporate information that supports a better understanding of the potential impacts on human health, risk, and sources of bacteria, which will support waterbody assessments.

The following process outlined herein supports the Practical Vision's desire to realize healthy waters through collaborative outcome-focused efforts.

The TMDL presented within this technical report is based on a consideration of the latest science and information about human health risks from pathogens, is consistent with the Practical Vision and Triennial Review Priorities, and has been developed to be protective of the recreational beneficial uses in the waterbodies included within the TMDL. For consistency across the region, technical information presented in this report will also be used to modify the TMDL for waterbodies included in the 2008 TMDL for Indicator Bacteria, Baby Beach Dana Point Harbor, and Shelter Island Shoreline Park in San Diego Bay.

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2. Problem Statement

The Bacteria TMDL was developed in response to data indicating that water quality at the creeks and beaches covered under this TMDL was not safe for REC-1 or REC-2 beneficial uses according to exceedances of WQOs based on FIB concentrations. Water quality standards to ensure waters are safe for swimming and other recreational uses rely on indicators rather than direct measures of pathogens. This has introduced some uncertainty into assessing the true conditions (health risk), stressors and sources of pathogens, as well as the selection of management actions and the ability to assess them. This uncertainty has created opportunities to improve the science supporting water quality standards protecting swimmers from illness.

In response to this uncertainty, the San Diego Water Board and Phase I MS4 permittees began a collaborative process to better investigate and define the risks to human health associated with swimming in waters with elevated FIB concentrations and better define the steps needed to ensure waterbodies in the San Diego Region are "safe to swim." The goal of the process was to utilize new information from scientific advancements, data collection and management actions available since the TMDL was developed to improve the collective ability of the San Diego Water Board and responsible parties to support recreational opportunities for citizens and visitors to the San Diego Region.

While a number of unknowns remain, one of the key outcomes of the process was consensus that protection of beneficial uses is best accomplished by focusing on risk to human health. Currently, numeric criteria for FIB are the only available objectives for translating human health risk into regulatory limits. However, both the San Diego Water Board and the MS4 permittees recognize that these indicators are not a direct measurement of the pathogens that can cause illness.

Indicator bacteria originate from the intestinal biota of warm-blooded animals, and their presence in surface water is used as an indicator of fecal contamination and the potential presence of pathogens capable of causing gastrointestinal (GI) illnesses. However, most strains of indicator bacteria are harmless and the actual risk to human health is caused by pathogens, microorganisms that are known to cause disease. Pathogens can cause illness in recreational water users and threaten or impair recreational beneficial uses. Measuring pathogens directly has traditionally been difficult, expensive and slow, so indicator bacteria have typically been used to indicate the presence of pathogens.

Sources of indicator bacteria under all conditions vary widely and can include natural sources such as feces from aquatic and terrestrial wildlife and persistent environmental sources of bacteria, and human sources such as sewer line leaks and breaks, improperly functioning septic systems, outdoor defecation by humans, illegal sewage disposal from boats along the coastline or RVs along creek banks. Non-human source indicator bacteria may also come from anthropogenic sources, such as illicit connections, trash, landscape runoff from over irrigation practices which comes in contact with domestic pet and other animal waste, and resuspension of contaminated sediments. Once in the environment, bacteria can also re-grow and multiply if conditions are favorable. A variety of FIB sources can impair water quality. However, as discussed in more detail in Section 4, the 2012 RWQC and other studies indicate that human sources of indicator bacteria are much more likely to be indicative of pathogens and therefore human health risk than other sources of FIB.

The San Diego Water Board and MS4 permittees agree that it is important to continue to reduce the risk to human health as further science and information is developed. At the same time, it is important to use information that has been developed to better target implementation requirements and actions towards those that will more effectively address human health risks. Therefore, TMDL revisions are needed to incorporate an approach that reflects the current regulatory situation (WQOs based on FIB) and science and management measures that more effectively target risk to human health. This is accomplished by incorporating revisions to the TMDL that support focusing on reducing FIB loads associated with human sources that have a clear link to human health impacts. The approach will reduce indicator bacteria loads most associated with human health risk and provide a structure for incorporating additional science and information on human health risk before implementing actions to address non-human sources of bacteria. The approach also prioritizes waterbodies with the highest recreational use intensities, at which human fecal pathogens could cause a greater number of illnesses.

These revisions represent a significant step towards achieving the goal of making waterbodies in the San Diego Region "safe to swim". Given recent scientific advancements in measuring pathogen risks and related studies, it is expected that additional refinement of the TMDL will be needed in the future to ensure that appropriate requirements are in place to achieve this goal. If needed, revisions to numeric targets, allocations, and implementation provisions will be developed to fully incorporate a risk-based approach. The process may also lead to revisions to WQOs in the future. In the interim, this TMDL provides a solid, scientifically defensible foundation that will be used to execute a well-designed implementation plan that better targets reducing human health risks and the actions needed to address potential sources.

2.1 Project Area

The Bacteria TMDL covers the Pacific Ocean in San Diego County and southern Orange County at various beach and coastal creek mouth segments and shoreline segments of San Diego Bay and Dana Point Harbor (referred to hereafter as "beaches"), in the waters of Aliso Creek, San Juan Creek, Tecolote Creek, Forrester Creek, the (lower) San Diego River, and Chollas Creek (referred to hereafter as "creeks"). The beaches and creeks are associated with five watersheds in Orange County (with a small portion in Riverside County) and nine watersheds in San Diego County. The combined watersheds cover roughly 1,740 square miles (4,500 square kilometers).

The Bacteria TMDL addresses waterbodies that include beaches, estuaries (creek mouths), and creeks listed on the 2010 303(d) list as impaired due to exceedances of WQOs for FIB (**Figure 2-1**, **Figure 2-2**, and **Table 2-1**). Several of the watersheds drain to and impact multiple water quality limited segments. In cases where the Pacific Ocean Shoreline is listed as impaired, the listing(s) at the shoreline are applied to all beaches located on the shorelines of the hydrologic sub areas (HSAs), hydrologic areas (HAs), and hydrologic units (HUs). **Table 2-1** lists the 33 water body segments that are listed on the 2010 303(d) list as impaired due to FIB that correspond to the listings addressed in the Bacteria TMDL.

Waterbodies that have been or may in the future be identified as no longer impaired are still included in the TMDL, but implementation actions are not required to reduce loadings of FIB to these waterbodies. Section 7 of this report describes implementation requirements for all waterbodies, including monitoring to assess compliance with the TMDL, and implementation actions that will be taken if needed to maintain compliance. Additionally, responsible parties are required to maintain existing implementation actions that support protection of recreational beneficial uses.

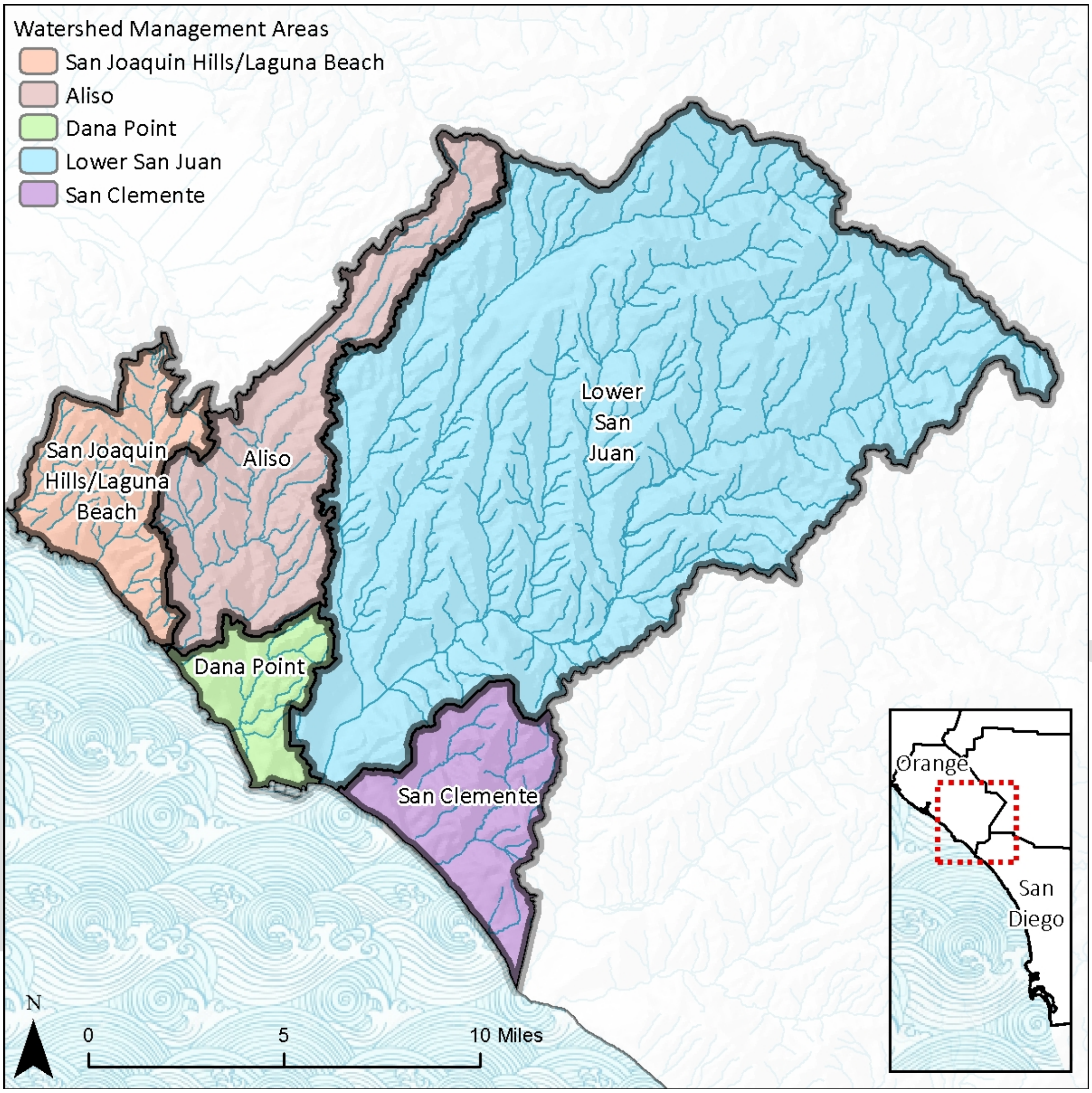

Figure 2-1. Watersheds Subject to TMDL Requirements in Orange County

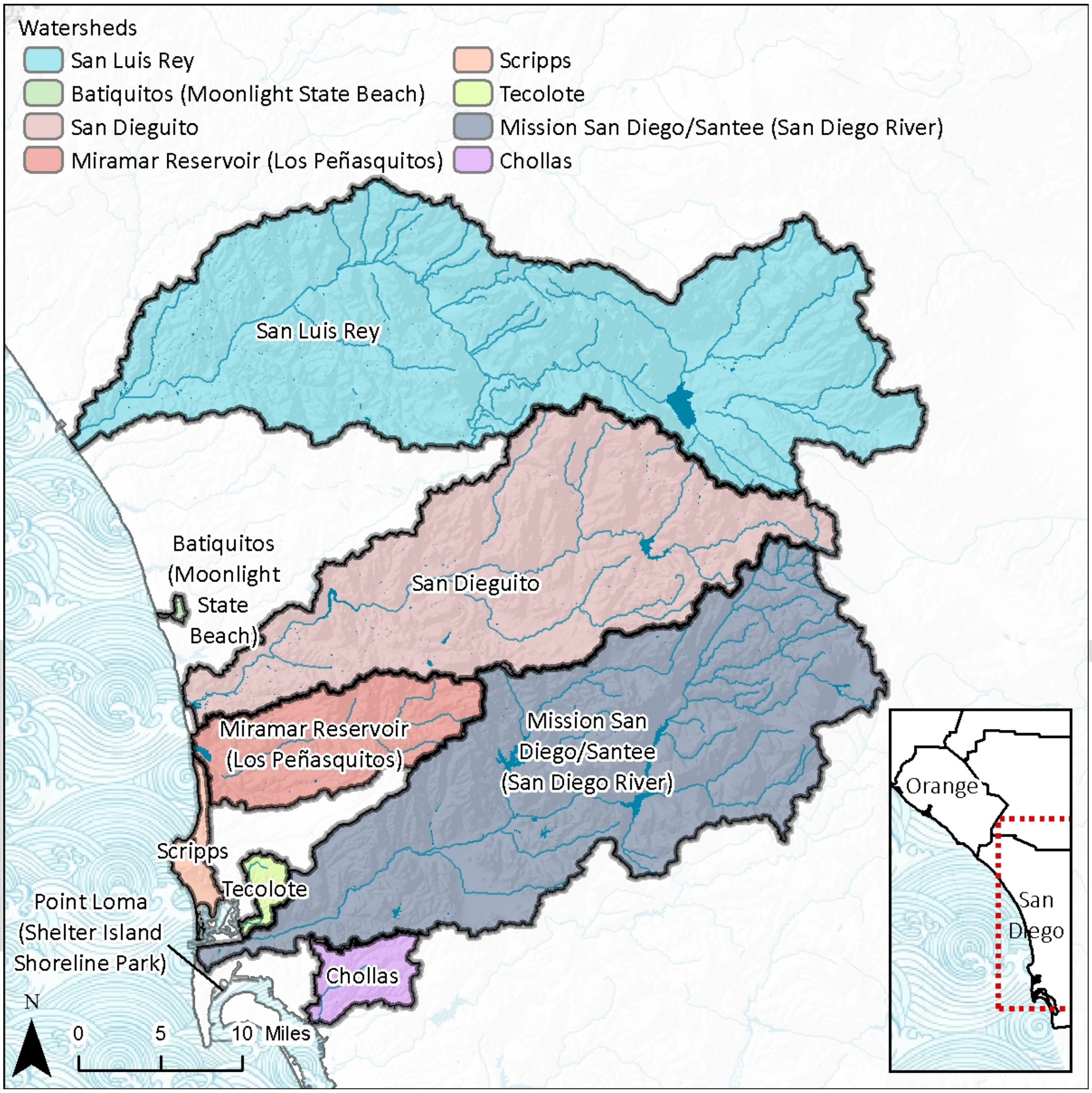

Figure 2-2. Watersheds Subject to TMDL Requirements in San Diego County

Table 2-1. Beaches and Creeks on the 2010 303(d) List Addressed in the Bacteria TMDL

Watershed Management Area [a]	Waterbody [a]		TC	FC	ENT	Indicator Bacteria
San Joaquin Hills HSA (901.11)/ Laguna Beach HSA (901.12)	Pacific Ocean Shoreline, San Joaquin Hills HSA	at Crescent Bay Beach	Delisted			
	Pacific Ocean Shoreline, Laguna Beach HSA [d]	at Bluebird Canyon	Delisted			
		at Laguna Beach at Cleo Street	Delisted			
		at Laguna Hotel	Delisted			
		at Dumond Drive at Victoria Beach	Delisted			
		at Main Beach [b]	**X**			
Aliso HSA (901.13)	**Aliso Creek**					**X**
	Aliso Creek mouth					**X**
	Pacific Ocean Shoreline, Aliso HSA	**at Aliso Beach middle**			**X**	
		at Aliso Beach north	Delisted			
		at Aliso Creek mouth	**X**	**X**	**X**	
		at Blue Lagoon	Delisted			
Dana Point HSA (901.14)	**Pacific Ocean Shoreline, Dana Point HSA [d]**	**at Aliso Beach at West St [b]**				**X**
		at Dana Strands Surfzone at Dana Strands Rd.	Delisted			
		at South of Salt Creek Outlet at Salt Creek Service Rd.	Delisted			
		at Table Rock Drive	Delisted			
		at Thousand Steps Beach	Delisted			
		Dana Point Harbor at Baby Beach [c]			**X**	
Lower San Juan HSA (901.27)	**San Juan Creek**					**X**
	San Juan Creek mouth					**X**

Watershed Management Area [a]	Waterbody [a]		TC	FC	ENT	Indicator Bacteria
	Pacific Ocean Shoreline, Lower San Juan HSA [d]	**at North Beach Creek**		**X**	**X**	
		at North Doheny State Park Campground			**X**	
		at San Juan Creek	**X**	**X**	**X**	
		at South Doheny State Park Campground			**X**	
San Clemente HA (901.30)	**Pacific Ocean Shoreline, San Clemente HA**	at Capistrano Shores at North Ole Hanson Beach	Delisted			
		at Poche Beach			**X**	
		at Riviera Beach	Delisted			
		at San Clemente City Beach at Linda Lane	Delisted			
		at San Clemente City Beach at Mariposa Lane	Delisted			
		at San Clemente City Beach at Pier			**X**	
		at San Clemente City Beach at South Trafalgar St. Beach	Delisted			
		at San Clemente City Beach at Trafalgar Canyon Outlet	Delisted			
		at South Capistrano Beach at Beach Road [e]			**X**	
		at South Capistrano County Beach [e]			**X**	
San Luis Rey HU (903.11)	**Pacific Ocean Shoreline, San Luis Rey HU**	**at San Luis Rey River Mouth**			**X**	
Batiquitos HSA (904.51)	Pacific Ocean Shoreline, Batiquitos HSA	No segments listed for recreation [f]				
San Dieguito HU (905.00)	**Pacific Ocean Shoreline, San Dieguito HU**	at San Dieguito Lagoon Mouth at Seascape Beach Park	Delisted			
Miramar Reservoir HA	Pacific Ocean Shoreline Miramar Reservoir HA	No segments listed for recreation [f]				

Watershed Management Area [a]	Waterbody [a]		TC	FC	ENT	Indicator Bacteria
Scripps HA (906.30)	Pacific Ocean Shoreline, Scripps HA	at Children's Pool		X	X	
		at Pacific Beach Point at Pacific Beach	X	X	X	
Tecolote HA (906.50)	Tecolote Creek					X
Mission San Diego HSA (907.11)/Santee HSA (907.12)	Forester Creek			X		
	San Diego River (Lower)			X	X	
	Pacific Ocean Shoreline, San Diego HU	at San Diego River Outlet at Dog Beach			X	
Point Loma HA (908.10)	San Diego Bay Shoreline, Shelter Island Shoreline Park [c]		X	X	X	
Chollas HSA (908.22)	Chollas Creek					X

Notes: HSA = hydrologic subarea; HA = hydrologic area; HU = hydrologic unit; TC = Total Coliform; FC = Fecal Coliform; ENT = Enterococcus; Indicator Bacteria = no specific indicator bacteria identified in 303(d) listing information. Segments that were originally included in the 2010 Bacteria TMDL, but were subsequently delisted are shown above for reference. Also, listed waterbody segments will be updated when the proposed 2014 303(d) list becomes effective.

a. In the 2002 303(d) list, the waterbodies were all listed as the entire Pacific Ocean shoreline within the HSA with a note in the potential sources portion of the list that identified specific areas of impairment along the shoreline. In the 2010 303(d) listing process, the Regional Water Board considered the previous listings to be inclusive of the entire HSA, HA, or HU and separated the listings into individual segments. **The segments listed in the table are based on the 2010 303(d) list segments, but the entire HSA, HA, or HU shown in the table is covered by the TMDL for consistency with the 2002 303(d) list that formed the basis of the previous TMDL**. All areas of impairment that were referenced on the 2002 303(d) list are covered by the revised TMDL, but only the currently listed segments in the table require further action to address impairments. See **Appendix A** for a comparison of 303(d) listed waterbodies included in the TMDL from the 2002, 2006, 2010, and proposed 2014 303(d) list. Segment descriptions are consistent with the 2010 303(d) list and may slightly differ from the R9-2013-0001 permit.
b. Delisted on the proposed 2014 303(d) list.
c. Explicitly identified in 2008 TMDL for Indicator Bacteria for Baby Beach in Dana Point Harbor and Shelter Island Shoreline Park in San Diego Bay
d. Additional beach segments have been proposed in this HSA on the 2014 303(d) list. Refer to **Appendix A** for new proposed segment listings.
e. In the 2002 and 2006 303(d) lists, South Capistrano Beach at Beach Road and South Capistrano County Beach were incorrectly listed as being in the Lower San Juan HSA. The error was corrected in the 2010 303(d) list and the waterbodies moved to the San Clemente HA.
f. San Marcos HA at Moonlight State Beach in the Batiquitos HSA and Torrey Pines State Beach at Del Mar (Anderson Canyon) in the Miramar Reservoir HA were included in the previous TMDL. However, no waterbody segments in these HAs are on the 2010 303(d) list for recreational impairments.

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3. Numeric Targets

When developing TMDLs, one or more numeric targets are required. Numeric targets are typically selected based on water quality standards, which include beneficial uses and the WQOs that are established at levels sufficient to protect those beneficial uses. For recreational waters, the purpose of recreational water quality objectives is to achieve the "safe to swim" goal of the Clean Water Act.

The beneficial uses of the beaches and creeks addressed by these TMDLs are set forth in the Water Quality Control Plan for the San Diego Basin (Basin Plan), and discussed in **Section 2**. These TMDLs specifically address the water contact recreation (REC-1) beneficial use, which involves recreational activities where head immersion and ingestion are reasonably possible. The WQOs are set forth in the Basin Plan and in the Water Quality Control Plan for Ocean Waters of California (Ocean Plan). Because the REC-1 bacteria WQOs are more stringent than the REC-2 WQOs (non-body contact recreation), waters that meet the REC-1 bacteria WQOs will also meet the REC-2 WQOs. For these TMDLs, numeric targets have been selected to protect REC-1 beneficial uses. These numeric targets set an acceptable level of risk associated with contracting a GI illness after water contact recreation. However, physical conditions may vary where beaches and creeks addressed by the TMDLs no longer support the REC-1 beneficial use. The State Water Board's Bacteria Provisions include an additional definition for beneficial use associated with Limited Water Contact Recreation (LREC-1), where body contact activities with water are limited by physical conditions such as very shallow depth or restricted access, making water exposure and ingestion infrequent (SWRCB, 2017). In cases where a waterbody is designated as LREC-1 in the future, numeric targets would be based on bacteria WQOs that may be identified at the time of designation, as needed.

Historically, levels of indicator bacteria (e.g., *E. coli* and enterococci) have been used to identify and manage potential public health risks associated with water contact recreation in waterbodies impacted by fecal pollution. Both human and non-human fecal sources contain indicator bacteria; however, USEPA notes that "potential human health risks could be different due to the nature of the source, the type and number of pathogens from any given source, as well as variations in the co-occurrence of pathogens and fecal indicators associated with different sources" (USEPA, 2012 p. 49). Indicator bacteria are convenient surrogates for the pathogens that actually cause illness because standard methods are available for measuring FIB in water samples, accredited laboratories are widely available to analyze indicator bacteria in collected water samples, the per-sample costs are relatively inexpensive, and sample processing times are as short as 18 hours. The key to application of FIB levels for protecting water contact recreation is their linkage to rates of illness following recreation events. The following is a brief history regarding the origin of REC-1 WQOs:

- In the 1940s and 1950s, elevated levels of FIB were linked to increased risk of GI illness after water contact recreation through epidemiological studies performed by the United States Public Health Service (Stevenson, 1953). Based on those early epidemiological studies, acceptable thresholds for FIB were established (total coliform density shall be less than 2300 organisms per 100 mL and fecal colifom shall be less than 200 organisms per 100 mL) and carried forward for decades by public health agencies. In the 1970s and 1980s, the USEPA conducted epidemiological studies that estimated the GI illness rates (i.e., the proportion of recreators likely to become ill) during water contact recreation in marine and fresh waters with fecal coliform levels at the historical threshold of 200 per 100 mL (Cabelli et al., 1983 and Dufour, 1984). The estimated illness rates at that threshold level of fecal coliform were 8 excess illnesses per 1,000 recreators in freshwater and 19 excess illnesses per 1,000 recreators in marine water.[2] The studies concluded that total coliform and fecal coliform were not correlated to public health risk, and recommended criteria for *E. coli* and enterococci instead (known as the 1986 USEPA criteria). The 1986 USEPA criteria along with results from an epidemiological study conducted in Southern California (Haile et al., 1999) were adopted into the San Diego Region Basin Plan. The Southern California study showed contradictory evidence to the USEPA studies in that there were associations between total coliform, fecal coliform, and the ratio of total to fecal coliform with adverse health effects among recreators exposed to storm drain runoff. Thus, the Basin Plan Objectives include values for enterococci, *E. coli*, total coliform, fecal coliform, and the ratio of total to fecal coliform.

- Between 2003 and 2009, USEPA conducted additional epidemiological studies known as the National Epidemiological and Environmental Assessment of Recreational Water (NEEAR; USEPA, 2010a). With a revised definition of GI illness[3] (known as the NEEAR-GI (NGI)), the NEEAR studies concluded that the 1986 USEPA criteria for FIB were protective of a similar illness rate in both marine and fresh waters of 36 excess illnesses per 1,000 recreators and established an updated set of criteria corresponding to that risk protection level. In addition, for the first time USEPA used the epidemiological data[4] within a risk-based (rather than water quality-based) approach, and developed an alternative, more stringent set of criteria for a risk protection level of 32 NGI illnesses per 1,000 primary contact recreators (incorporated in the 2012 RWQC). A major difference between the 2012 RWQC and previous EPA recreational criteria was the inclusion of tools for developing site-specific criteria based on the characteristics of local fecal sources and conditions. This was a critical addition because USEPA acknowledged that local site-specific conditions (different sources, different pathogens) could significantly change the risk level associated with a given FIB level. In 2017, the State Water Board adopted statewide REC-1 WQOs based on the 2012 RWQC (SWRCB, 2017) which will result in future updates to the San Diego Region Basin Plan.

The above timeline of epidemiological studies (and corresponding public health guidelines and criteria) demonstrates how the science available to evaluate the utility and accuracy of REC beneficial use indicators is continually evolving. In fact, USEPA is currently developing additional recommended REC criteria based on coliphage (viruses that infect *E. coli*), with draft criteria expected to be released in late 2017 (USEPA, 2016). Furthermore, through funding provided by the State Water Board and regulated entities, southern California is at the forefront of scientific advancements related to recreational water quality, including [1] development of more rapid methods to quantify fecal indicator bacteria and human pathogen levels (e.g., processing times less than 4-hours), [2] development of methods to quantify the presence of human versus non-human sources that are impacting waterbodies, and [3] local epidemiological and risk assessment studies that better represent conditions of local waters compared to national studies that have been conducted outside of southern California. To avoid this TMDL quickly becoming outdated, it is critical for the TMDL targets and TMDL implementation process to emphasize the metric that is core to all of the previous studies and criteria – level of human health risk protection. By

[2] These illnesses and the illnesses defined by subsequent USEPA criteria are based on “excess” illnesses when compared to individuals who did not contact the water.

[3] The NEEAR studies defined illness as a case of illness with any of the following within 10 to 12 days after swimming: (a) diarrhea, (b) vomiting, (c) nausea and stomachache or (d) nausea or stomachache and impact on daily activity (USEPA, 2010a). The epidemiological studies that formed the basis of the 1986 USEPA criteria used a narrower definition of gastrointestinal illness that also required fever.

[4] The process to develop the 2012 USEPA criteria broadly incorporated findings from epidemiological studies conducted at multiple beaches in southern California by the Southern California Coastal Water Research Program (SCCWRP) between 2007 and 2014 (Griffith et al., 2016, Love et al., 2014; Arnold et al., 2013; Colford et al., 2007).

emphasizing protection and reduction of human health risk (rather than solely focusing on reduction of indicator bacteria levels), the TMDL can encourage and incorporate the best-available science.

3.1 Components of Numeric Targets

To allow this TMDL (and potential future revisions) to incorporate the best-available science, the numeric targets include the following two components:

1. Numeric targets based on the 2012 RWQC and Bacteria Provisions developed by the State Water Board;
2. Site-specific targets for waterbodies where site-specific tools have been applied in accordance with guidelines published by USEPA: [1] local epidemiological studies, [2] QMRA, and [3] alternative indicators and analytical methods.

When combined with the implementation provisions of the Basin Plan and this TMDL, this framework encourages responsible parties to collect and utilize the best-available scientific data to focus resources on addressing the highest-risk sources and waterbody conditions, while ensuring that all waterbodies are sufficiently protected for water contact recreation. The TMDL sets numeric targets based on the 2012 RWQC with the provision to include site specific targets if appropriate data are collected. The 2012 RWQC allow for site-specific targets to be developed in lieu of the numeric targets specified by the 2012 RWQC, using local epidemiological studies, QMRA, or alternative indicators and analytical methods. These tools can be used to develop site-specific targets based on achieving an equivalent level of risk protection as the targets identified in the 2012 RWQC. This will ensure that all waterbodies are sufficiently protected for REC-1 beneficial uses. Development of site specific targets will allow responsible parties to use the best available science to more effectively assess risk to human health and manage and prioritize implementation actions. **Figure 3-1** provides an overview of the process for incorporating site-specific analyses as site-specific TMDL targets. Given the recent advancements in science and understanding of local conditions, a streamlined approval process is envisioned to facilitate adoption of site-specific targets as shown.

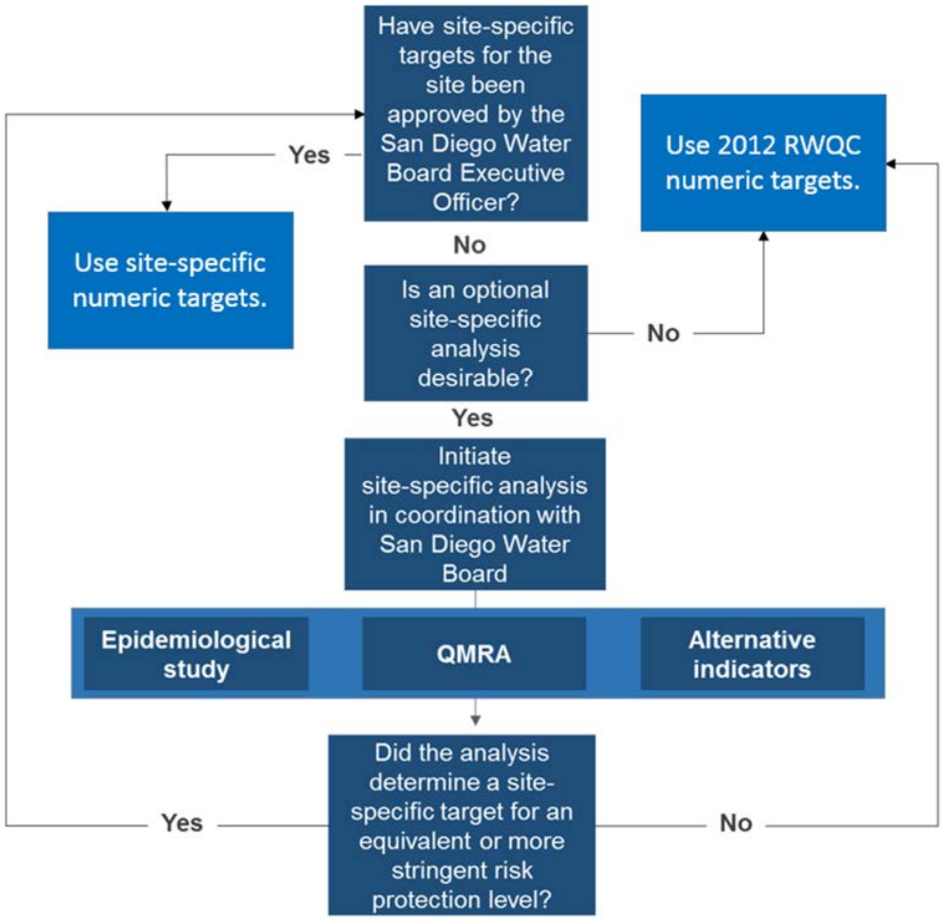

Figure 3-1. Process for Incorporating Site-Specific Analyses as Site-Specific TMDL Targets

3.2 Numeric Targets

The numeric targets for this TMDL are shown in **Table 3-1**, organized by waterbody type (beaches and creeks) and weather condition (wet weather and dry weather). Consistent with the 2012 RWQC and Bacteria Provisions, the targets for marine waters are based on enterococci and the targets for freshwater are based on *E. coli*, with magnitudes that correspond to a risk protection level of 32 excess NGI illnesses per 1,000 primary contact recreators (SWRCB, 2017). The targets include both geometric mean targets calculated based on a minimum sample size and statistical threshold value (STV) targets that are compared to individual sample concentrations. The Bacteria Provisions specify a 6-week (i.e., 42-day) rolling period for assessment of the geometric mean and a monthly period for assessment of the STV. A longer time period is recommended for TMDL compliance assessments to encourage larger sample sizes which provide more accurate assessments, which in turn leads to more effective implementation efforts. The TMDL numeric targets focus on calculation of winter and summer season geometric means to assess dry weather compliance and aggregating all wet weather samples collected each year to assess wet weather compliance based on comparison to the STV. Although the 2012 RWQC and Bacteria Provisions recommend use of both geometric mean and STV values for all samples, calculation of a geometric mean provides a more conservative measure for assessing dry weather compliance given the typical weekly sampling regime at many beaches (during the AB411 season) and the lower (more stringent) geometric mean WQOs, consistent with the Bacteria Provisions. A minimum of five samples collected during each season are necessary to calculate the geometric mean. If an insufficient number of samples are collected, dry weather compliance will be determined by comparing sample concentrations against the STV. A geometric mean will not be used to assess wet weather samples, as storms are relatively infrequent in the region, thus, the resultant samples sizes will be well below the minimum required. In addition, assessment of wet weather samples based on comparison to the STV is preferable, versus aggregating disparate samples over time for calculation of a geometric mean. As a result, the STV is applied to wet weather numeric targets by comparing all of the wet weather samples to the STV. Additional provisions of the numeric targets are noted in **Table 3-1** and further described in Section 6 and Section 7.

Table 3-1. TMDL Numeric Targets for Beaches and Creeks

TMDL Monitoring Location Type	Indicator Bacteria [f]	Target Component	Dry Weather [d]	Wet Weather [e]
			Target (organisms per 100 mL)	**Target** (organisms per 100 mL)
Creeks (fresh) [a, b, c, k, g]	*E. coli*	Statistical Threshold Value [i]	320	320
		Geometric Mean [j]	100	N/A
Beaches (marine) [a, b, c, k, h]	Enterococci	Statistical Threshold Value [i]	110	110
		Geometric Mean [j]	30	N/A

a – For sites where a site-specific target has not been approved, the numeric targets in this table serve as the default targets. Otherwise, the site-specific target applies.
b – Numeric targets are suspended during temporary beneficial use suspensions, as applicable. In addition, if a waterbody is designated as LREC-1 in the future, numeric targets would be based on bacteria WQOs that may be identified at the time of designation, as needed.
c – The TMDLs include an Allowable Exceedance Frequency which specifies the percentage of samples collected annually at each approved Bacteria TMDL monitoring location that may exceed the numeric target.
d – Dry weather is defined as days that do not meet the wet weather definition.
e – Wet weather is defined as days with greater than 0.1 inch of rainfall observed plus the following three days at the designated rainfall gage(s) for the approved TMDL monitoring location.
f – For listed TMDL waterbodies that are estuaries, the applicable indicator depends on the dominant salinity (resembling marine or freshwater conditions) measured the majority of the time, consistent with the Bacteria Provisions.
g – Creeks are inland surface waters upstream of tidal influence (fresh).
h – Targets for beaches (marine) also apply to all TMDL monitoring locations under tidal influence.
i – All wet weather samples collected each year are compared against the STV numeric target to determine TMDL compliance, as described in Section 7. Dry weather sample concentrations are compared against the STV numeric target only when the geometric mean cannot be calculated for each season. The applicable STV shall not be exceeded more than 10 percent of the time, unless a regional Allowable Exceedance Frequency is applied.
j – Based on all dry weather samples collected within each season (winter and summer). A minimum of 5 samples is required for geometric mean calculation, consistent with the Bacteria Provisions. If 5 samples are not available within each season, then sample concentrations are compared against the STV numeric target.
k – Attainment of numeric targets will be assessed in accordance with the procedures provided in Section 7.
N/A – Not applicable, the geometric mean target applies to samples collected during dry weather only.

E. coli is selected as the primary indicator organism for creeks (fresh) because it "is the most effective method to protect the REC-1 beneficial use" and is not limited by false positives, as stated in the Bacteria Provisions. Use of enterococci for beaches (marine) is supported by the 2012 RWQC. For estuarine environments below the tidal prism, where salinity is high and is similar to marine waterbodies, enterococci will also serve as the sole indicator organism consistent with the Bacteria Provisions. Also, use of total and fecal coliform bacteria indicators is no longer recommended since the results from the vast majority of epidemiological studies conducted worldwide now suggest that these FIB are not adequate indicators of GI illness (Pruss, 1998; Wade et al., 2003; Zmirou et al., 2003).

Although site-specific numeric targets are not currently being utilized, the process for incorporating site-specific TMDL targets over the course of TMDL implementation is presented in **Figure 3-1,** and tools for developing site-specific criteria are further discussed below.

3.3 Site-Specific Numeric Targets

Collection of site-specific data through special studies and development of site-specific targets is encouraged as these efforts will increase the reliability of public health protection efforts and promote the use of best-available science to effectively manage human health risk. As described in **Section 4**, different fecal sources contain unique types and levels of pathogens that have differing likelihood of causing illness,[5] and the indicator-risk relationship may vary at sites with distinctly different bacteria source types. The San Diego Water Board Executive Officer will approve (or disapprove) site-specific targets on a case-by-case basis based on the considerations below over the course of TMDL implementation. Development of site-specific targets shall be based on achieving an equivalent level of risk protection as the 2012 RWQC. USEPA has described tools for developing site-specific criteria (USEPA, 2012). USEPA has also released guidelines for Technical Support Materials (TSM) that describes tools to evaluate site conditions that support development of site-specific criteria and application of some of those tools (USEPA, 2014a; USEPA, 2014b). The site-specific tools developed by USEPA are described in the following subsections.

3.3.1 Quantitative Microbial Risk Assessment

QMRA is a quantitative process based on collection of local pathogen and other microbial data coupled with application of statistical models to estimate illness rates during water contact recreation. For watersheds with predominantly[6] non-human fecal sources or non-fecal sources, QMRA is a USEPA-supported approach for developing site-specific WQOs or targets. QMRA can be applied to any waterbody, but may be particularly useful for creeks and estuaries where the intensity of recreation is low thereby making epidemiological studies infeasible due to the impracticality of enrolling participants. The following is an excerpt from the 2012 RWQC document describing QMRA:

> *QMRA can be used to develop alternative site-specific criteria, where sources are characterized predominantly as nonhuman or nonfecal (U.S. EPA, 2009b). EPA's research indicates that understanding the predominant source of fecal contamination could help characterize the human health risks associated with recreational water exposure. Various epidemiological investigations, including EPA's have documented human health effects in waters impacted by human fecal contamination. QMRA studies have demonstrated that the potential human health risks from human and nonhuman fecal sources could be different due to the nature of the source, the type and number of pathogens from any given source, as well as variations in the co-occurrence of pathogens and fecal indicators associated with different sources.*

[5] For example, the risk of gastrointestinal illness induced by sewage is primarily due to norovirus, for which a dose of 21 genomes is required to produce infection in 50% of exposed individuals, while the risk induced by bird feces is primarily due to *Campylobacter jejuni*, for which a dose of 800 organisms is required to produce infection in 50% of exposed individuals (Schoen and Ashboldt, 2010).

[6] The 2012 REC criteria establish the level of acceptable risk associated with water contact recreation, and state that site-specific criteria by QMRA are appropriate for watersheds with "predominantly non-human sources." The 2012 federal REC criteria are not specific about the threshold of human fecal contamination (15%, 20%, 30%,…) that corresponds to predominantly non-human. For example, risk calculations by Schoen and Ashbolt (2010) estimate that GI risks associated with recreation in a waterbody whose culturable enterococci are 20% from sewage may, on average, have GI risks approximately 10 times lower than those predicted by default WQOs.

> *Further, research demonstrates that swimming-associated illnesses are caused by different pathogens, which depend on the source of fecal contamination. For example, in human-impacted recreational waters, human enteric viruses appear to cause a large proportion of illnesses (Soller et al., 2010a). In recreational waters impacted by gulls and agricultural animals such as cattle, pigs, and chickens, bacteria and protozoa are the etiologic agents of concern...*

Thus, QMRA is a tool that can aid in the development of site-specific targets in order to promote the application of best-available science for protecting water contact recreation uses. The San Diego Water Board Executive Officer will approve (or disapprove) site-specific targets calculated using QMRA on a case-by-case basis over the course of TMDL implementation. Due to the highly technical nature of QMRA studies, the San Diego Water Board encourages peer-review during QMRA design and data analysis. The peer-reviewed stakeholder processes used by local studies such as the Tecolote QMRA (City of San Diego, 2013) may serve as a model for future QMRA studies. In addition, USEPA is in the process of finalizing a TSM for QMRA applications – it is expected that local QMRA studies that have been conducted in the San Diego region (Soller et al., 2017) will be consistent with the guidelines presented in that TSM.

3.3.2 Epidemiological Studies

Site-specific epidemiological studies have been the primary tool for calculating WQOs and TMDL numeric targets based on local conditions. The waterbodies of the San Diego Region have different bacteria source conditions than the sites used for all but one of the USEPA epidemiological NEEAR studies. The USEPA studies were conducted mostly at sites impacted by wastewater point sources (predominantly disinfected secondary treatment for the NEEAR studies), while San Diego Region beaches and creeks are primarily impacted by a variety of sources other than treated wastewater (see Section 4). Thus, the types of pathogens and their relationships to indicator bacteria are expected to be different from what USEPA concluded in deriving the 2012 RWQC (and the State Water Board Bacteria Provisions). Epidemiological studies such as the Surfer Health Study (SHS) and others conducted to date within the region are critical to understanding the indicator-risk relationship in local waterbodies (SCCWRP, 2016a; Griffith et al., 2016; Love et al., 2014; Arnold et al., 2013 and 2017; Colford et al., 2007). It is acknowledged that epidemiological studies require enrollment of a large number of individuals and thus are likely infeasible for creeks and other areas where swimming and other full body immersion recreation activities are uncommon. Also, epidemiological studies are very expensive and infeasible to perform for all waterbodies. Due to the highly technical nature of epidemiological studies, the San Diego Water Board encourages peer-review during study design and data analysis.

3.3.3 Alternative Indicators and Analytical Methods

Alternative indicators and methods for enumerating indicators of fecal contamination are being rapidly developed by the scientific community. For example, molecular methods like polymerase chain reaction (PCR) have progressed from coarse qualitative methods (presence/absence) to precise digital methods over the past decade. Furthermore, these methods are more rapid and more efficient for measuring pathogens that are not readily culturable, such as human viruses and anaerobic bacteria. Some of these alternative indicators and methods show promise for use in more accurately identifying potential health risks. Norovirus GI and GII have been shown to be predictors of the presence of other pathogens, such as adenovirus measured by quantitative Polymerase Chain Reaction (qPCR). Anaerobic bacteria belonging to the order *Bacteroidales*, are growing in popularity as alternative indicators. *Bacteroidales* make up a large portion of gut microbiota, similar to traditional FIB. Detection and quantification of *Bacteroidales* has the added benefit of providing source information; specific genetic sequences are associated with different fecal sources (human, dog, bovine, etc). For example, the human-associated HF183 gene marker measures *Bacteroides dorei*, which are bacteria that are associated with human waste. In addition, *Bacteroidales* measured by qPCR have been shown to be highly correlated with *Enterococcus* spp. and *E. coli* when either culture-based methods or qPCR methods were used (Wuertz et al., 2011).

As technology advances there may be newer indicators or methods that offer advantages over the current USEPA-published methods. The 2012 RWQC identify alternative indicators/methods as one of the tools for establishing site-specific targets. For example, a new indicator-method combination can be statistically compared to a USEPA method recommended in the 2012 RWQC (Methods 1600, 1603, and 1611 or equivalent). The San Diego Water Board Executive Officer will approve (or disapprove) site-specific targets calculated using alternative indicators on a case-by-case basis over the course of TMDL implementation. USEPA has released a TSM regarding application of alternative indicators/methods for development of site-specific criteria (USEPA, 2014b). It is expected that applications of alternative indicators based on correlation to USEPA-approved methods will be consistent with the guidelines presented in that TSM.

Alternative indicators may have a role within TMDL implementation beyond development of site-specific targets. In particular, source identifiers such as human-associated *Bacteroidales* have been shown to be reliable (sensitive and specific) for identifying water samples with human fecal contamination (Stewart et al., 2013). The presence of human fecal contamination is a key factor for determining whether a waterbody or condition poses significant risk of illness after water contact recreation. Therefore, optional measurements of "human marker" levels are envisioned to have a significant role within the TMDL compliance monitoring program. Boehm et al. (2015) recently used a QMRA framework to illustrate an approach for determining the level of the human marker HF183 in a waterbody that corresponds to a specified risk protection level. Similar approaches can support TMDL compliance determination and establish human marker thresholds that would trigger follow-up implementation actions (i.e., source identification and abatement). The role of optional monitoring of human markers for compliance determination is described below and in the Implementation Plan section (Section 7).

3.4 Linkage to Implementation Provisions

The numeric targets for this TMDL are coupled with implementation provisions that determine the conditions under which the targets are applicable. The following implementation provisions are considered when determining whether or not targets are being attained within a waterbody. These provisions may be used to assess compliance using the procedures outlined in Section 7. Note, these provisions may also apply to waterbodies designated as LREC-1 in the future, depending on the requirements associated with this designation and any resulting numeric targets.

- Reference system and antidegradation approach (RSAA),
- Natural sources exclusion approach (NSEA),
- Temporary suspension of REC-1 beneficial uses in creeks during exceptionally high and/or low flow conditions, and
- Determination of the human marker level during TMDL compliance monitoring.

Compliance with numeric targets can be demonstrated using multiple pathways and different implementation provisions, with the aim to protect recreational beneficial uses of the waterbodies included in this TMDL. A number of special studies, including the SHS which is further discussed below, have provided a better understanding of the link between indicator bacteria, pathogens, and associated human health risks due to water exposure. Based on the best-available data and information, and supported by the 2012 RWQC, the numeric targets and implementation provisions were developed to maintain an acceptable risk level in order to protect recreational beneficial uses. The monitoring framework and implementation provisions focus on recreational use intensity and reduction of high risk sources, specifically human sources that are known to pose a greater risk. A detailed description of the monitoring framework and implementation provisions is provided in Section 7.

3.4.1 Reference System and Antidegradation Approach (RSAA)

The reference system and antidegradation approach (RSAA) is integral to bacteria TMDLs in the San Diego Region (RWQC, 2010). The RSAA is intended to avoid cases where TMDLs would require treatment or diversion of natural waterbodies or to require treatment of natural sources of indicator bacteria. Discussion of sources of bacteria and their associated health risks are detailed in Section 4. The RSAA also incorporates anti-degradation principles in that, if water quality is better than that of the reference system in a particular location, no degradation of existing bacteriological water quality is permitted. The RSAA is an alternative approach to the natural source exclusion approach and should not be used in combination with it.

Following this approach, an Allowable Exceedance Frequency (AEF) is typically calculated based on monitoring of natural reference watersheds and accounts for natural, and largely uncontrollable sources of indicator bacteria (e.g., bird and wildlife feces). These natural sources have been shown to, by themselves, cause exceedances of the REC-1 WQOs. Information on the calculation of a regional AEF is summarized below and detailed information on its application for use in assessing compliance is provided in Section 7.

3.4.1.1 Allowable Exceedance Frequency (AEF)

A Basin Plan Amendment adopted by the Regional Board and approved by the State Board supports implementation provisions such as a reference system or AEF, to account for bacteria loading due to natural uncontrollable sources (Resolution No. R9-2008-0028).The calculation of an AEF is based on the Bacteria TMDL and supported by San Diego regional special studies that have been conducted in recent years, coupled with data collected throughout Southern California coastal reference watersheds. When the Bacteria TMDL was adopted, the best-available reference system data were from Leo Carrillo Beach in Los Angeles County. An AEF of 22% under wet weather conditions was calculated based on data collected from Leo Carrillo Beach and incorporated into the Bacteria TMDL. While the Leo Carrillo data were from a marine beach, the 22% was applied to all waterbodies addressed by the Bacteria TMDL, including inland creeks. Since adoption of the Bacteria TMDL, new reference system data have been collected for both wet and dry weather conditions including data from the San Diego Region. A summary of the additional reference studies that included wet weather data is presented in **Table 3-2**.

Table 3-2. Wet Weather Reference Studies

Water Type	Reference Study Name	Period of Study	No. of Sampling Locations	FIB measured	Citation
Coastal beaches	Microbiological Water Quality at Reference Beaches in Southern California During Wet Weather	2004 - 2005	4	Total coliform, *E. coli*, enterococci	SCCWRP, 2005
Coastal beaches	Microbiological Water Quality at Non-human Impacted Reference Beaches in Southern California During Wet Weather	2004 - 2006	6	Total coliform, *E. coli*, enterococci	SCCWRP, 2006
Creeks	Assessment of Water Quality Concentrations and Loads from Natural Landscapes	2004 - 2006	17	Total coliform, *E. coli*, enterococci	SCCWRP, 2007
Creeks	Wet and Dry Weather Natural Background Concentrations of Fecal Indicator Bacteria in San Diego, Orange, and Ventura County, California Streams	2010 - 2014	7	Total coliform, fecal coliform, *E. coli*, enterococci	SCCWRP, 2015
Coastal beach	Santa Monica Bay Beaches Bacteria TMDLs Coordinated Shoreline Monitoring Plan [a]	2004 - 2015	1	Total coliform, *E. coli*, enterococci	SMBBB CSM Data

[a] Includes Leo Carrillo Beach.
* See References for full citations.

Data collected from these reference systems supports the wet weather AEF of 22%, consistent with the Bacteria TMDL and San Diego Basin Plan. The Bacteria TMDL applied the 22% AEF to total coliform, fecal coliform, and enterococci WQOs. Data collected as part of these studies (presented in **Table 3-2**) were analyzed to determine if an update to the wet weather AEF was warranted, if separate AEFs should be identified for beaches and creeks, and to determine if the data supported development of a dry weather AEF. Although various methods were used to compile and assess the data, the calculated values generally fell within the range of the current 22% AEF for *E. coli* (freshwater creek sites) and enterococci (marine beach sites). The new reference study results did not provide strong evidence for a change in the regional wet weather AEF, in part due to inherent differences among reference sites. Based on this information, and given the 22% AEF is referenced within the San Diego Basin Plan, there was no compelling reason to change the regional wet weather AEF for beaches and creeks.

For dry weather, data from Leo Carrillo Beach was limited during development of the Bacteria TMDL and an AEF was not applied. Dry weather was excluded because "available water quality data from San Diego Region reference systems indicate that exceedances of the single sample WQOs during dry weather conditions are uncommon." A summary of the additional reference studies that included dry weather data is presented in **Table 3-3**.

Table 3-3. Dry Weather Reference Studies

Water Type	Reference Study Name	Period of Study	No. of Sampling Locations	FIB measured	Citation
Freshwater creeks	Fecal Indicator Bacteria Levels During Dry Weather from Southern California Reference Streams	2006-2007	15	Total coliform, *E. coli*, enterococci	SCCWRP, 2008
Freshwater creeks	Assessment of Water Quality Concentrations and Loads from Natural Landscapes	Spring 2005, Fall 2005, and Spring 2006	19	Total coliform, *E. coli*, enterococci	SCCWRP, 2007
Freshwater creeks	Wet and Dry Weather Natural Background Concentrations of Fecal Indicator Bacteria in San Diego, Orange, and Ventura County, California Streams	2012 - 2014	10	Total coliform, fecal coliform, *E. coli*, enterococci	SCCWRP, 2015
Beaches, creeks, and estuary	Microbiological Water Quality at Reference Beaches and an Adjoining Estuary in Southern California during a Prolonged Drought [a]	2014-2016	1- 2 [b]	Total coliform, fecal coliform, *E. coli*, enterococci	SCCWRP, 2016b
Coastal beach	Santa Monica Bay Beaches Bacteria TMDLs Coordinated Shoreline Monitoring Plan [c]	2004 - 2015	1	Total coliform, *E. coli*, enterococci	SMBBB CSM Data

[a] Sampling was done in both wet weather and dry summer and dry winter seasons
[b] Two beach sites were sampled; however, only one creek site and one estuary site were included within the study.
[c] Includes Leo Carrillo Beach
* See References for full citations

Similar to the wet weather analysis, data collected as part of these studies were analyzed to determine if a dry weather AEF is appropriate to support the evaluation of bacteria WQOs and TMDL numeric targets during dry conditions. Exceedances were generally below 7% when data were assessed for *E. coli* (freshwater creek sites) and enterococci (marine beach sites). Although these results provide some evidence that natural sources may cause exceedances of the bacteria WQOs during dry weather, incorporation of a regional dry weather AEF is not proposed at this time based on the relatively infrequent occurrence of bacteria WQO exceedances and to provide a margin of safety. Future reconsideration for incorporation of a dry weather AEF, if appropriate, would be based on further review of reference studies and available data.

3.4.2 Natural Sources Exclusion Approach (NSEA)

Based on the Bacteria Provisions and current San Diego Basin Plan implementation provisions for the bacteria objectives, this approach requires identification and quantification of naturally occurring sources of bacteria. The NSEA is an alternative approach to the RSAA and should not be used in combination with it. Prior to applying this approach, all anthropogenic sources must be identified, quantified, and controlled such that they do not cause or contribute to exceedances of the bacteria WQOs and TMDL numeric targets. Once quantified, natural source levels become the baseline bacteria level. Examples of some natural sources include fecal inputs from birds, wildlife (aquatic or terrestrial), beach wrack, and aquatic plants (e.g., eelgrass). Exceedances caused by natural sources are used to quantify an AEF; however, information sufficient to quantify all naturally-occurring sources of indicator bacteria for each waterbody does not exist at this time, but may be available in the future.

3.4.3 Temporary Suspension of Recreational Beneficial Uses

The attainment of recreational uses not only relies on acceptable water quality, but also depends on physical conditions supporting the uses. There are two types of temporary suspensions that relate to creeks in the region: High Flow Suspension (HFS) and Low Flow Suspension (LFS, referenced as a "seasonal suspension" in the Bacteria Provisions). Bacteria WQOs and TMDL numeric targets would not need to be met within applicable creek segments during these periods. Development of approved HFS and LFS thresholds based on the information provided below and any additional analyses that may be required (also to support appropriate LREC-1 designations) is discussed in Section 7. An update to the San Diego Basin Plan would likely be needed to apply these provisions in a streamlined and consistent manner throughout the region.

3.4.3.1 High Flow Suspension (HFS)

During high flow conditions, recreational uses in inland surface waters may be unsafe because the water is too deep or too fast. If recreational uses are designated to reflect these physical constraints (high flow or high velocity), local agencies can better prioritize bacteria control measures by focusing on water quality conditions that have the greatest regional impacts and waterbodies and areas where conditions support water contact recreation activities. The TMDL numeric targets consider a high flow suspension (HFS) for wet weather as supported by the Bacteria Provisions (within the ISWEBE), which represents a temporary suspension of recreational uses in creeks when high flow or high velocity conditions are unsafe for recreational activities in inland surface waters; suspensions do not apply downstream at REC-1 beaches. For this TMDL, HFS applies to engineered and non-engineered channels given that a temporary suspension due to hazardous conditions is appropriate regardless of channel type. A HFS is applied to impaired creeks by temporarily suspending recreational uses on any day with a rainfall depth greater than 0.5 inch and the following 24 hours. This is consistent with the HFS approach taken by the Los Angeles Water Board, which applied a HFS by amending the beneficial uses chapter of the Los Angeles Basin Plan (Chapter 2) in 2003 (Resolution No. 2003-010). An analysis by the Los Angeles Water Board found that these rainfall conditions generally correspond to unsafe water conditions (defined as periods when stream velocity multiplied by the water depth exceed 10 feet squared per second). The analysis also reviewed days on which swift water rescue teams had attempted rescues. The rainfall conditions used to trigger a HFS are a surrogate for the actual unsafe water depth and velocity conditions. For the purpose of this TMDL, this methodology and the HFS threshold provides the critical information for determining use attainability.

3.4.3.2 Low Flow Suspension (LFS)/Seasonal Suspension

During dry weather conditions when low or intermittent stream discharge from the creek to the ocean would be minimal or non-existent, a low flow suspension (LFS) would apply because the water may be too shallow for water contact recreation (hence head immersion is impossible and ingestion unlikely). The 2012 RWQC defines primary contact recreation as "activities where immersion and ingestion are likely and there is a high degree of bodily contact with the water". This approach allows local agencies to better prioritize bacteria control measures by focusing on the waterbodies and water quality conditions where recreational activities are supported. Low flow suspensions are referenced as a "seasonal suspension" in the Bacteria Provisions.

For the purpose of this TMDL, interpretation of the LFS is discussed below. The TMDL numeric targets consider a LFS in creeks during dry weather, which represents a temporary suspension of recreational uses when flows are non-existent or too low to support water contact recreation. Suspensions do not apply downstream at REC-1 beaches. For this TMDL, LFS applies to engineered and non-engineered channels given that a temporary suspension due to low flow conditions is appropriate regardless of the type of channel. A depth threshold will be used to identify periods when LFS would apply. Two potential options for the LFS depth threshold are as follows:

- 3-Inch depth threshold: the 3-inch threshold is supported by research conducted by the Instream Flow Group (IFG), formed in the 1970s under the sponsorship of the U.S. Fish and Wildlife Service and funded by the USEPA. The IFG's mission was to evaluate methods of quantifying instream flow needs for fish, wildlife, and recreation. The details of the REC research and findings were published in 1976 in Instream Flow Information Paper: No. 6 (Methods of Assessing Instream Flows for Recreation). The IFG considered swimming, water skiing, boating, and wading. Of the REC uses analyzed by the IFG, wading requires the lowest water depth (3-inches). Note that wading is the activity most affected by high flow conditions, meaning wading could be considered the "critical recreational use".
- 6-Inch depth threshold: the 6-inch threshold has been acknowledged in various southern California efforts as the minimum water depth that supports water contact recreation. In the Los Angeles region, the Recreational Use Re-evaluation (RECUR) study recently performed by the Los Angeles Regional Board considered a water depth of 6 inches as a benchmark for categorizing waterbodies as supportive or unsupportive of REC-1 uses (LARWQCB, 2014).

Low flow conditions have not been used to modify beneficial uses in California; however, the Midwest states of Kansas, Iowa, and Missouri[7] have adopted use attainability analysis (UAAs) based on low flow conditions that preclude recreational uses. Although a LFS has not been pursued at this time, potential future implementation would require additional data collection or flow modeling studies to be conducted to define the number of LFS days within each creek (or monitoring location) that are below an appropriate depth threshold.

3.4.4 Surfer Health Study and Human Marker Use to Support Compliance Assessment

Recent scientific advancements indicate that human marker testing using HF183, or other similar indicators, provide valuable information on the potential presence of human sources of bacteria in water samples. Current methods can accurately detect human marker levels, which can be related to possible human health risks in receiving waters. As discussed below, the SHS results were used to identify a HF183 threshold that can be reliably used to help support assessments of the bacteria WQOs and TMDL numeric targets.

3.4.4.1 Background on Surfer Health Study and Current Conditions

A comprehensive epidemiological study was recently conducted across popular surfing locations in the San Diego region, known as the SHS (SCCWRP, 2016a). At this time, the SHS is the best-available scientific dataset regarding health risks associated with recreation during wet weather conditions (including the three days following rainfall events) for southern California beaches. Epidemiological studies conducted by USEPA did not measure illness risk during wet weather conditions and thus are most reliable for dry conditions. The SHS enrolled 654 adult surfers between January 2014 and April 2015, with a total of 10,081 documented ocean exposure events. This represents the second highest number of exposure events of any water quality-related epidemiological study conducted to date in the United States.

[7] http://water.epa.gov/scitech/swguidance/standards/uses/uaa/casestudies_index.cfm; http://www.iowadnr.gov/InsideDNR/RegulatoryWater/WaterQualityStandards/DesignatedUses/UseAssessments.aspx; http://www.dnr.mo.gov/env/wpp/cwforum/uaa-protocol-adv-grp.htm

The SHS found that when surfers enter the water during or within 72 hours following a storm event, an average of 30 per 1,000 contract GI illness, compared to 18 per 1,000 surfers that contract GI illness without entering the water, and 25 per 1,000 that contract GI illness when entering the water during dry weather. From a health risk perspective, that is an extra – or excess – risk of 12 surfers per 1,000 on average who will become ill when they enter the ocean in wet weather, compared to when they do not enter the ocean (Arnold et al., 2017). This "risk difference" (12/1,000) is most comparable to the illness rates specified in the 2012 RWQC.

3.4.4.2 Comparison of SHS and 2012 RWQC

The 2012 RWQC described USEPA's "recommended final recreational water quality criteria for the protection of primary contact recreation in both coastal and non-coastal waters". The 2012 RWQC recommends that states make a risk management decision regarding illness rate. The recommended average illness rates are 32 and 36 NGI per 1,000 primary contact recreators (USEPA, 2012).

A key question is whether the SHS results represent water quality conditions that are protective of the primary contact recreation use. To answer that question, the SHS results were compared to the criteria set forth as protective in USEPA's 2012 RWQC. Although both the SHS and the 2012 RWQC use a metric of excess illness attributable to recreational activities (the SHS reported a "risk of 12 surfers per 1,000 on average who will become ill when they enter the ocean in wet weather, compared to when they do not enter the ocean" and the 2012 RWQC specified an estimated (average) illness rates of 32 or 36 NGI per 1,000 primary contact recreators), there are several notable factors that complicate a direct comparison between the SHS and the 2012 RWQC including the following:

- Duration – the time period for which the SHS results are reported are different (shorter time period during and following wet weather) than those specified in the 2012 RWQC (up to 30 days following recreation activity);
- Population – the population included in the SHS did not include children under 18 years old, whereas the studies that underpin the 2012 RWQC did (see Appendix B for details on exposed population);
- Source of contamination and the associated spectrum of expected illnesses – treated wastewater effluent was the presumed predominant source in the 2012 RWQC compared to untreated human sources in the SHS. These sources could result in a different mixture of illnesses;
- Indicator bacteria sampling regime. SHS water quality sampling occurred in near-shore areas of the two sentinel beaches, whereas most of the SHS exposures occurred in offshore areas throughout the region. The 2012 RWQC were based on NEEAR studies in which sampling occurred in near-shore, as well as deeper areas near a beach. NEEAR exposures occurred generally in the monitored areas.
- The SHS relationship between enterococci and GI illness includes a substantial amount of model uncertainty (i.e., the confidence bounds of SHS water quality – health relationship are broad). It is important to note that the confidence bounds are also broad for water quality and health relationships in the 2012 RWQC NEEAR studies. Some degree of model uncertainty is expected when examining these types of relationships.
- Hydrologic conditions evaluated – A total of 10 rainstorms (>0.25 cm) were included in the study ranging in size from 4.8 to 64.mm, and 13% of the exposures (surf sessions) took place within 0-3 days of rain events. The SHS was conducted during the winters of 2013-2014 and 2014-2015. The long-term annual average rainfall (at the San Diego Airport) is 300-350 mm annual precipitation with 129 mm reported in 2013-2014, and 303mm reported in 2014-2015. Although a more balanced distribution between dry and wet weather exposure would have improved the precision of the wet weather exposure associations, the hydrologic conditions included in the study are generally representative of the types of wet weather events that have historically occurred in Southern California.

Comparing the results of the SHS and the 2012 RWQC recommendations requires a holistic and comprehensive consideration of all of these factors together. Using the reported results (excess risk of 12 surfers per 1,000 on average who will become ill when they enter the ocean in wet weather, compared to when they do not enter the ocean (Arnold et al., 2017)) as a starting point, it is reasonable to consider how these factors would influence the interpretation of the SHS results relative to water quality conditions that are protective of the primary contact recreation use.

Although the duration examined in the SHS was shorter than that used to derive the 2012 RWQC, the fact that exposure and illness rates were only examined during and immediately following wet weather events in the SHS (which is when indicator bacteria concentrations are generally much higher than during dry weather), enhances confidence that the SHS results are indicative of water quality conditions that are protective of the primary contact recreation use. In addition, recent evidence indicates that the vast majority of individuals (~88%) who engage in head immersion recreation during post-storm time periods in San Diego County are adults (Baker, 2017). Given that a low percentage of head-immersion recreators are children during wet weather time periods at southern California beaches and the small change in relative susceptibility of children aged 5-10 compared to those 10 and over (Arnold et al., 2016), it is reasonable to infer that the observed rates of illness in the SHS would likely not have changed dramatically if children were included in the SHS. Also, water quality sampling occurred just below the water surface in near-shore areas and may not be representative of the typical Enterococcus exposure that occurred during the study. However, concentrations at the near-shore are likely higher than concentrations offshore, primarily due to dilution. Thus, the illness rates reported for surfers could be related to a different (i.e., lower) *Enterococcus* concentration than what was used in the SHS analyses.

The implications of the duration, exposed population, and sampling location relative to exposure factors add incremental confidence that the reported results do represent water quality conditions that are protective of the primary contact recreation use (as further detailed in Appendix B). The fact that children were not represented in the SHS and the SHS water quality sampling locations were not coincident with the locations of actual exposure, decrease confidence that the results represent water quality conditions that are protective of the primary contact recreation use. The lack of information regarding contamination sources and geographical extent of key pathogens and their sources in the SHS represent uncertainties that neither increase nor decrease confidence that water quality conditions are currently protective of the primary contact recreation use.

Using the reported SHS results as a starting point and considering these factors cumulatively, this summary provides a basis to reasonably infer that the SHS results appear to represent water quality conditions that are protective of the primary contact recreation use as defined by the 2012 RWQC. See Appendix B for further description of how the SHS results and its relevant factors compared to the 2012 RWQC.

3.4.4.3 SHS-Derived Compliance Threshold

The SHS was a three-part study, comprised of not only an epidemiological study, but also a microbial source tracking (MST) study that measured pathogens in the discharge and bacteria in receiving waters of SHS sites, and a QMRA study that calculated human health risk using statistical models informed by empirical data from the SHS. Data from the SHS MST and QMRA were used to generate a human marker-based compliance threshold as one pathway for demonstrating attainment of the TMDLs, given the SHS results suggest that current water quality conditions are likely protective of primary contact recreation use as defined by the 2012 RWQC and Bacteria Provisions (32 NGI illnesses per 1,000 primary contact recreators).

A HF183 compliance threshold for wet weather was derived based on data obtained from the SHS (SCCWRP, 2016a), as well as through the use of SHS-informed QMRA modeling (Soller et al., 2017). Concurrent with *Enterococcus* monitoring at various locations at the SHS beaches, HF183 levels were also measured at the discharge point associated with each beach (San Diego River for Ocean Beach; Tourmaline Creek for Tourmaline Beach). This information was used to derive a HF183 threshold of 2,655 copies/100 ml, which represents a 90th percentile calculation that is associated with the observed SHS excess GI illness rate. Additional detail on the derivation of this HF183 threshold value is provided in Appendix B. The compliance framework is structured to focus on reduction of human health risk through monitoring of HF183 as a verification tool for human sources, as supported by the SHS. Use of this threshold to support wet weather compliance assessments is discussed in Section 7. Note: development of a dry weather H183 threshold value is currently being evaluated and may be incorporated to help support dry weather compliance assessments.

4. Source Analysis

The purpose of the source analysis is to identify the sources of FIB that pose health risks to recreators at beaches and creeks in the TMDL watersheds and are potentially causing or contributing to exceedances of water quality objectives. FIB and pathogens are generated by three categories of sources (human, anthropogenic non-human, and non-anthropogenic) and are discharged to the environment via point and non-point sources. Understanding the relative risks posed by different categories of sources allows for improved protection of the REC-1 beneficial use and supports attainment of the Clean Water Act's "safe to swim" goal. The goals of the source analysis are to:

- Identify and prioritize the sources that pose risk to recreators at beaches and creeks in the TMDL watersheds.
- Utilize up to date information, technical findings, and scientific understanding to support the decision making process.
- Provide the technical support needed to establish a risk-based approach to TMDL compliance.
- Support the identification of implementation actions (and prioritized locations for those actions) that target the sources likely to pose the greatest human health risk.
- Support the development of performance-based outcomes that will result in risk reductions.

Scientific literature and region-specific data were used to identify potential sources of FIB and human health risk. Point sources typically discharge from a specific location from pipes, outfalls, and conveyance channels from, for example, municipal wastewater treatment plants or municipal separate storm sewer systems (MS4s). These discharges are regulated through waste discharge requirements (WDRs) that implement federal National Pollutant Discharge Elimination System (NPDES) requirements issued by the State Water Board or the San Diego Water Board through various orders. Nonpoint sources are diffuse sources that have multiple routes of entry into surface waters. Nonpoint sources in the San Diego region include transient encampments, failing onsite wastewater treatment systems (i.e., septic systems), wildlife, and regrowth of FIB in sediment and on vegetation. Additional nonpoint sources, such as agriculture, livestock, and horse ranch facilities (hereafter referred to collectively as agriculture land uses) may be regulated through WDRs, or may be eligible for conditional waivers of WDRs.

4.1 Categories of Sources

FIB originate from the three categories of sources within the watershed, from human or non-human origin, and either as a result of anthropogenic or non-anthropogenic activities. Bacteria and other microbes that cause disease (pathogens) are of greatest concern. Bacteria sources can be divided into three main categories as follows:

- <u>Human sources</u> that contribute FIB and pathogens from human waste. These sources include overflows and exfiltration from sewage collection systems, illicit connections, failing onsite wastewater treatment systems, transient encampments, vessel waste, and illegal discharges. Abatement of human fecal sources is the highest priority for public health protection because these sources pose the greatest risk to recreators (Soller et al., 2010b).
- <u>Anthropogenic non-human sources</u> that contribute FIB (and a more limited potential for pathogens) from non-human sources as a result of human activities. Examples include domesticated animal waste, trash-related sources, agriculture, landscaping manure/compost, commerical and industrial facilities, secondary wildlife sources (e.g. seagulls, seals) that congregate in specific locations and/or in excessive numbers due to human influence, contaminated soils, and bacterial regrowth in MS4 infrastructure.

- Non-anthropogenic sources that are not associated with human activities and less likely convey human pathogens than human sources. Examples include naturally occuring sources in the environment such as wildlife and growth/regrowth in the wrack line at the beach, in soils, and in the MS4 system.

Certain sources, such as bacterial regrowth, overlap multiple categories. Regrowth may occur in the MS4 system (anthropogenic non-human source), but could also be considered non-anthropogenic sources because there are environmentally adapted strains considered non-fecal in origin. Specific human health risks associated with the three main categories are discussed immediately below. **Sections 2** and **3** of this document discuss sources in the context of point and non-point sources.

4.2 Human Health Risks

Recreational water quality criteria were developed based on epidemiological studies that link elevated FIB levels with increased incidence of gastrointestinal illness caused by waterborne pathogens (see Section 3.2.4 of USEPA, 2012). Research from the USEPA in support of the 2012 RWQC indicated that the source of fecal contamination is an important factor in understanding the human health risk associated with recreational waters. Most notably, the potential human health risk from human versus non-human sources can vary (Schoen and Ashbolt, 2010; Soller et al., 2010b). Exposure to waters contaminated with non-human fecal sources generally poses a reduced risk of infection to recreators when compared to human fecal sources (Soller et al., 2014; Harwood et al., 2014). A conceptual illustration of the relative risks posed by different fecal source types is presented in **Figure 4-1**.

Recent research has used quantitative microbial risk assessment (QMRA) to quantify the differential risks by source type (Soller et al., 2015, Schoen and Ashbolt, 2010; Soller et al., 2010a, Soller et al., 2010b, Schoen et al., 2011). The predominant finding of these risk assessment research efforts is the following: the level of risk at a site depends on the relative strength of human fecal sources, with mixtures dominated by non-human sources having substantially lower risks, and risks in waters dominated by non-human sources generally below the USEPA benchmark of 32 illnesses per 1,000 exposures (see Soller et al., 2014 for a series of QMRA outputs for varying levels of human-source influence[8]).

The concept in **Figure 4-1** is used to prioritize sources and implementation actions in this TMDL – human fecal sources pose the greatest risk and are therefore the highest priority. Assuming the same concentration of bacteria from each source, **Figure 4-1** compares relative risk amongst different human and non-human source types. Note that although human fecal sources result in the greatest risk in part due to the higher potential for containing human pathogens, lower risk sources (e.g., dogs, wildlife) that contribute high loading can also result in an increased health risk. The following subsections provide an overview of the risk of illness associated with the three FIB source categories: human, anthropogenic non-human, and non-anthropogenic.

[8] Note that sewage is generally assumed to be more infective than feces from individual humans because sewage is mixed and therefore contains a mixture of pathogens while individual humans may or may not be infected by a pathogen-of-concern.

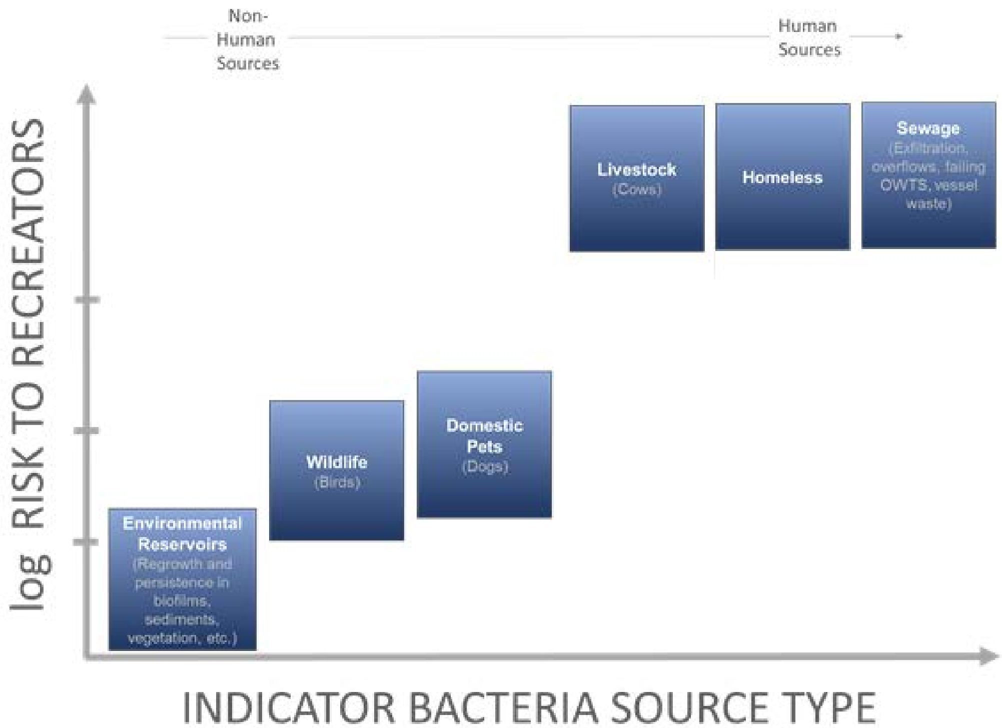

Figure 4-1. Representation of Relative Risks by Indicator Bacteria Source Type Assuming Equivalent Bacteria Concentration (example sources listed under each type)

4.2.1 Human Health Risks from Human Sources

Human sources that generate FIB and pathogens include wastewater (e.g., overflows and exfiltration from the sewage collection system, illicit connections, failing onsite wastewater treatment systems, vessel waste), illegal discharges, direct discharges, and direct inputs from transient populations. The vast majority of epidemiologic studies linking FIB levels to human health risk in recreational waters were from point source pollution due to sewage-impacted beaches, where pathogens originated from a known human fecal source, and there was a clear link between *Escherichia coli* (*E. coli*) or enterococci levels and gastrointestinal illness (USEPA, 2012; Cabelli et al., 1982; Wade et al., 2003 and 2006; Zmirou et al., 2003). Recent studies have incorporated measurement of host-associated DNA markers, in addition to measurement of traditional FIB (*E. coli* and enterococci), to better assess the contribution from fecal pollution of human origin. A study by Boehm and colleagues (Boehm et al., 2015) used QMRA to calculate the relationship of human-associated molecular markers and risk of contracting a swimming-related illness. They found human health risk increases as the levels of human-associated markers increase in water impacted by raw sewage; therefore, human sources of fecal contamination within the TMDL waterbodies could pose a risk to human health.

4.2.2 Human Health Risks from Non-Human Sources

While the human health risk associated with sewage is well documented, the health risk from recreational exposure to elevated FIB in urban runoff-impacted receiving waters is less well known (Haile et al., 1999, Urban Water Resources Research Council, 2014). The differences in health risks between human versus non-human sources are complex, and may be due to differing infectious agents present in human and nonhuman fecal contamination. For instance, many studies have indicated that viruses are likely the cause of illnesses resulting from exposure to wastewater treatment plant effluent (Soller et al., 2010a; WERF, 2011), and human viruses are less likely to occur in animal feces. However, domestic pet waste, particularly due to dogs, can still potentially impact water quality and human health risk. In addition, domestic and feral cats can contribute waste to the environment and contaminate downstream waters. The Feral Cat Coalition of San Diego has reported spaying/neutering up to 40,000 feral cats within the San Diego region, which are then released back to the environment. The East County Animal Rescue estimates a population of 900,000 feral cats within San Diego County. Anthropogenic non-human sources that can contribute FIB to downstream waters include domesticated animal waste, feral cats, secondary wildlife (e.g., seagulls, seals), landscaping manure/compost, trash related sources, non-stormwater discharges, agriculture land uses, commercial and industrial facilities, and regrowth in MS4 infrastructure.

Current research suggests that certain non-human (animal) sources may have lower risk to human health (USEPA, 2009), while other sources have comparable risk to known human fecal inputs. For example, certain non-human sources, specifically cattle, may have similar health risks as human sources (Soller et al., 2010b; USEPA, 2010a; USEPA, 2010b). The study by Soller et al. (2010b) considered cases of direct contamination to surface waters (feces deposited directly to surface waters, rather than transported over land through storm runoff). In the case of direct contamination, the risks from cattle-impacted waters were higher than those from pig or chicken-impacted waters. A more recent study by Soller et al. (2015) examined indirect transport by evaluating risk levels associated with agricultural runoff (manure mobilized by rainfall events), and determined that the associated risks were at least an order of magnitude lower than the 2012 recreational water quality criteria benchmarks based on contamination from human sewage sources. Similarly, a study by McBride et al. (1998) compared human-impacted waters in New Zealand with waters impacted by animal wastes (cattle and sheep in rural areas), and reported similar potential illness risks, while lowest risk was observed at non-impacted waters (reference sites without known fecal inputs).

Non-anthropogenic sources, such as wildlife that naturally occur in the environment (e.g., deer, coyotes, rodents, raccoons, shore birds) produce waste that may add to overall FIB loading within the watershed. Other non-anthropogenic sources include vegetation and sediments that can serve as reservoirs for FIB to regrow and persist. Due to emergence of environmentally adapted strains, FIB regrowth on sediments (Yamahara et al., 2009) and vegetation (Imamura et al., 2011; Ferguson et al., 2016) may not always be considered fecal in origin, confounding the relationship between high FIB levels and inferred human health risk. Scientific studies have indicated a lower potential health risk due to non-human sources (WERF, 2011; Schoen and Ashbolt, 2010; Soller et al., 2010b). Fecal waste from wildlife is generally considered to pose little health risk to water contact recreators. Natural background levels of FIB due to wildlife is often expected, and not generally included in regulatory actions or targeted for reduction. Epidemiological studies of waterbodies primarily impacted by fecal inputs from non-human sources have reported little or no correlation between human illness and elevated levels of FIB (Calderon et al., 1991; Colford et al., 2007).

Further, a workgroup of experts convened by USEPA in 2011 evaluated human health risks due to avian and wildlife sources of fecal pollution by comparing QMRA studies of recreation in poultry, livestock, and waterfowl-impacted water, where different pathogen composition within fecal material from different sources accounted for the risk variation among sources. In this comparison study, avian feces had far fewer different types of pathogens in relation to other animal sources (USEPA, 2011). Although wildlife feces were found to generally have low pathogenic potential, waste from wildlife can still be a large source of FIB. For example, although gulls are considered a low health risk, this source may be more important at beaches with lagoon systems where birds tend to roost for long hours, and have been found to contribute high loading of bacteria directly to receiving waters. High loading may be an important factor to consider when evaluating health risks.

In summary, human sources of bacteria are clearly correlated with human health risk and available information suggests cattle sources of bacteria may pose similar risk to human sources. Other bacteria sources, such as wildlife, domesticated animals, and regrowth likely pose less risk to human health; however, loading of sources may alter risks and prioritization of sources for load reduction.

4.3 Point Sources

Point sources typically discharge at a specific location from pipes, outfalls, and conveyance channels, and are regulated through WDRs that implement federal NPDES requirements issued by the State Water Board or the San Diego Water Board through various orders. MS4s, wastewater treatment facilities, wastewater collection systems (including private sewer laterals), industrial stormwater, and vessel discharges are all point sources of FIB, and are discussed below.

4.3.1 Municipal Separate Storm Sewer System

MS4s are categorized as Phase I (populations >100,000) and Phase II (populations <100,000). Phase I communities have been regulated by NPDES stormwater permits since 1990. Phase II communities have been regulated under a General Permit since 2003, which covers both traditional (municipal government) and non-traditional (e.g., state and federal facilities, schools, transit districts, and universities, military bases) small MS4s. The MS4 sources discussed below pertain to both Phase I and Phase II MS4s. Bacteria loads attributable to point sources are discharged in urban runoff from the following land use types:

- Residential,
- Commercial/industrial,
- Industrial/transportation,
- Caltrans,
- Military,
- Parks/recreation, and
- Transitional (construction activities).

These land use types were classified as generating point source loads because, although the bacteria sources on these land use types may be diffuse in origin, the pollutant loading is transported and discharged to receiving waters through MS4s. The principal MS4s contributing bacteria to receiving waters are owned or operated by either municipalities located throughout the watersheds or Caltrans.

In urban areas, FIB and pathogens are washed off the land surface and via shallow groundwater by dry weather and wet weather flows and transported through pipes and conveyance channels of the MS4s to surface waters. Additional sources of FIB and pathogens to the MS4s include illegal dumping, cross connections, and infiltration of raw wastewater from private sewer laterals and exfiltration from the sanitary sewer. Bacteria are ubiquitous in urban environments, and numerous studies have shown consistently high levels in urban runoff nationwide as well as in Southern California (CWP, 1999; Liefenthaler et al., 2011; Reeves et al., 2004). A large-scale study including field sampling for indicator bacteria and pathogens across four regions of the United States and comparing concentrations across land use types indicated that urban runoff contains high levels of FIB across all land use types, with residential land uses contributing higher levels relative to commercial and dry season runoff (WERF, 2011).

The Southern California Coastal Water Research Project (SCCWRP) has conducted extensive FIB monitoring, and researchers have published studies characterizing bacteria levels in urban runoff

(McQuaig et al., 2012). Reeves et al. (2004) measured concentrations of FIB in dry weather runoff in the Talbert watershed, an urbanized coastal watershed draining to Huntington State Beach. Geometric mean fecal coliform levels were 1,000 cfu/100 mL overall (median 700 cfu/100 mL), with the highest levels from residential land uses (median of 2.9 x 10^3 cfu/100 mL). FIB levels in forebays receiving dry weather urban runoff were universally high, and decreased across an inland-to-coastal gradient. Median *E. coli* levels in one forebay over three study years ranged from 10 to 8,000 MPN/100 mL.

A study in the Tecolote Creek Watershed indicated that wet weather bacteria loads did not differ substantially between different land uses, but that higher loads may be attributable to transportation corridors, commercial areas, and industrial land uses. Dry weather loads were higher in residential and commercial areas due to specific activities such as poorly maintained dumpsters leaking high concentrations of indicator bacteria. A key transport mechanism found especially in commercial and industrial areas was over-irrigation (Weston Solutions, 2010). These results are similar to findings in other Southern California watersheds. SCCWRP developed a wet weather urban runoff dataset in Los Angeles County over five wet seasons from 2000-2005 (Stein et al., 2007). Eight land uses, from high density residential to open space were sampled and the results indicated:

- All land uses exhibited event mean concentrations (EMCs) at least an order of magnitude (10x) greater than the water quality objectives (WQOs).
- *E. coli* concentrations from the horse recreation land use site were the highest, significantly higher than all of the other land use categories. There were no statistical differences in *E. coli* concentrations among other land use sites.
- The total number of *E. coli* discharged per acre (the “flux”) was similar among open space and developed land uses.

Overall, the SCCWRP land use data support a hypothesis that wet weather runoff from all land uses exhibits *E. coli* concentrations well above the WQOs.

Natural FIB sources likely contributed high numbers of enterococci, including regrowth on the walls of the MS4 system. The high flows generated during wet weather were found to cause significant biofilm sloughing, impacting wet weather loads. Sediments and biofilms within the creek and MS4 system were found to be significant reservoirs (Weston Solutions, 2010).

4.3.2 Wastewater Treatment Facilities

Wastewater treatment facilities are located in the watersheds addressed by the TMDL; however, most of the effluent from these facilities is discharged to the Pacific Ocean through offshore ocean outfalls and does not affect near shore water quality. The only exception is the Padre Dam Municipal Water District Water Reclamation Plant (Padre Dam), which discharges treated effluent to the San Diego River via a series of ponds that feed the Santee Lakes. However, Padre Dam’s effluent meets the REC-1 water quality standard, and therefore it is assumed that discharges from Padre Dam do not contribute to the San Diego River’s FIB impairment.

4.3.3 Wastewater Collection Systems

Wastewater infrastructure/collection systems convey wastewater to treatment facilities, and have the potential to contribute bacteria directly or indirectly to receiving waters through leaking pipes and sanitary sewer overflows (SSOs). The State Water Board issued a Statewide General WDR for Wastewater Collection System Agencies in 2006 (Order No. 2006-0003). The State Water Board WDR findings note that SSOs often contain high levels of pathogenic organisms, and may cause a public nuisance when raw untreated wastewater is discharged to areas with high public exposure, such as streets or surface waters used for drinking, fishing, or body contact recreation, and that SSOs may pollute surface or ground waters, threaten public health and impair the recreational use of surface waters. SSOs may also contaminate sediments, or reach MS4s; these systems act as reservoirs of bacteria, and can be later mobilized by storm events, resulting in elevated indicator bacteria concentrations in receiving waters. Exfiltration due to leaky pipes can also result in chronic contamination of the environment. All federal and state agencies, municipalities, counties, districts, and other public entities that own, operate, acquire, or assume responsibility for sanitary sewer systems greater than one mile in length that collect and/or convey wastewater are required to apply for coverage under the statewide general WDRs. As noted on the San Diego Water Board's website,[9] 54 Sewage Collection Agencies in Region 9 fall under this category.

Prior to the State Water Board's WDR, the San Diego Water Board issued WDRs to regulate wastewater collection systems, and the State Water Board WDR noted that 44 out of 46 collection system agencies in the San Diego region had reported spills over the four and a half year period prior to the release of the WDR in 2006, resulting in 1,467 reported SSOs. Out of all the collection system agencies, there are 38 collection system agencies within the TMDL watersheds identified in the California Integrated Water Quality System (CIWQS) database for SSOs (**Table 4-1**).

Table 4-1. List of Wastewater Collection System Agencies in TMDL Watersheds Reported in the CIWQS Sanitary Sewer Database

- 22nd District Agricultural Association
- Buena Sanitation District
- Ca Dept of Parks & Rec Winterhaven
- Carlsbad Municipal Water District
- City of Coronado
- City of Del Mar
- City of El Cajon
- City of Encinitas
- City of Escondido
- City of La Mesa
- City of Laguna Beach
- City of Lemon Grove
- City of San Clemente
- City of San Juan Capistrano
- City of Solana Beach
- CSU San Diego
- El Toro Water District
- Emerald Bay Service District
- Fallbrook Public Utility
- Helix Water District
- Lakeside Water District
- Leucadia Wastewater District
- Moulton Niguel Water District
- Olivenhain Municipal Water District
- Rainbow Municipal Water District
- Ramona Municipal Water District
- Rincon del Diablo Municipal Water District
- San Juan Capistrano City
- San Diego County Sanitation District
- San Luis Rey Municipal Water District
- Santa Fe Irrigation
- Santa Margarita Water District
- South Coast Water District
- South Orange County Water Authority
- Trabuco Canyon WD
- UC San Diego

[9] http://www.waterboards.ca.gov/rwqcb9/water_issues/programs/sso/index.shtml visited on May 20, 2016.

- City of Oceanside
- City of Poway
- City of San Diego
- City of Santee
- Otay Water District
- Padre Dam Municipal Water District
- Pauma Municipal Water District
- Pendleton Military Res Remainder
- Valley Center Municipal Water District
- Vallecitos Water District
- Vista Irrigation
- Yuima Municipal Water District

Information related to certain SSOs (>1,000 gallons) is now reported to CIWQS. Between March 2007 and April 2016, 1,752 SSOs occurred within the area encompassed by the TMDL, accounting for approximately 37 million gallons spilled (**Figure 4-2**). Of these 37 million gallons, approximately 30 million gallons reached nearby surface waters. Given that the fecal coliform, *E. coli*, and enterococci densities of raw sewage are estimated to be 6.4 x 10^6 MPN/100 mL (CWP, 1999), 10.8 x 10^6 MPN/100 mL (CREST, 2008), and 8.7 x 10^5 MPN/100 mL (CREST, 2008), respectively, it appears that SSOs from wastewater collection systems have the potential to be significant contributors of bacteria to receiving waters. Smaller SSOs on private property may not always be reported (<1,000 gallons); therefore, these figures represent a conservative estimate of the contribution of FIB originating from SSOs.

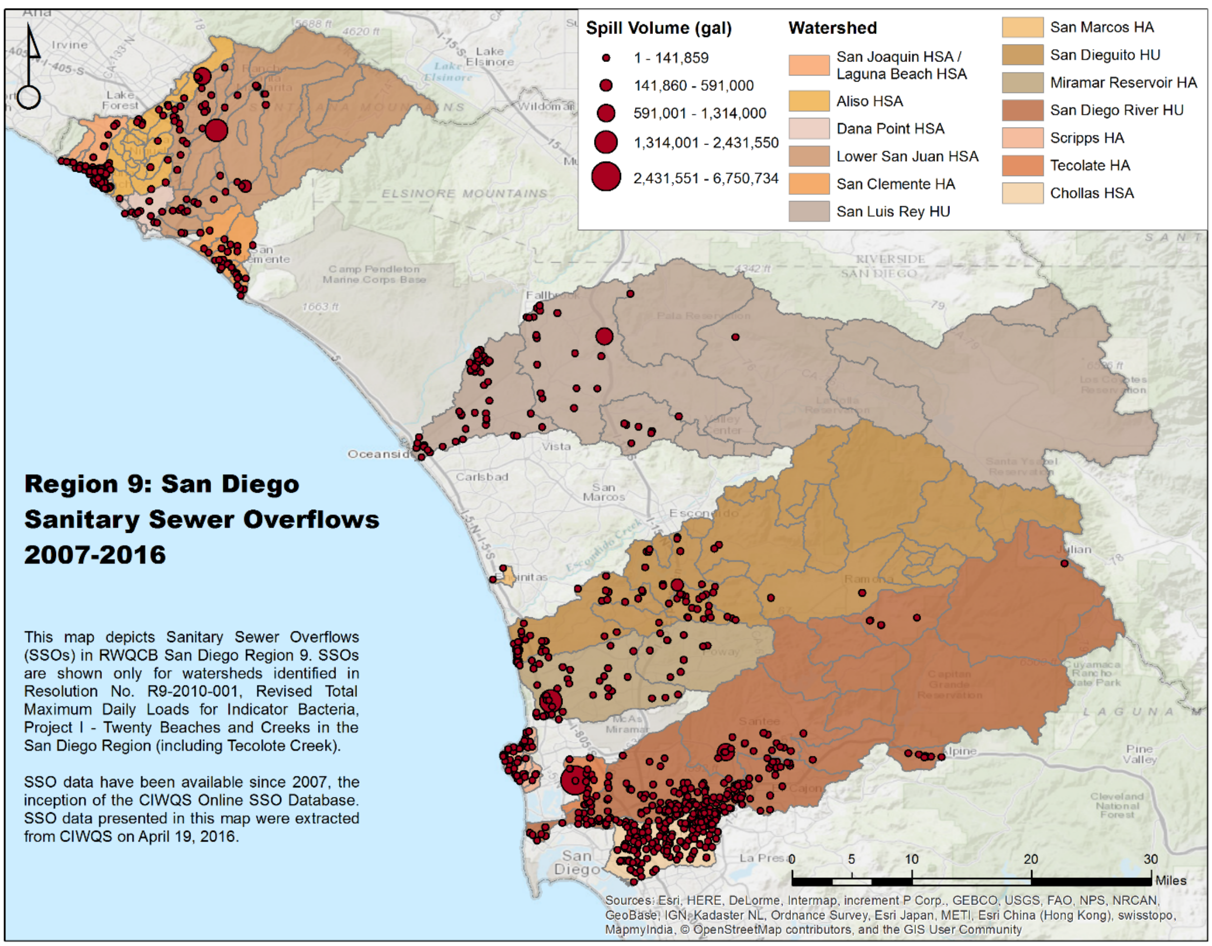

Figure 4-2. Sanitary Sewer Overflows Observed within the San Diego Region from 2007-2016

In addition to SSOs, wastewater collection systems may affect receiving waters via exfiltration (i.e., underground leaks). That is, there is potential for exfiltration from wastewater infrastructure (including both private laterals and public conveyances) to discharge through the subsurface either directly into nearby waters or into conveyances (e.g., storm drains). Certain pipe materials, such as clay, may be more vulnerable to formation of cracks that allow exfiltration. A SCCWRP study conducted during dry weather used an intensive, 30-hour study of bacterial water quality and a simultaneous rhodamine dye test of the local collection system and microbial source tracking (MST) to investigate the potential contribution of FIB from collection systems to San Juan Creek and Doheny State Beach. The rhodamine dye tracer results indicated the wastewater collection system near the beach was leaking and MST results in seawater were consistent with a diffuse source of human fecal material (Layton et al., 2015). In addition, MST results from storm drain discharge sampling suggest that sewage infiltration into storm drains may be occurring (Layton et al., 2015). Additional local studies have shown areas of exfiltration in the local infrastructure, with the potential to impact receiving waters:

- A microbial source identification study conducted at Baby Beach in Dana Point Harbor identified several areas of exfiltration where nine of the fifteen segments tested were not "water tight". A follow-up tracer dye study was conducted after sewer repairs were completed that did not identify further exfiltration impacts to the beach and adjacent harbor (Underground Service Company and Electro Scan, 2015).
- Leaking sewage infrastructure at Avalon Beach resulted in high FIB levels and human virus detection, indicating human health impacts (Love et al., 2014).
- A study by the Orange County Sanitation District indicated that quantitative determination of exfiltration from individual sewer defects is feasible, and that sites showed variable measured rates of exfiltration, ranging from zero to 0.26-0.92 liters/hour. The variability may be attributed to factors such as surrounding soil permeability, solids content of sewage, nature of the sewer defect, and changes in soul moisture (Brown and Caldwell, 2005).

Other studies have shown that the sanitary sewer may be a prevalent source of human-derived bacteria, particularly during dry weather flows (Field et al., 1994; Sauer et al., 2011; Sercu et al., 2009, 2011). Sercu et al. (2011) determined that sewage is transmitted directly from leaking sanitary sewers to storm drains, suggesting that chronic sanitary sewer leakage may contribute to downstream fecal contamination of coastal beaches. Marsalek and Rochfort (2004) noted that levels of *E. coli* in urban runoff greater than 105 CFU/100 mL suggest the presence of cross-connections with sanitary sewers. In addition to cross-connections, leaking sanitary sewers can contribute bacteria to groundwater (Paul et al., 2004; Guerineau 2014), which can then infiltrate into the MS4 system or impact surface waters directly. Corson (2015) investigated the transport mechanisms of FIB from sewer infrastructure to the stormwater conveyance system and found multiple breaches and vulnerabilities in the existing sanitary sewer system in Southeastern Wisconsin. Further, a MST study at two public beaches in Virginia identified human fecal contamination at the beaches, which led to investigations and repair of leaking sewage infrastructure by municipal officials, resulting in mitigation of the contamination (Dickerson et al., 2007).

Private sewer laterals connect a private residence or building's sewer to a sanitary agency's sewer system. It would be expected that private sewer laterals would experience similar infrastructure issues as the sanitary sewer system. However, private sewer laterals are not regulated by the Statewide WDR. Sewer laterals less than one mile in length, often connecting private residences to municipal lines are also not regulated, as the responsible party is not always aware of his or her role in maintaining the line. Unless there is some type of blockage affecting service within the private residence or building, a private lateral is unlikely to be inspected, cleaned, or maintained.

Private sewer lateral discharges (PSLDs) are voluntarily reported to CIWQS by program enrollees. Between March 2007 and April 2016, 892 PSLDs were reported within the area encompassed by the TMDL, accounting for approximately 260,000 gallons spilled (**Figure 4-3**). Of the 260,000 gallons, approximately 60,000 gallons reached nearby surface waters. Despite these reported figures, it is unknown how consistently PSLDs are reported, because the primary responders to PSLDs are private contractors and reporting is not required by the Statewide WDR. Additionally, PSLDs represent failures that are known. Private sewer laterals can leak underground without a known failure occurring due to various causes such as breaks, cracks, and root intrusion. Given that the fecal coliform, *E. coli*, and enterococci densities of raw sewage are estimated to be 6.4 x 106 MPN/100 mL (CWP, 1999), 10.8 x 106 MPN/100 mL (CREST, 2008), and 8.7 x 105 MPN/100 mL (CREST, 2008), respectively, it is possible that discharges from private sewer laterals have the potential to be significant contributors of FIB to receiving waters. Discharges from private sewer laterals are a human source that presents a relatively higher human health risk.

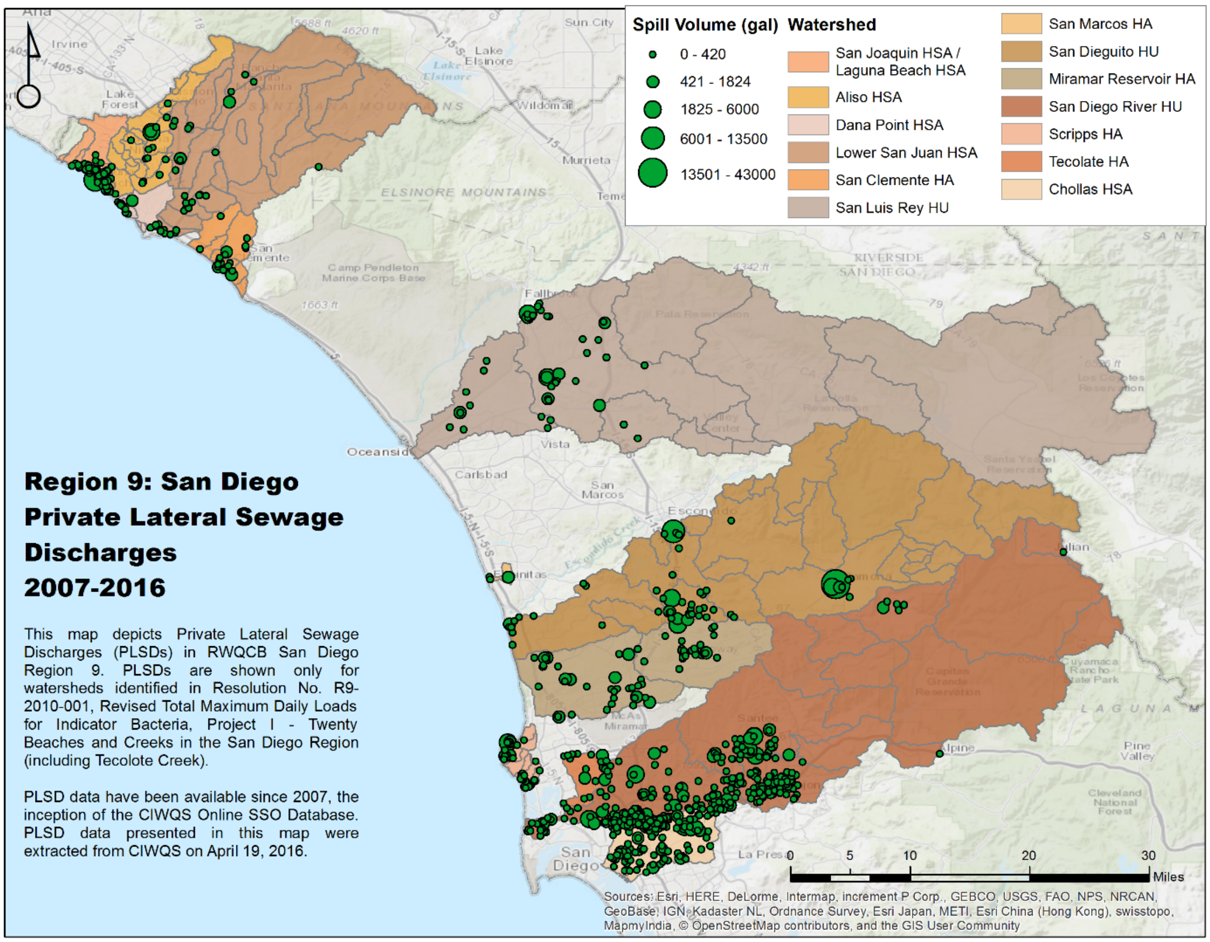

Figure 4-3. Private Lateral Sewage Discharges Reported within the San Diego Region from 2007-2016

4.3.4 Industrial Stormwater

The industrial stormwater regulations require that stormwater discharges from industrial activity either directly to surface waters or indirectly through MS4s must be regulated by an NPDES permit. Industrial stormwater is regulated through California's statewide General Permit or individual permits. The most recent statewide General Permit, issued by the State Water Board in 2014, applies to all stormwater discharges requiring a permit except construction activity. A small subset of industrial stormwater discharges are regulated by individual permits. In general, the stormwater runoff from industrial facilities has the potential to mix with process wastewater and materials (e.g., oil) and thus requires treatment prior to discharge.

FIB levels in industrial stormwater are lower than most other land uses (agriculture, residential, mixed use), but are typically slightly higher than levels seen in dry season urban runoff (WERF, 2011). A study by SCCWRP in the Los Angeles region showed *E. coli* and enterococci concentrations of a similar magnitude (10^3-10^4 MPN/100 mL) in low density residential and open space land uses to industrial stormwater, which indicates that it is a potentially substantial contributor of FIB (Stein et al., 2008). A literature review of traditional and alternative indicator bacteria and pathogens in non-wastewater discharges showed that human and universal *Bacteroides* were rarely detected in industrial stormwater; however, detection rates of human viruses, such as enterovirus were generally higher in commercial/light industrial discharges. Thus, human markers may be periodically present in industrial stormwater, although typically at lower detection rates than other discharge types (CSOs, agriculture, residential, urban runoff) (WERF, 2011) and may serve as a potential human source of fecal contamination in some cases, though risk due to industrial stormwater warrants further investigation.

4.3.5 Vessel Discharges

Vessel discharges are defined as a point source in CWA section 502(6). Illegal sewage discharged from boats is a potential source of bacteria. The 1992 Clean Vessel Act identifies vessel sewage discharges as a substantial contributor to localized degradation of water quality in the United States (USEPA, 1994). Although vessel discharge is not present in most TMDL watersheds, illegal sewage discharged from boats was identified as a potential point source of bacteria in the receiving waters of the Baby Beach and Shelter Island State Park shorelines (RWQCB, 2008). Vessel discharges are a potential human source of fecal contamination, and are therefore considered a potential high risk source.

4.4 Nonpoint Sources

Nonpoint sources are diffuse sources that have multiple routes of entry into surface waters. Nonpoint sources in the San Diego region include transient encampments, failing septic systems, wildlife, regrowth, and agriculture land uses. These nonpoint sources are discussed in the following sections.

4.4.1 Transient Populations/Encampments

Homeless encampments are recognized as a potential source of human-derived bacteria to urban waterways. Pollution of waterways due to improper waste disposal has become the number one consistently cited problem associated with encampments in the western U.S. (DeVuono-powell, 2013). The Regional Task Force on the Homeless estimates that the total number of homeless individuals living in San Diego County on January 27, 2017 was 9,116, with 5,621 of those homeless individuals being unsheltered (Regional Task Force on the Homeless, 2017). Number of unsheltered homeless individuals has increased by 14% from 2016 to 2017 alone. Number of San Diego homeless were similar to those reported in a case study conducted in Contra Costa County, CA. Although homeless counts can vary, demonstrating the difficulty in accurately determining the transient population at a given time, the Contra Costa County estimated a homeless population up to 15,000, of which 4,800 were determined to be living on the street (DeVuono-powell, 2013).

As part of their annual study, the Regional Task Force on the Homeless documents the location of where unsheltered homeless persons are seen. **Figure 4-4** presents locations where homeless persons were observed during the 207 study. As shown, a significant number of individuals were observed near surface waters, and it can be expected that a portion of the bacteria load to these surface waters may be attributed to these individuals. As a human source, FIB loading from transient populations represents a relatively higher human health risk.

A SCCWRP study conducted during dry weather in the San Juan Creek Watershed and at Doheny State Beach observed that homeless persons practice open defecation near the surface water and within storm drains flowing to San Juan Creek. MST results from storm drain discharge sampling suggest that homeless encampments may be a source of FIB to surface waters (Layton et al., 2015). In addition, a study in Santa Barbara attributed FIB in urban streams to multiple sources, including contamination from a transient population (Izbicki et al., 2009). One study in Santa Barbara examined sources of human fecal contamination to Arroyo Burro Beach, and found a transient encampment along a creek was a source of elevated human-associated markers (Ervin et al, undated). The researchers noted that, in the upper Arroyo Burro Watershed, it will be necessary to continuously and vigilantly monitor and remove encampments near the creeks as fecal inputs from only a few individuals can have a large impact on creek water quality. Another MST study in the Topanga Creek watershed recorded presence of transient activity and encampments within the creek and near the Topanga Lagoon. A mass balance calculation showed that a 200 g mass of human fecal waste from a direct deposit in the Topanga Lagoon could lead to an exceedance of the water quality objective at this site (Riedel et al., 2015). As transient populations contribute FIB from human sources, they represent a relatively higher risk to human health.

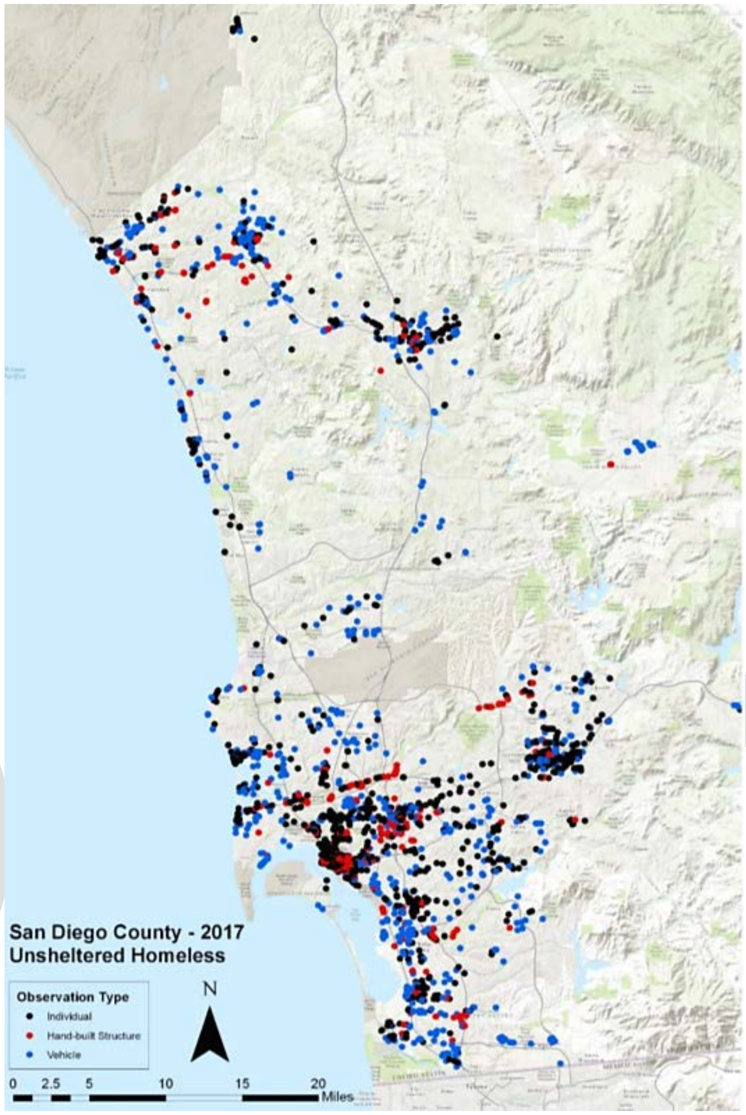

Figure 4-4. Locations of Where Homeless Persons Were Seen within the County of San Diego in January, 2017 (Regional Task Force on the Homeless, 2017)

4.4.2 Onsite Wastewater Treatment Systems

While the majority of households in the TMDL area discharge to a sanitary sewer system, onsite wastewater treatment systems (OWTS) are also utilized. The County of San Diego Department of Environmental Health (DEH) and the Orange County Health Authority regulate OWTS in the TMDL watersheds. OWTS, commonly referred to as septic systems, are passive systems designed to treat small quantities of sewage waste. On June 19, 2012, the State Water Board adopted Resolution No. 2012-0032, "The Water Quality Control Policy for Siting, Design, Operation, and Maintenance of Onsite Wastewater Treatment Systems (OWTS Policy)." The State OWTS Policy aims to reduce bacteria contributions from poorly operating septic systems. The following is an excerpt from OWTS Policy document:

> *This Policy establishes a statewide, risk-based, tiered approach for the regulation and management of OWTS installations and replacements and sets the level of performance and protection expected from OWTS. In accordance with Water Code section 13290 et seq., the*

OWTS Policy sets standards for systems that are constructed or replaced, that are subject to a major repair, that pool or discharge waste to the surface of the ground, and that have affected, or will affect, groundwater or surface water to a degree that makes it unfit for drinking water or other uses, or cause a health or other public nuisance condition. The OWTS Policy also includes minimum operating requirements for OWTS. These operating requirements may include siting and construction constraints. In addition, there may be specific requirements for OWTS near certain waters listed for nitrogen or pathogens as impaired under Clean Water Act section 303(d)18. These are requirements that will be in accordance with local TMDL implementation plans to address pathogen (bacteria) impairments where applicable.

The basic OWTS are designed to conduct primary treatment of wastewater by settling out heavier solids in the sewage and slowly discharging the liquid into a subsurface drainage field. It is generally held that when correctly sited, operated, and maintained OWTS are highly effective at removing bacteria. However, when OWTS are not properly designed or maintained, bacteria removal efficiencies can decrease dramatically, and pathogens-of-concern can be discharged to the environment (Harris, 1995). A failing OWTS is recognized as a system that does not adequately contain or treat raw sewage and threatens or results in direct discharge of sewage to the ground surface, groundwater, and/or receiving surface waters. Any system has the potential to fail as a result of age, short-circuiting systems, improper use, and/or poor design (proximity to the groundwater table or surface waters). These OWTS failures lead to surfacing effluent, exfiltration from holding tanks or infiltration of groundwater in some cases. OWTS contaminated ground surface sediments are also available for wash off and potential remobilization of indicator bacteria to receiving waters. As a human source of FIB and pathogens, failing OWTS discharges that reach surface waters would pose a relatively higher risk to human health. Multiple studies have shown that malfunctioning OWTS can contaminate waterbodies with various pollutants including FIB (Carroll 2006; Sieyes et al., 2008). In the Malibu Watershed Bacteria TMDL (LARWQCB, 2004), it was assumed that normally operating leach field systems remove 100 percent of the fecal coliform bacteria, failing systems remove 60 percent, and short-circuited systems (i.e., wastewater flows directly to the outlet) did not reduce bacteria levels. Note, a failed OWTS does not necessarily impact surface waters due to attenuation, decay, and dilution during subsurface transport of discharged bacteria.

In 2003, a baseline inventory of existing OWTS throughout Orange County was performed (RBF Consulting, 2003). The study estimated that 2,776 OWTS were active within Orange County at that time. The locations of the active OWTS as of 2003 are shown in **Figure 4-5**. It is estimated that 70,000 OWTS are in use within San Diego County based on the number of developed parcels outside wastewater service areas and estimates of OWTS within wastewater services areas. The San Diego Union Tribune estimates over 80,000 septic systems in San Diego County as of 2005, making this area the fourth-largest grouping of septic systems in California, and states that approximately 1,500 new systems come online each year to serve homes and residents throughout the county (Lee, 2005). As such, because the bacterial density of failed OWTS is estimated to be between 10^4-10^6 MPN/100 mL (CWP, 1999), failed OWTS have the potential to be significant contributors of FIB to receiving waters when located within close proximity to receiving waters.

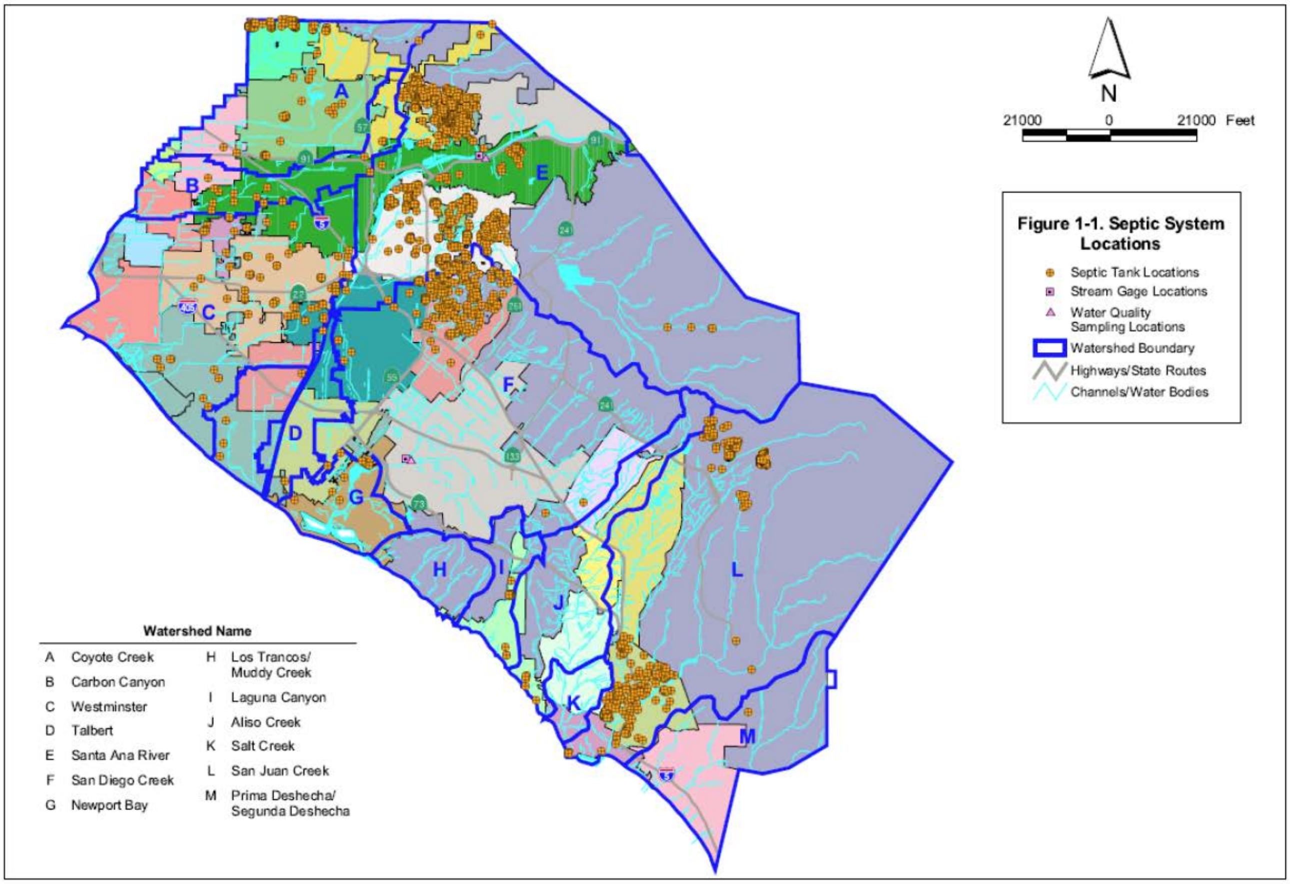

Figure 4-5. Septic Tank Inventory of Orange County, California (RBF Consulting, 2003)

4.4.3 Wildlife

Wildlife sources in the TMDL area that can contribute FIB loads include birds and small (e.g., squirrels, rabbits) and large mammals (e.g., coyotes). Wildlife sources have the potential to contribute FIB loads that can cause or contribute to exceedances of WQOs. However, wildlife sources of FIB pose a low human health risk. Numerous studies completed by SCCWRP in watersheds draining to beaches and reference streams in San Diego, Orange, Los Angeles and Ventura counties document the extent to which natural sources (including wildlife) can cause exceedances of WQOs (SCCWRP, 2015), and provide considerable evidence that natural sources are significant contributors of FIB (Tiefenthaler et al., 2015; Stein and Yoon, 2007; Tiefenthaler et al., 2008; Schiff et al., 2005). Additional efforts are continuing as part of the recent San Diego region effort to assess impacts of natural sources at beaches.

A SCCWRP study conducted during dry weather in the San Juan Creek watershed and at Doheny State Beach evaluated the contribution from avian wildlife to a lagoon that forms immediately upstream of the drainage system's connection to the ocean. The study compared weekly bird counts to FIB levels in the lagoon, characterized the fecal bacteria of this population, and estimated FIB fluxes from birds to the lagoon. Bird counts correlated significantly to FIB levels in the lagoon (Layton et al., 2015). In addition, a "back of the envelope" calculation showed that through-berm transport would allow FIB from lagoon-dwelling birds to affect water quality in the surf zone; however, beach-based sources potentially far overshadow the magnitude of FIB added to the surf zone via through-berm transport (Layton et al., 2015). Field observations obtained during the SCCWRP study conducted during dry weather in the San Juan Creek watershed and at Doheny State Beach indicate that the beach source may be bird droppings deposited on sand and wrack; however, the SCCWRP study did not specifically investigate FIB loadings from sand and wrack. Regardless, all of the lines of evidence collected during the SCCWRP study conducted during dry weather in the San Juan Creek watershed and at Doheny State Beach suggest (although cannot confirm) that the bird population is a major source of FIB to all compartments of the beach environment (Layton et al., 2015; SCCWRP, 2014). A source identification study at Poche Beach suggested that birds on the beach were a source of bacteria in receiving waters at Poche Beach, and enterococci and fecal coliform concentrations were correlated to gull marker concentrations for ocean samples collected adjacent to a scour pond where birds congregate. In addition, canine markers were present, suggesting that coyotes were a possible source (Weston Solutions, 2013). A similar investigation is ongoing at Salt Creek/Monarch Beach (personal communication with the County of Orange and City of Dana Point).

4.4.4 Regrowth

There is evidence that a subset of FIB are capable of surviving and establishing populations in the environment. Numerous studies have shown that indicator bacteria, including *E. coli*, are ubiquitous in watersheds (Davies et al., 1995; Byappanahalli et al., 2003, Ishii et al., 2006). FIB are present in high concentrations in sediments in storm drain infrastructure (Reeves et al., 2004). Other studies show that strains of FIB associated with vegetation (Ferguson et al., 2016; Imamura et al., 2011; Badgley et al., 2010) and soils/sediments (Desmarais et al., 2002; Byappanahalli et al., 2012) can become naturalized or may persist and regrow in these reservoirs depending on environmental conditions. There is some evidence that unique environmental strains have evolved which do not match human or animal feces-derived strains (Field and Samadpour, 2007; McLellan et al., 2003; Power et al., 2005).

A dry weather monitoring study conducted in San Diego County found that enterococci in storm drain systems came from predominantly natural sources and include strains that are capable of growing on drain pipe surfaces (Griffith and Ferguson, 2012). Regrowth in street gutters was found to be the likely source of bacteria in residential sidewalk wash-off in another study conducted in Orange County (Skinner et al., 2010). A recent source identification study at Poche Beach noted that regrowth of total coliform, fecal coliform, and enterococci occurred at all sites within the Mainstem and Cascadita Channels. A bench test under conditions found in the storm drain system indicated that colonization of concrete substrates occurred rapidly (within 8-9 days), and all three types of FIB were maintained over the 6-month time frame of the study. These results indicated that biofilms within the storm drain system could serve as a reservoir of FIB, and a source of bacteria to the ocean receiving waters at Poche Beach (Weston Solutions, 2013). Regrowth is a non-human source, and represents a low human health risk.

4.4.5 Agriculture

Indicator bacteria from agricultural land uses can come from livestock, manure, compost, and regrowth in soils. Indicator bacteria levels in agricultural samples have been similarly shown to be variable and high. Studies show compost generally decreases levels of indicator bacteria, but regrowth can occur under favorable conditions, dependent on microflora, temperature, and moisture (Zaleski et al., 2005) and certain point-of-sale composts can harbor pathogens (Brinton et al., 2009). Researchers also evaluated fecal coliform concentrations and loading to surface water from 10 coastal dairies and ranches in the Tomales Bay Watershed in Northern California during storm events from manure management systems, gutters, storm drains, pastures, and corrals and lots. Fecal coliform loads from management units of concentrated animals and manure were significantly higher than units such as pastures, though storm flow amounts were significantly lower. Fecal coliform concentrations generally exceeded water quality objectives, and were as high as 1.8×10^6 cfu/100 mL in samples from dairy pasture runoff (Lewis et al., 2005). In the Talbert Watershed in Southern California, researchers observed concentrations of indicator bacteria in dry weather agricultural runoff that were similar to commercial and industrial land uses (Reeves et al., 2004). Agriculture is a non-human source of FIB, so it is expected to pose a lower human health risk; however, runoff from cattle ranches may pose a high human health risk (Soller et al., 2010b).

In 2016, the San Diego Water Board adopted General Waste Discharge Requirements for Discharges from Commercial Agricultural Operations for Dischargers that are Members of a Third-Party Group in the San Diego Region (R9-2016-0004) and General Waste Discharge Requirements for Discharges from Commercial Agricultural Operations for Dischargers *Not* Participating in a Third-Party Group in the San Diego Region General Agricultural Orders (R9-2016-0005). Overall, the General Agricultural Orders set forth enforceable requirements for Agricultural Operations to manage pollutant discharge loading into local receiving waters.

4.5 Summary

FIB within the San Diego region originate from human, anthropogenic non-human, and non-anthropogenic sources. Contributors of FIB include point and nonpoint sources. The human health risks from these sources vary, with human sources presenting the highest health risk. As such, the following point and nonpoint sources pose relatively higher risks to recreators: discharges from wastewater collection systems (including private sewer laterals), transient populations and encampments, and failing septic systems. While some non-human sources (such as cows) may pose a comparable heath risk, epidemiological and QMRA research supports a lower prioritization for most non-human sources such as birds, other wildlife, and regrowth, based on a lower health risk.

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5. Linkage Analysis

The objective of this section is to define the linkage between the selected numeric targets and identified sources of indicator bacteria for these waterbodies. This linkage provides the necessary connection between the TMDLs and attainment of water quality standards. In addition, the numeric targets represent the total assimilative capacity, or loading capacity, which is the maximum amount of pollutant that a waterbody can assimilate while maintaining water quality standards.

Numeric targets for indicator bacteria were selected based on a risk level that will ensure the protection of public health and recreational beneficial uses. Indicator bacteria have long been used as a surrogate for direct pathogen monitoring to assess water quality. Epidemiological studies have linked elevated levels of fecal indicator bacteria, such as enterococci, to increased risk of contracting GI illness (Arnold et al., 2017). Numeric targets were identified for wet and dry weather conditions based on the 2012 RWQC and Bacteria Provisions. These targets correspond to the more stringent risk protection level of 32 excess NGI illnesses per 1,000 primary contact recreators. The numeric targets were also structured to encourage incorporation of best-available science (see Section 3), and any future scientific advancements in the detection of pathogens and corresponding human health risk. A compliance monitoring framework was developed that aims to support the reduction of human health risk that is based on regional special studies, including the SHS. Under this framework, multiple pathways can be used to demonstrate compliance and attainment of the final numeric targets and allocations, as described in Section 7.

A concentration-based approach was chosen to link the numeric targets with appropriate WLAs and LAs in order to ensure the protection of water quality and water contact recreation in these waterbodies (see Section 6). Concentration-based TMDLs have several advantages, including the direct relationship between receiving water concentrations and human health risk, as well as consistency of application throughout the region. In addition, concentration-based TMDLs can be applied universally to all point and nonpoint sources. These TMDLs also include alternative expressions, such as establishment of load-based allocations, which can be used to demonstrate compliance and help encourage efficient and effective TMDL implementation.

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6. Total Maximum Daily Loads (TMDLs) and Allocations

The TMDL (i.e., loading capacity or allowable load) for a specific pollutant and waterbody combination is the total amount of the pollutant of concern that can be assimilated by the receiving waterbody while still achieving water quality standards under all conditions. In California, water quality standards primarily consist of beneficial uses and the WQOs that support those uses. For recreational waters, the purpose of recreational water quality objectives is to achieve the "safe to swim" goal of the Clean Water Act.

Quantitative numeric targets were selected for development of these TMDLs within the context of a risk-based framework that encourages incorporation of best-available science. For these TMDLs, the numeric targets are based on the 2012 RWQC and Bacteria Provisions that incorporate these criteria. The numeric targets currently apply to all waterbodies under dry and wet weather conditions for beaches and creeks. It is important to note that these targets may be revised in the future based on additional studies and development of better measures of human health risk.

TMDLs are set equal to the sum of individual waste load allocations (WLAs) for point sources and load allocations (LAs) for both nonpoint sources and natural background levels. In addition, the TMDL must include a margin of safety (MOS), either implicitly or explicitly, to account for the uncertainty in the relationship between pollutant loads and the quality of the receiving waterbody. Conceptually, this definition is represented by the following equation:

$$\text{TMDL} = \sum \text{WLAs} + \sum \text{LAs} + \text{MOS}$$

In TMDL development, pollutant source allocations must be identified or calculated to provide the basis for establishing water quality based controls. The San Diego Water Board is responsible for incorporating the WLAs into the enforceable regulatory mechanisms that are available to compel controllable sources to reduce pollutant contributions (RWQCB, 2010). Controllable sources are responsible for taking actions to meet their assigned WLAs. When all the regulated controllable sources meet their assigned WLAs and LAs, and the numeric targets (with applicable allowable exceedance frequencies described later in this section) are also met in the receiving waters in accordance with the procedures outlined in Section 7, protection of beneficial uses will be achieved.

TMDLs can be expressed as a concentration, mass per time (i.e., mass-loading basis), or other appropriate measure. These TMDLs were revised to focus on meeting the applicable numeric targets in terms of concentration, together with an AEF to address natural conditions. To help facilitate compliance and associated implementation efforts, alternative expressions of these concentration-based TMDLs were also identified. Each of these expressions, such as the development of mass-loading based TMDLs, has been successfully used in TMDLs throughout California and across the country, to interpret concentration-based limits and demonstrate compliance with applicable water quality standards. This approach provides the flexibility needed to encourage efficient and effective implementation efforts for all controllable sources.

The revised TMDLs described below include concentration-based and alternative expressions that are appropriate for each waterbody type and condition (wet or dry weather). These TMDLs were allocated to the identified point and nonpoint sources following established methods in order to equitably assign responsibilities for water quality improvement and facilitate implementation actions.

6.1 Wet Weather TMDLs and Allocations

6.1.1 Previous Approach for 2010 Bacteria TMDL

The 2010 Bacteria TMDL established concentration-based numeric targets (and TMDLs) in receiving waters consistent with the Basin Plan WQOs of: 10,000 MPN/100 mL for total coliforms, 400 MPN/100 mL for fecal coliforms, and 61 or 104 MPN/100 mL for enterococci as single sample maximum targets. Using the numeric targets, wet weather TMDLs and allocations were calculated based on model predictions of daily bacteria loads using a load duration curve (LDC) approach. The LDC approach used modeling results to calculate the TMDLs and allocations for each waterbody.

The calculation of TMDLs and allocations was based on a critical wet year, which was selected to ensure compliance during wet weather events. Water year (WY) 1993 was selected as the critical year, which represented the wettest year in the TMDL analysis period and the 90th percentile for rainfall in the Southern California region (1947-2000). An AEF, calculated based on a reference system (i.e., Leo Carrillo Beach in Los Angeles), was incorporated in the 2010 Bacteria TMDLs to allow for exceedances that are caused by natural conditions. Waste load allocations (WLAs) were calculated for municipal discharges and Caltrans discharges to urban lands. Load allocations (LAs) were calculated for controllable nonpoint source discharges (agricultural uses) and for uncontrollable nonpoint sources from undeveloped lands. Loads from uncontrollable nonpoint sources were taken into account in the TMDL calculations using the reference system approach.

6.1.2 Revised TMDL Approach

Since development of the Bacteria TMDL, much effort has been invested in the San Diego Region and other areas to better understand the sources of bacteria, their impact on receiving waters, and how to effectively address impairments. The revised TMDLs were developed to utilize these efforts and establish meaningful allocations that provide a clear pathway for implementation for wet weather.

6.1.2.1 Concentration-based TMDLs

Consistent with the Bacteria TMDL approach, concentration-based TMDLs were established for wet weather to meet the numeric targets. For most pollutants, TMDLs are expressed on a mass loading basis (e.g., kilograms per year). Federal regulations (40 CFR §130.2(1)) provide that TMDLs do not need to be expressed as loads (mass per unit time), but may be expressed as an “other appropriate measure”. For pathogen indicators, the number of organisms in a given volume of water (i.e., concentration), is significant with respect to public health and protection of beneficial uses.

The wet weather TMDLs are the same as the numeric targets presented in Section 3. The targets for beaches (marine) are based on enterococci and the targets for creeks (fresh) are based on *E. coli*, with magnitudes that correspond to a risk protection level of 32 excess NGI illnesses per 1,000 contact recreators consistent with the 2012 RWQC and Bacteria Provisions. **Table 6-1** presents the wet weather TMDLs.

Table 6-1. Wet Weather TMDLs for Beaches and Creeks

TMDL Monitoring Location Type	Indicator Bacteria [f]	TMDL Component	TMDL (organisms per 100 mL)
Creeks (fresh) [a, b, c, d, e, g]	*E. coli*	Statistical Threshold Value [i]	320
Beaches (marine) [a, b, c, d, e, h]	Enterococci	Statistical Threshold Value [i]	110

a – Wet weather is defined as days with greater than 0.1 inch of rainfall observed plus the following three days at the designated rainfall gage(s) for the approved bacteria TMDL monitoring location.
b - For sites where a site-specific target has not been approved, the TMDLs in this table serve as the default TMDLs. Otherwise, the TMDL based on the site-specific target applies.
c – WQIPs may develop numeric goals and water quality improvement strategies based on either default TMDLs, site-specific TMDLs or level of risk protection, subject to approval by the San Diego Water Board Executive Officer.
d – Numeric targets are suspended during temporary beneficial use suspensions, as applicable. In addition, if a waterbody is designated as LREC-1 in the future, numeric targets would be based on bacteria WQOs that may be identified at the time of designation, as needed.
e – The TMDLs include an AEF, which specifies the percentage of samples collected annually at each approved TMDL monitoring location.
f – For listed TMDL waterbodies that are estuaries, the applicable indicator depends on the dominant salinity (resembling marine or freshwater conditions) measured the majority of the time, consistent with the Bacteria Provisions.
g – Creeks are inland surface waters upstream of tidal influence.
h – Targets/TMDLs for beaches (marine) also apply to all TMDL monitoring locations under tidal influence.
I – All wet weather samples collected each year are compared against the STV to determine TMDL compliance, as described in Section 7. The applicable STV shall not be exceeded more than 10 percent of the time, unless a regional AEF is applied.

The concentration of FIB in a discharge and in receiving waters is a relevant criterion for assessing the impact of discharges, the quality of the affected receiving waters, and human health risk. Monitoring of indicator bacteria in the discharge and in the receiving waters will be used to evaluate progress toward attainment of the concentration-based TMDLs.

Concentration-based TMDLs have several advantages, including the direct relationship between receiving water concentrations and human health risk, as well as consistency of application throughout the region. In addition, concentration-based TMDLs can be applied universally to all point and nonpoint sources; whereas, other methods (e.g., mass-loading based TMDLs) may include additional steps and calculations that are dependent on available data, key assumptions, and other information. Concentration-based TMDLs can be easily incorporated into NPDES permits, WDRs, and other regulatory requirements. TMDL compliance can also be more easily demonstrated in several respects through development and implementation of a comprehensive monitoring program. These attributes help encourage shared responsibility among all contributing sources.

6.1.2.2 Alternative TMDL Expressions

The revised TMDL allows for interpretation of the wet weather concentration-based TMDLs using an alternative expression. Compliance with the concentration-based TMDLs can be demonstrated based on one of the following alternatives to help encourage the development of more efficient and effective TMDL implementation plans and strategies, including revisions to WQIPs that are required under the Regional MS4 Permit (Order No. R9-2013-0001), WDRs, and other regulatory/implementation requirements. It is important to note that these alternative TMDL expressions are not appropriate for sanitary sewer systems, failing septic systems, vessel discharges, and other sources that are prohibited from discharging bacteria. Additional information is provided later in the allocation discussions.

6.1.2.2.1 Model/Mass-Load Based Calculation

Watershed modeling and a mass-loading approach was used to calculate the original Bacteria TMDL for wet weather. Mass-load based TMDLs provide information on the linkage between sources and WLAs and clear endpoints for implementation efforts. This approach is also consistent with the current Regional MS4 Permit compliance pathway presented in Attachment E part 6.b.3, which allows MS4 co-permittees to demonstrate compliance via implementation of a WQIP. The WQIP includes an analysis to demonstrate that the implementation of BMPs will achieve load-based targets as required in the Bacteria TMDL.

Since original development of the Bacteria TMDL models that began in 2003, there are newly available spatial and land use datasets that have been used to improve the representation of watershed physical characteristics in a number of watersheds addressed. Additionally, significant investments have been made in the calibration of wet weather modeling parameters for hydrology and bacteria loading that are specific to the San Diego Region. As a result, the models have evolved over time and the current state-of-the-science in watershed modeling varies significantly from the information and models used to develop the original Bacteria TMDL. Where applied, these new model configurations can result in changes to estimates of existing loads and required load reductions. Further, as discussed in Section 4, available information indicates that sources other than MS4s (e.g., wastewater, failing septic systems, transient population) contribute considerably to FIB concentrations in receiving waters. Following this approach, the model/load based calculation will need to account for the contribution from these sources to provide better information in the future to help improve water quality conditions and implementation strategies.

The revised TMDLs include an option to recalculate the mass-loading based TMDLs and allocations using updated modeling and additional data. This approach also allows for continued incorporation of the TMDLs and allocations that are currently included in the Bacteria TMDL and various permits/implementation plans for contributing sources if an updated model is not available for a given watershed/waterbody.

6.1.2.2.2 Critical Storm Size

For stormwater sources, an approach that focuses on identifying a critical storm size for the treatment of runoff can be considered. This approach is based on the assumption that treating all storms up to an appropriate critical storm size will effectively reduce bacteria concentrations and meet compliance targets. The Los Angeles County MS4 NPDES Permit (Order No. R4-2012-0175) applied this approach as a compliance design storm for an enhanced watershed management program (EWMP): Permittees implementing a regional ground water replenishment project in lieu of onsite controls are required "to ensure the volume of runoff captured by the project shall be equal to: runoff from the 0.75 inch, 24-hour storm event or the 85th percentile storm, whichever is greater".

If this option is selected, conservative estimates shall be used to identify an appropriate critical storm size that will provide reasonable assurance for meeting the TMDL numeric targets within receiving waters in any given year. Bacteria concentrations in stormwater can vary widely due to differences in storm size, intensity, frequency, duration, and many other factors. Because of this variability, the selection of a critical storm size would have a significant impact on the sizing of stormwater controls in order to adequately capture and treat/infiltrate stormwater during wet weather and may result in higher BMP costs. The critical storm should be selected based on a wide range of storm conditions and considering the uncertainty associated with bacteria concentrations in stormwater. If this alternative expression is selected, a detailed approach for identifying the critical storm size and to demonstrate reasonable assurance for achieving the TMDL numeric targets will be required for approval by the Regional Board.

6.1.3 Previous Approach for 2010 Bacteria TMDL Allocations

In the Bacteria TMDL, the calculation of wet weather TMDLs and allocations was based on model predictions of daily bacteria loads during the critical condition year using the LDC approach. The product of this process included 1) the total existing load, 2) the TMDLs, and 3) the exceedance load requiring reduction. Further analysis of the modeling results was used to determine the percent of bacteria load generated by different land uses in each watershed. This information was used to calculate WLAs for MS4s and Caltrans, and LAs for agriculture and open space. In the Bacteria TMDL, no load reductions were assumed for Caltrans or open space. For agriculture, load reductions were assigned depending on its relative proportion of the total existing load. If agriculture represented greater than 5% of the total watershed existing load, then a load reduction was assigned.

6.1.4 Revised Allocation Approach

6.1.4.1 Concentration-based Allocations:

Concentration-based allocations for applicable bacteria source categories are the same as the numeric targets and TMDLs listed in **Table 3-1** and **Table 6-1**, respectively. Wet weather LAs and WLAs were identified for the TMDL beaches (**Table 6-2**) and creeks (**Table 6-3**) separately. Consistent with the numeric targets, it is assumed that REC-1 uses for creeks would be temporarily suspended during high flow periods when conditions are hazardous. During HFS days, the LAs/WLAs will not be applied for impaired creeks.

Table 6-2. Wet Weather LAs and WLAs for Beaches

Source Category		***Enterococcus*** **Statistical Threshold Value (organisms per 100 mL)**
Point Sources	MS4	<110 [a]
	Wastewater Treatment Facilities	0
	Wastewater Collection Systems [b]	0
	Industrial	<110 [a]
	Construction	<110 [a]
	Vessels	0
Non-point Sources	Transient Populations/Encampments	0
	Onsite wastewater treatment systems (OWTSs)	0
	Agriculture [c]	<110 [a]

[a] Wet weather STV based on 2012 RWQC and Bacteria Provisions.
[b] Includes overflows and exfiltration from sewage collection systems, illicit connections, and failing private laterals.
[c] Includes feed lots and other agriculture land uses.
* Wildlife is not a controllable source of bacteria and, therefore, is not listed above. No management measures will be required for wildlife sources.

Table 6-3. Wet weather LAs and WLAs for Creeks

Source Category		*E. coli* Statistical Threshold Value (organisms per 100 mL)
Point Sources	MS4	<320 [a]
	Wastewater Treatment Facilities	0
	Wastewater Collection Systems [b]	0
	Industrial	<320 [a]
	Construction	<320 [a]
	Vessels	0
Non-point Sources	Transient Populations/Encampments	0
	Onsite wastewater treatment systems (OWTSs)	0
	Agriculture [c]	<320 [a]

[a] Wet weather STV based on 2012 RWQC and Bacteria Provisions.
[b] Include overflows and exfiltration from sewage collection systems, illicit connections, and failing private laterals.
[c] Includes feed lots and other agriculture land uses.
[*] Wildlife is not a controllable source of bacteria and, therefore, is not listed above. No management measures will be required for wildlife sources.

6.1.4.2 Alternative Allocation Expressions

The revised TMDL allows for interpretation of the wet weather concentration-based allocations using an alternative expression. Compliance with the concentration-based allocations can be demonstrated based on one of the following alternatives to help encourage the development of more efficient and effective TMDL implementation plans and strategies, including revisions to WQIPs that are required under the Regional MS4 Permit (Order No. R9-2013-0001), WDRs, and other regulatory/implementation requirements. It is important to note that these alternative allocation approaches are not appropriate for sanitary sewer systems, failing septic systems, vessel discharges, and other sources that are prohibited from discharging bacteria (allocations in these cases would be zero).

6.1.4.2.1 Model/Load-Based Calculation

The revised TMDL includes an option to demonstrate compliance by meeting the mass-load based WLAs estimated via watershed modeling. The mass-load based WLAs can be either the WLAs included in the Bacteria TMDL or revised WLAs that may be calculated in the future, if desired, using updated modeling and additional data.

6.1.4.2.2 Critical Storm Size

Under the critical storm size approach, compliance with the WLAs and LAs can be demonstrated via a reasonable assurance analysis to determine the critical storm size which will achieve compliance with the TMDL numeric targets and the implementation of BMPs to capture and treat/infiltrate storm runoff generated from all storm sizes up to the critical storm.

6.2 Dry Weather TMDLs and Allocations

6.2.1 Previous Approach for 2010 Bacteria TMDL

The 2010 Bacteria TMDL established concentration-based numeric targets (and TMDLs) in receiving waters consistent with the Basin Plan WQOs that were established based on USEPA 1986 criteria (geometric mean concentrations): 1,000 MPN/100 mL for total coliforms, 200 MPN/100 mL for fecal coliforms, and 35 MPN/100 mL for enterococci (or 33 MPN/100 mL for select few sites). Extensive dry weather monitoring data were available only for four watersheds in the region: Aliso Creek and San Juan

Creek watersheds in Orange County, and the Rose Creek and Tecolote Creek watersheds in San Diego County. During this time, similar monitoring data were not available for the other watersheds included in the Bacteria TMDL; therefore, an approach was developed to utilize these data to provide a method for predicting dry weather flows and loads for all watersheds included in the Bacteria TMDL.

The calculation of TMDLs and allocations was based on a critical condition year, as described in the wet weather section above. An AEF was not calculated for dry weather; therefore, natural and uncontrollable sources were not considered, as discussed below. Allocation of the dry weather TMDLs assumed that no surface runoff discharged to receiving waters occurs from Caltrans, agriculture, or open space and assigned zero allocations to these sources. The entire dry weather mass-load based TMDL for each waterbody (i.e., allowable load) was allocated to municipal discharges.

6.2.2 Revised TMDL Approach

In 2003 when development of the Bacteria TMDL began, most of the dry weather data available to characterize bacteria were collected at the beaches, with little data available to characterize sources of bacteria loading and conduct a linkage analysis to establish the impact of source loads on receiving waters. Over the past 13 years, much effort has been invested in the San Diego Region and other areas to better understand the sources of bacteria, their impact on receiving waters, and how to effectively address impairments. The revised TMDLs were developed to utilize these efforts and establish meaningful allocations that provide a clear pathway for implementation for dry weather.

6.2.2.1 Concentration-based TMDLs

Consistent with the Bacteria TMDL approach, concentration-based TMDLs were established for dry weather to meet the numeric targets. For most pollutants, TMDLs are expressed on a mass loading basis (e.g., kilograms per year). Federal regulations (40 CFR §130.2(1)) provide that TMDLs do not need to be expressed as loads (mass per unit time), but may be expressed as "other appropriate measure". For pathogen indicators, the number of organisms in a given volume of water (i.e., concentration), is significant with respect to public health and protection of beneficial uses. The concentrations of FIB in a discharge and in the receiving waterbodies can be used in assessing the impact of discharges, the quality of the affected receiving waterbodies, and human health risk.

The dry weather TMDLs are the same as the numeric targets in Section 3. The targets for beaches (marine) are based on enterococci and the targets for creeks (fresh) are based on *E. coli*, with magnitudes that correspond to a risk protection level of 32 excess NGI illnesses per 1,000 contact recreators consistent with the 2012 RWQC and Bacteria Provisions. **Table 6-4** presents the dry weather TMDLs.

Table 6-4. Dry Weather TMDLs for Beaches and Creeks

TMDL Monitoring Location Type	Indicator Bacteria [f]	TMDL Component	TMDL (organisms per 100 mL)
Creeks (fresh) [a, b, c, d, e, g]	*E. coli*	Statistical Threshold Value [i]	320
		Geometric Mean [j]	100
Beaches (marine) [a, b, c, d, e, h]	Enterococci	Statistical Threshold Value [i]	110
		Geometric Mean [j]	30

a – Dry weather is defined as days that do not meet the wet weather definition.
b - For sites where a site-specific target has not been approved, the TMDLs in this table serve as the default TMDLs. Otherwise, the TMDL based on the site-specific target applies.
c – WQIPs may develop numeric goals and water quality improvement strategies based on either default TMDLs, site-specific TMDLs or level of risk protection, subject to approval by the San Diego Water Board Executive Officer.
d – Numeric targets are suspended during temporary beneficial use suspensions, as applicable. In addition, if a waterbody is designated as LREC-1 in the future, numeric targets would be based on bacteria WQOs that may be identified at the time of designation, as needed.
e – The TMDLs include a zero AEF in dry weather.
f – For listed TMDL waterbodies that are estuaries, the applicable indicator depends on the dominant salinity (resembling marine or freshwater conditions) measured the majority of the time, consistent with the Bacteria Provisions.
h – Targets for beaches also apply to all TMDL monitoring locations under tidal influence.
g – Creeks are inland surface waters upstream of tidal influence.
i – Dry weather sample concentrations are compared against the STV numeric target only when geometric mean cannot be calculated for each season.
j – Based on all dry weather samples collected within each season (winter and summer). A minimum of 5 samples is required for geometric mean calculation, consistent with the Bacteria Provisions. If 5 samples are not available within each season, then sample concentrations are compared against the STV numeric target.

6.2.2.2 Alternative TMDL Expression

The revised TMDL allows for interpretation of the dry weather concentration-based TMDLs using an alternative expression. Compliance with the concentration-based TMDLs can be demonstrated based on the following alternative to help encourage the development of more efficient and effective TMDL implementation plans and strategies, including revisions to WQIPs that are required under the Regional MS4 Permit (Order No. R9-2013-0001), WDRs, and other regulatory/implementation requirements. It is important to note that these alternative TMDL expressions are not appropriate for sanitary sewer systems, failing septic systems, vessel discharges, and other sources that are prohibited from discharging bacteria. Additional information is provided later in the allocation discussions.

6.2.2.2.1 Load Reduction Strategy

A Load Reduction Strategy (LRS) may be used to demonstrate compliance with dry weather allowable loads for stormwater sources. The LRS approach represents an implementation strategy that was developed by stakeholders within the Los Angeles River watershed and was incorporated into the adopted Los Angeles River (LAR) Bacteria TMDLs. The LRS has been applied by a number of MS4s to implement the requirements of the LAR TMDLs. The LRS approach uses either an outfall-based or downstream-based strategy, as summarized below.

- Outfall-based approach: The outfall-based approach emphasizes reducing loading from outfalls that discharge either directly to a receiving water or to the MS4 system that ultimately discharges to receiving waters. This approach provides a stepwise process that includes monitoring of bacteria discharges from outfalls, implementation of actions to reduce MS4 discharges below allowable loads (estimated based on monitoring and/or modeling data), and follow-up assessment of additional actions needed. Dry weather discharges still continuing from MS4 after the LRS will be either diverted or treated (as much as feasible).

- Downstream-based approach: While the outfall-based LRS approach systematically addresses discharges to a waterbody, the downstream-based approach protects recreational uses below a given location by implementing actions within or adjacent to the waterbody. A downstream-based LRS may include in-stream projects to enhance waterbodies while reducing bacteria concentrations, diversions to the sanitary sewer, diversion for infiltration, or treatment and release to the waterbody. The downstream-based LRS has the potential to lead to more reliable, more protective, faster, and less-expensive solutions for protection of recreational users when compared to the outfall-based approach

Each LRS approach is intended to allow for adaptive and iterative TMDL implementation. Due to the highly variable nature of bacteria, each LRS follows a stepwise process and may include multiple iterations during TMDL implementation prior to the final compliance date.

6.2.3 Previous Approach for 2010 Bacteria TMDL Allocations

Due to limited data availability on both flow and bacterial concentrations during the development of the Bacteria TMDL, WLAs and LAs were calculated based on regression analyses using limited data from a few TMDL watersheds and land use information. The following approach was used.

- Estimation of dry weather runoff and fecal coliform concentrations: multivariable regression analyses were performed on the limited dry weather flow measurements (available for three TMDL watersheds) and fecal coliform data (available from four TMDL watersheds) to establish relationships with land use types. The resulting regression equation predicted dry weather flows or fecal coliform densities as a function of areas of differing land use types. Using land use areas within each of the Bacteria TMDL watersheds, the equation was applied to estimate runoff or fecal coliform densities expected to occur over a typical dry weather period for all watersheds within the TMDL. Total coliform and enterococci concentrations were estimated using relationships with fecal coliform concentrations developed based on limited bacteria data.
- Dry weather model: The existing mass loads were calculated by multiplying model-predicted flows with predicted bacteria concentrations. The mass-load based TMDLs were determined by model predicted flows multiplied by 30-day geometric mean numeric targets. The required load reductions were determined by taking the difference of existing loads and mass-load based TMDLs. Dry weather mass-load based TMDLs assumed that surface runoff does not reach receiving waters from Caltrans, agriculture, or undeveloped open space areas and were assigned a WLA = 0 (Caltrans) or LA = 0 (agriculture and open space).
- For the Bacteria TMDL, all dry weather loads were assumed to result from urban runoff. As a result, all loads were assigned to the Municipal source, with no allocations assigned to other sources. This also meant that Municipal sources were assigned responsibility for the entire load reduction.

This allocation approach contains certain limitations. Mainly there was limited information regarding irrigation, and therefore associated dry weather loads were not accurately simulated. In 2003 when the development of the Bacteria TMDL began, most of the dry weather data available to characterize bacteria were collected at the beaches, with little data available to characterize sources of bacteria loading through a TMDL linkage analysis that establishes the effect of source loads on receiving waters. Further, at the time of initiation of TMDL development in 2003, extensive dry weather monitoring data were available only for four watersheds in the region: Aliso Creek and San Juan Creek in Orange County, and Rose Creek and Tecolote Creek in San Diego County. These studies included flow and bacteria data within the mainstem of the creeks and within multiple tributaries. During this time, similar monitoring data were not available for the other watersheds included in the Bacteria TMDL; therefore, an approach was developed to utilize these data to provide a method for predicting dry weather flows and loads for all watersheds included in the TMDL.

6.2.4 Revised Allocation Approach

6.2.4.1 Concentration-based Allocations

Concentration-based allocations for bacteria source categories are the same as the numeric targets and the TMDLs listed in **Table 3-1** and **Table 6-1**, respectively. Dry weather LAs and WLAs were identified for the TMDL beaches (**Table 6-5**) and creeks (**Table 6-6**) separately. Consistent with the numeric targets, it is assumed that REC-1 uses for creeks would be temporarily suspended during low flow periods when conditions do not allow for contact recreation. During LFS days, the LA/WLAs will not be applied for impaired creeks.

Table 6-5. Dry Weather LA and WLA for Beaches

Source Category		Enterococcus	
		Geometric Mean [a] (organisms per 100 mL)	Statistical Threshold Value (organisms per 100 mL)
Point Sources	MS4	<30	<110
	Wastewater Treatment Facilities	0	0
	Wastewater Collection Systems [b]	0	0
	Industrial	<30	<110
	Construction	<30	<110
	Vessels	0	0
Non-point Sources	Transient Populations/Encampments	0	0
	Onsite wastewater treatment systems (OWTSs)	0	0
	Agriculture [c]	<30	<110

[a] Based on a minimum of 5 samples collected within each season.
[b] Include overflows and exfiltration from sewage collection systems, illicit connections, and failing private laterals
[c] Includes feed lots and other agriculture land uses.
[*] Wildlife is not a controllable source of bacteria and, therefore, is not listed above. No management measures will be required for wildlife sources.

Table 6-6. Dry Weather LA and WLA for Creeks

Source Category		*E. coli* Geometric Mean [a] (organisms per 100 mL)	*E. coli* Statistical Threshold Value (organisms per 100 mL)
Point Sources	MS4	<100	<320
	Wastewater Treatment Facilities	0	0
	Wastewater Collection Systems [b]	0	0
	Industrial	<100	<320
	Construction	<100	<320
	Vessels	0	0
Non-point Sources	Transient Populations/Encampments	0	0
	Onsite wastewater treatment systems (OWTSs)	0	0
	Agriculture [c]	<100	<320

[a] Based on a minimum of 5 samples collected within each season.
[b] Include overflows and exfiltration from sewage collection systems, illicit connections, and failing private laterals.
[c] Includes feed lots and other agriculture land uses.
* Wildlife is not a controllable source of bacteria and, therefore, is not listed above. No management measures will be required for wildlife sources.

6.2.4.2 Alternative Allocation Expression

The revised TMDL allows for interpretation of the dry weather concentration-based allocations using an alternative expression. Implementation of concentration-based allocations can be demonstrated based on one of the following alternative to help encourage the development of more efficient and effective TMDL implementation plans and strategies, including revisions to WQIP, WDRs, and other regulatory/implementation requirements. It is important to note that these alternative allocation approaches are not appropriate for sanitary sewer systems, failing septic systems, vessel discharges, and other sources that are prohibited from discharging bacteria (allocations in these cases would be zero).

6.2.4.2.1 LRS

As described above, MS4s can demonstrate compliance with dry weather allowable WLAs by following an outfall or downstream-based LRS approach, as described above. Overall, MS4s that follow a LRS approach accept a tradeoff that could potentially provide an iterative BMP-based compliance pathway for final WLAs but requires a more rigorous process by which implementation activities are performed and documented.

6.3 Margin of Safety (MOS)

There are two ways to incorporate a MOS: (1) implicitly incorporate the MOS using conservative model assumptions to develop TMDLs and (2) explicitly specify a portion of the total TMDL as the MOS and use the remainder for allocations. In the revised TMDLs, the numeric targets and TMDLs/allocations were developed with conservative assumptions following an implicit MOS approach. The following describe the conservative assumptions that constitute the implicit MOS in the revised TMDLs.

The 2012 RWQC contains two sets of criteria: 1) criteria based on 36 excess NGI illnesses per 1,000 contact recreators, which would retain the same water quality levels associated with the USEPA 1986 Criteria and 2) criteria based on 32 excess NGI illnesses per 1,000 primary contact recreators, which "would encourage an incremental improvement in water quality." The revised TMDLs and allocations apply the numeric targets based on the more conservative criteria of the two illness rates at 32 excess NGI illness per 1,000 primary contact recreators.

Concentration-based TMDLs and allocations: A concentration-based approach was chosen to link the numeric targets with appropriate WLAs and LAs in order to ensure the protection of water quality and water contact recreation in these waterbodies. Concentration-based TMDLs have several advantages, including the direct relationship between receiving water concentrations and human health risk, as well as consistency of application throughout the region. This direct relationship provides an implicit margin of safety because additional calculations, modeling assumptions, and other sources of uncertainty are not introduced into the TMDL and WLAs/LAs. In addition, concentration-based TMDLs can be applied universally to all point and nonpoint sources.

No dry weather AEF: Since development of the Bacteria TMDL, several reference studies have been completed that included dry weather data collection at reference beaches and creeks. Although the results provide some evidence that natural sources may cause exceedances of the bacteria WQOs during dry weather, incorporation of a regional dry weather AEF is not proposed at this time based on the relatively infrequent occurrence of bacteria WQO exceedances and to provide a margin of safety.

Critical condition: The revised TMDLs and allocations are based on the critical condition, the set of environmental conditions for which controls designed to protect water quality will ensure attainment of FIB WQOs for all other conditions. The revised TMDLs and allocations include concentration-based limits which apply during all conditions (except if a temporary suspension or LREC-1 designation is applied). A concentration-based TMDL approach provides protection during critical conditions, as discussed above. In addition, if alternative model/mass-based TMDLs and allocations are developed for wet weather, the critical condition used for the modeling analysis will be updated to WY 2005 as described below.

6.4 Critical Conditions

The critical condition is the set of environmental conditions for which controls designed to protect water quality will ensure attainment of objectives for all other conditions. Critical conditions typically include the location and the period of time in which the waterbody exhibits the most vulnerability. The revised TMDLs and allocations include concentration-based limits which apply during all conditions (except if a temporary suspension or LREC-1 designation is applied). A concentration-based TMDL approach provides protection during critical conditions, as well as other advantages discussed in Section 6.3.

In addition, if alternative model/mass-based TMDLs and allocations are developed for wet weather, the critical condition used for the modeling analysis will be updated to WY 2005. This year was selected based on a re-evaluation historical rainfall records to identify an extreme wet weather loading year. Among National Climatic Data Center (NCDC) rainfall stations located throughout San Diego, Orange, and Riverside Counties, two stations were selected for analysis of rainfall records to identify a critical period: Laguna Beach (COOPID 049378) and San Diego Lindbergh Field (WBAN 23188). These stations were selected due to their representation of historic rainfall that occurred in the most northern and southern portions of the region addressed by the Bacteria TMDL. For each of the selected stations, historic data from 1986 to 2014 (29 years) were analyzed to determine the total rainfall for each WY (October 1 to September 30). For both stations, the wettest year during this period was WY 2005, with 30.2 and 22.6 total inches of rainfall occurring at Laguna Beach and San Diego Lindbergh Field, respectively. As a result, WY 2005 was selected as the new critical year. Implementation of BMPs based on the critical condition will reduce bacterial contribution from both the wet and dry weather conditions.

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7. TMDL Implementation Plan

Because federal regulations require TMDLs to be incorporated into the Basin Plan, and because they are developed to implement previously established water quality standards (i.e., beneficial uses and WQOs), state statute requires the Basin Plan amendment to include a program of implementation (or implementation plan) for achieving water quality objectives.

The ultimate goal of the implementation plan is to protect the recreational beneficial uses of the waterbodies addressed by these TMDLs. As discussed in the Problem Statement, and in accordance with the original Bacteria TMDL implementation plan, a number of recent studies have produced locally relevant data that improve our understanding of current health impacts to recreators and how different levels of bacteria and pathogens correspond to these health effects. These studies, along with the 2012 RWQC, provide evidence that implementing actions focused on reducing human health risk, rather than generally focusing on indicator bacteria load reduction, is a more efficient and effective way of protecting recreational beneficial uses. As a result, this implementation plan provides an implementation and compliance structure and monitoring program that focuses on actions and strategies that are likely to have the biggest impact on reducing human health risk.

Specifically, monitoring and implementation actions will prioritize the reduction of human sources of bacteria, which have been found to pose a higher risk of illness than bacteria deriving from non-human sources as discussed in Section 4 (Soller et al., 2010b). The monitoring approach will apply recent scientific developments pertaining to the use of human genetic markers to assess and identify bacteria sources of human origin. Additionally, required monitoring and implementation actions are prioritized based on the recreational use intensity and associated risk to human health in different types of waterbodies addressed by the TMDL. The implementation schedule has also been modified to allow for regulatory adjustments in response to scientific advances, modified numeric targets, and a broadening of involvement in the TMDL to all parties responsible for managing high risk bacteria sources (e.g., sanitary sewer agencies that will be required to inspect for and correct collection system deficiencies).

7.1 Overview of Implementation Structure

The implementation plan prioritizes actions to reduce human health risk in order to protect recreational beneficial uses. While imperfect, FIB are currently the best available and scientifically supportable indicators for translating human health risk to TMDL targets. However, as discussed throughout this TMDL report, human sources of fecal contamination present a higher risk to human health than non-human sources. Additionally, the risk to human health is also dependent on the type of recreational use and the frequency at which a waterbody is used for recreation. By using human source tracking methods, combined with a focus on areas with the highest recreational use intensity, the San Diego Water Board anticipates that more effective management strategies can be implemented compared to focusing solely on FIB reductions.

The approach will also provide increased benefit at a lower cost to ratepayers (Environmental Incentives and EONorthwest, 2017). The San Diego Bacteria TMDL Cost-Benefit Analysis (CBA) Report from October 2017 was produced to evaluate the costs and benefits of a range of scenarios and implementation methods for achieving the wet weather targets in the Bacteria TMDL (Environmental Incentives and ECONorthwest, 2017). The scenarios explored variations on the following: implementation of traditional stormwater best management practices (BMPs) targeting FIB, changing the Bacteria TMDL compliance schedule, targeting human waste sources of bacteria, and reducing bacteria through stream restoration. The study found that targeting human waste sources was the most cost-effective method to reduce health risk and protect water recreation opportunities. Additionally, the projected number of avoided infectious illnesses per million dollars invested for targeting human sources was more than ten times higher than implementing stormwater BMPs. The findings of the CBA reflect the benefits and reduction in human health risk from addressing human fecal sources, and show that addressing these sources will be the most effective investment toward avoiding illnesses in swimmers and surfers.

Figure 7-1 provides an overview of the use intensity and human source influence (and therefore illness risk) associated with different types of waterbodies regulated by these TMDLs, with the highest overall risk to human health (i.e., highest illness risk and highest exposure rates) in the top right corner of the figure. The implementation structure and compliance schedule is based on moving all waterbodies towards the left of the figure (i.e., reducing human sources and associated illness risk), starting with waterbodies that have the highest exposure/use intensity.

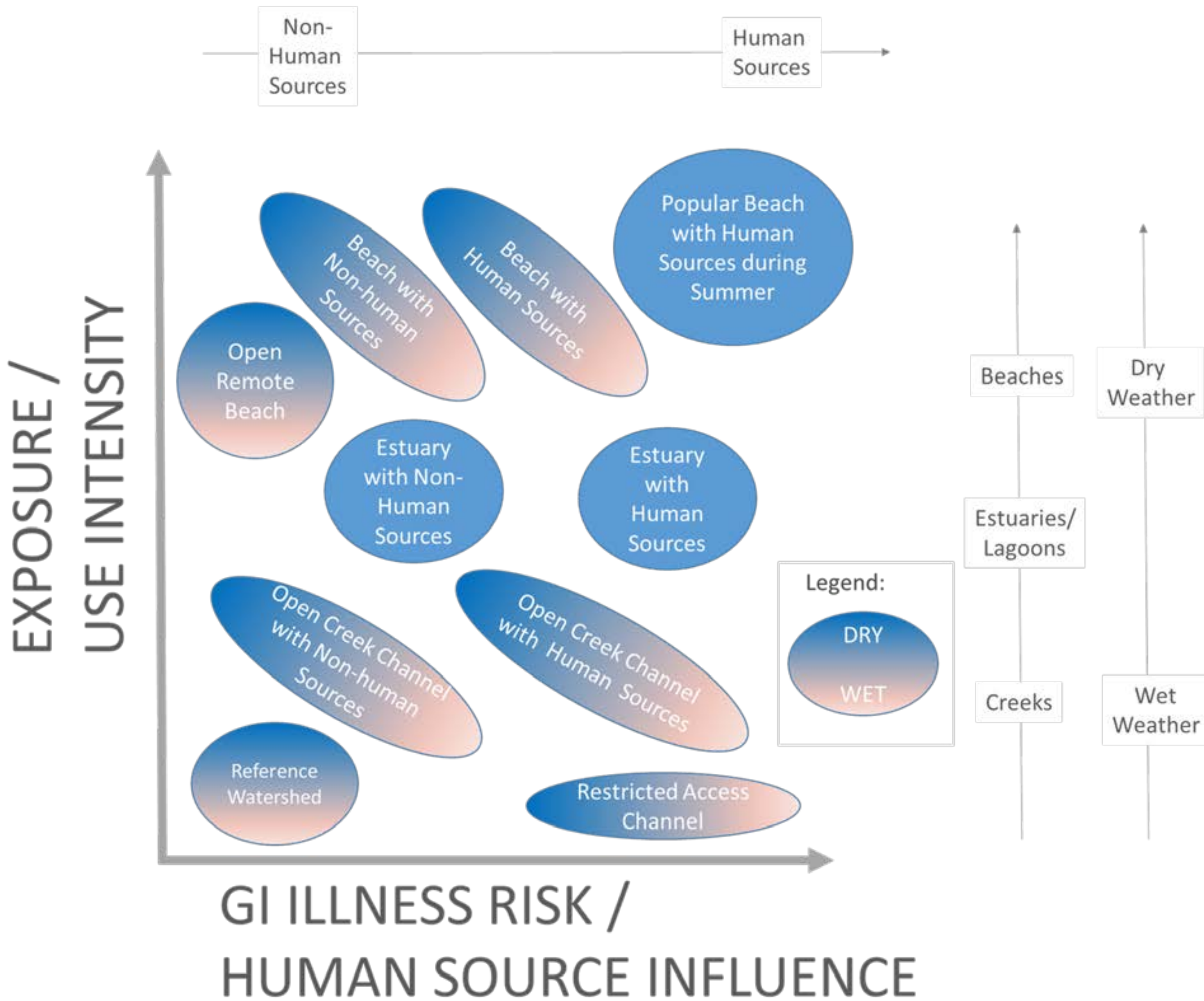

Figure 7-1. Recreational Use Intensity and Illness Risk by Waterbody Type

The implementation structure for all responsible dischargers is as follows:

1. Implement a human source reduction program as outlined in Section 7.3, consisting of:
    a. Maintain existing, or more effective alternative non-structural and structural control measures and programs that address discharges of bacteria.
    b. Implement expanded actions in areas with existing impairments to address high-risk sources of bacteria.

2. Implement a monitoring program, as outlined in Section 7.2, consisting of:
    a. A receiving water compliance monitoring program, and
    b. A program to conduct followup investigations in response to monitoring results indicating the presence of human sources through the receiving water compliance monitoring program.
3. Develop and implement an adaptive management program that results in implementing additional human source reduction actions, as needed, in response to the followup investigations, to address identified human sources of bacteria.

A compliance structure has been developed to support the reduction of human health risk that is based on special studies conducted in the San Diego Region (including the SHS) that are described in **Appendix B**. A flow chart describing the compliance structure is shown in **Figure 7-2.** Compliance Pathways. Each element of the compliance flow chart is then described in more depth in the monitoring and implementation actions sections. Finally, this section includes a compliance schedule, process for reevaluating the TMDL, and summary of potential Basin Plan actions necessary to support the information in this TMDL.

For each waterbody, responsibility for reducing human sources of bacteria will fall on several different entities as shown in **Table 7-1**. The responsibility for meeting the TMDL shall be shared among all the implementing entities within the drainage area to the waterbody. Cooperation is necessary not only to reach the numeric targets, but also to avoid duplicate actions, such as monitoring and reporting.

The San Diego Water Board will incorporate requirements consistent with this implementation approach into the applicable orders for the responsible parties. These requirements will include development of a monitoring program in accordance with the requirements in Section 7.2 and development of a human source reduction program, including an adaptive management program, in accordance with the requirements in Section 7.3. The human source reduction program development requirements can be met through existing planning requirements in applicable regulatory authorities. The applicable regulatory authorities and discharger-specific provisions are described in Section 7.4.

7.1.1 Compliance Structure

The applicable WQOs and corresponding TMDL numeric targets are designed to protect recreational uses based on FIB measurements. FIB are currently used for waterbody listing and delisting purposes and it is likely that development of alternative indicators that are more direct measurements of human health risk from pathogens will take time. While FIB-based objectives are currently in place and used as numeric targets in the TMDL, it is the intent of the TMDL to use the best available science and information to result in implementation actions that will have the greatest likelihood for reducing human health risk and reflect information developed about the current level of human health risk in waterbodies in the San Diego Region through the SHS.

The selected mechanism for achieving this goal was to develop implementation procedures for the numeric targets that will be used to determine attainment of targets. Three “compliance pathways” were developed. Any of the three pathways may be used to assess attainment of targets, as long as the information needed to assess attainment is available for a given waterbody. Additionally, waterbodies can be assessed using different compliance pathways over time depending on the types of data and information available for assessing attainment. Increasing levels of data and information are required for Pathways 2 and 3 as compared to Pathway 1. Delisted waterbodies will be considered to be attaining targets based on Pathway 1 and dischargers to those waterbodies will not be required to conduct upstream assessment or source identification monitoring or implement human source reduction programs to comply with this TMDL, unless the receiving water monitoring data demonstrates the waterbodies are not attaining targets in the future. Responsible parties for the delisted waterbodies will be required to conduct receiving water monitoring in accordance with Section 7.2.

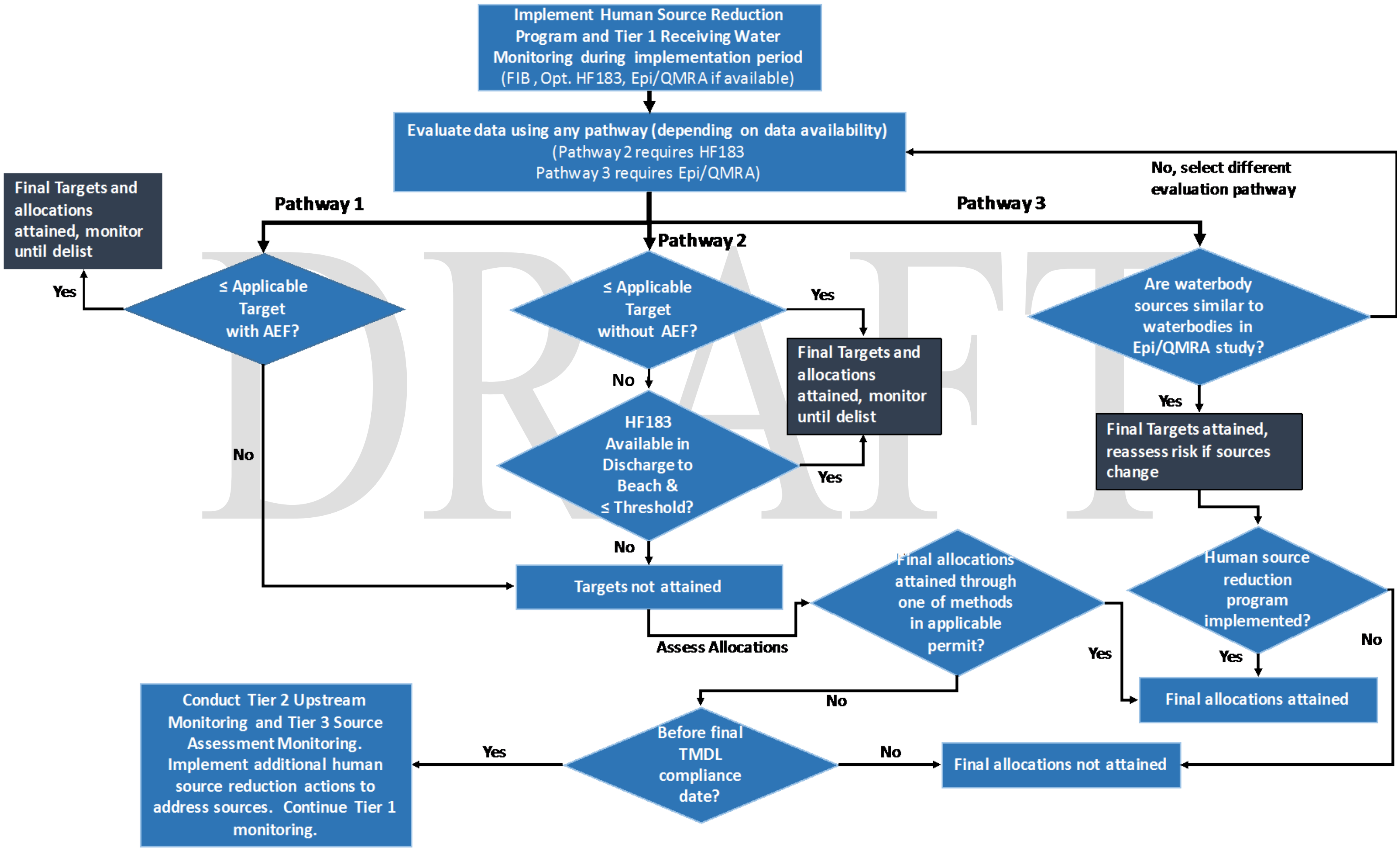

Figure 7-2. Compliance Pathways

Each compliance pathway consists of a monitoring program that evaluates attainment of targets in the receiving waters at specified compliance points on an annual basis. If the targets are attained based on the assessment mechanism for the pathway, the dischargers to that waterbody are considered to be in compliance with their allocations and the waterbody is considered to be attaining targets for that year. Receiving water monitoring will continue to be conducted and assessed on an annual basis until sufficient information is developed to show the waterbody is consistently attaining targets, is no longer impaired, and can be delisted.

7.1.1.1 Compliance Pathway 1 – TMDL/Numeric Targets Assessment

Compliance Pathway 1 relies solely on FIB data for the assessment of target attainment and is equivalent to the receiving water assessment process used to implement the Bacteria TMDL. FIB concentrations collected at the receiving water compliance locations are compared to the applicable target for the waterbody and condition in **Table 3-1**, along with the applicable implementation provisions for the waterbody described in Section 3.4 (e.g., AEF, HFS/LFS) using the procedures in Section 7.2.6. If the seasonal geometric means calculated for dry weather are less than the associated numeric target and the annual STV calculated for wet weather is less than the AEF shown in Section 3.4, the waterbody is attaining the targets for that year and no further action is needed. As discussed in Section 3.4 and consistent with San Diego Water Board Resolution No. R9-2008-0028, the AEF is designed to ensure that responsible parties are not required to address natural sources of bacteria and make waterbodies cleaner than reference waterbodies. This pathway represents a conservative pathway as wet weather FIB exceedance rates are generally above the acceptable limit (AEF) for most waterbodies and dry weather exceedances are typically low. In addition, this pathway reduces the need for additional data collection and monitoring expenditures, in order to focus resources on implementation actions as needed.

Waterbodies will be considered in attainment and may be delisted if there are no persistent exceedances as determined by the guidelines found in Section 4 (California Delisting Factors) of the Listing Policy.

7.1.1.2 Compliance Pathway 2 – TMDL/Numeric Targets Assessment

Compliance Pathway 2 utilizes FIB monitoring, combined with human marker data (HF183), to identify when FIB concentrations are associated with human sources and are more likely to pose a human health risk. Pathway 2 cannot be used if HF183 data are not available. Under this pathway, HF183 replaces the AEF as the mechanism for avoiding the need to treat natural sources of bacteria. The use of HF183 encourages a focus on the human sources that are more likely to pose a risk to recreators and avoids the need to treat bacteria from sources that are less likely to pose a risk to human health. Compliance Pathway 2 was developed as a mechanism to better link the risk of exposure to the FIB concentrations as compared to the AEF approach. Under Pathway 2, FIB concentrations from the receiving water are compared to the targets for the year using the procedures in Section 7.2.6. Waterbodies will be considered in attainment based on the FIB assessment for dry and wet weather conditions, along with a paired analysis using available HF183 data. For dry weather, if the seasonal geometric means for FIB are less than the associated numeric target and less than 10% of the paired HF183 samples exceed the applicable threshold, then the waterbody is attaining the targets for that year and no further action is needed. For wet weather, a waterbody is attaining targets if less than 10% of the paired FIB and HF183 samples exceed the STV and HF183 threshold, respectively. Only a wet weather threshold has been identified at the present time – 2,655 copies/100ml, based on the results of the SHS which primarily focused on wet weather associated health risks. Note: development of a dry weather H183 threshold value is currently being evaluated and may be incorporated to help support dry weather compliance assessments.

In these cases, the targets are considered to be attained because the FIB concentrations above the target are not anticipated to cause additional risk to recreators above the levels observed during the SHS, which showed existing risk levels to be well within the bounds of USEPA recommended criteria (i.e., 32 excess gastrointestinal illnesses per 1000 exposures). Based on feedback from microbiology experts at SCCWRP and other leading researchers involved in the SHS, HF183 levels may be below detection thresholds in ocean waters. As a result, responsible parties choosing to collect HF183 data will collect those measurements in the freshwater discharge to the beach (creek, river, or outfall depending on the location), prior to discharge to the ocean to provide a conservative assessment of the levels of HF183 associated with the measured FIB concentrations in the ocean.

The waterbody will be considered to be in attainment and may be delisted if there are no persistent exceedances as determined by the guidelines found in Section 4 (California Delisting Factors) of the Listing Policy.

7.1.1.3 Compliance Pathway 3 – TMDL/Numeric Targets Assessment

Compliance Pathway 3 shifts from using FIB and other water quality monitoring data as proxies for estimating risk to conducting studies that more directly measure the estimated risk to recreators. Under this pathway, an epidemiological or QMRA study that meets the requirements of USEPA guidance must be conducted. If the study demonstrates that the risk to human health is below the risk level that was used as the basis for determining the FIB objectives (less than 32 excess NGI illnesses per 1,000 primary contact recreators), the waterbody is considered to be attaining targets. Demonstrating compliance via Pathway 3 requires that the sources of bacteria associated with the listed waterbody be similar to the waterbodies that were included in the Epidemiology or QMRA study. Unlike water quality monitoring, assessment of compliance will not occur on an annual basis because the studies are costly and considered to be representative of general waterbody conditions given the sources present in the watershed. Risk would only be expected to increase if new, high risk sources are introduced to the watershed, or if there is an unanticipated change to risk presented by existing sources. Therefore, sanitary surveys will be conducted every 5 years to assess whether sources have changed sufficiently to warrant a reevaluation of the study findings. FIB monitoring will also be conducted to allow assessment of changes in water quality that could indicate a change in sources warranting a reevaluation of study results. However, as long as the sanitary surveys and FIB monitoring remain consistent, the waterbody will be considered to be in attainment of the target.

For the purposes of this TMDL, the SHS can be utilized to demonstrate compliance using Pathway 3 for beaches in the TMDL for wet weather (and potentially dry weather in the future depending on identification of an appropriate HF183 threshold through this study or others). The results of the SHS have been determined to be sufficient to demonstrate that the risk level at Tourmaline Surfing Park and Ocean Beach is consistent with the level of protection provided by the FIB numeric targets (See Appendix B for details of the assessment). Because the SHS included epidemiological data from beaches throughout the San Diego Region, the illness levels associated with the study are applicable to most beaches in the San Diego Region. However, because of the potential for waterbodies to contain sources that present a larger risk or are larger than those present in the waterbodies where water quality was sampled, thereby resulting in greater exposure to recreators in that specific waterbody, a sanitary survey is required to demonstrate that the waterbody sources are similar to those in the watersheds draining to Ocean Beach and Tourmaline Surfing Park. A discussion of the process for conducting this assessment is in Section 7.2.5. If the other beaches are determined to have similar sources to Tourmaline Surfing Park and Ocean Beach, then the SHS applies and the beach is considered to be in compliance. If the beach is determined to not have similar sources or is an inland waterbody not covered by the SHS, then Pathway 3 cannot be used unless an epidemiological study or QMRA is conducted specific to the waterbody or a waterbody with similar sources.

To ensure that high risk sources are managed in a way to maintain the risk level observed during the SHS, compliance under Pathway 3 requires implementation of a human source reduction program. The human source reduction program is described in Section 7.3 and is designed to require implementation of programs and management measures that will reduce the presence of human bacteria sources in the waterbodies over time. While the risk level in the SHS may have been determined to be less than the USEPA criteria under Pathway 3, continued management and reduction of human sources of bacteria to maintain or reduce the risk level is required to use this pathway for compliance. Because waterbodies that meet the requirements for compliance Pathway 3 are considered in attainment of numeric targets, there is no assessment of allocations for this pathway other than confirmation that a human source reduction program was implemented.

7.1.1.4 Compliance Pathways 1 and 2 – Allocation Assessment

If targets are not attained, compliance Pathways 1 and 2 include an assessment process specific to each responsible party to determine if they are attaining allocations and in compliance with their respective waste discharge requirements. The assessment process will be specific to the responsible party and include options for comparing discharge monitoring data to the allocations and options for evaluations consistent with the alternative expressions of the allocations discussed in Section 6.

If the TMDLs/numeric targets and allocations are both not being attained and it is within the implementation period for the TMDL, monitoring and implementation requirements are required in accordance with Section 7.2.

7.1.2 TMDL Responsible Parties

Implementation of the regional monitoring and source abatement effort will require collaboration between responsible parties within each watershed, sub-watersheds, and region-wide. **Table 7-1** presents a list of responsible parties for waterbodies with current impairments that will be responsible for implementing monitoring and implementation actions in accordance with this section.

Table 7-1. TMDL Responsible Parties by Watershed

Watershed	Waterbody	Segment or Area	Responsible Parties
San Joaquin Hills HSA (901.11) & Laguna Beach HSA (901.12)	Pacific Ocean Shoreline, San Joaquin Hills HSA	at Crescent Bay Beach	City of Laguna Beach County of Orange Orange County Flood Control District South Orange County Wastewater Authority Caltrans Owners/operators of small MS4s
	Pacific Ocean Shoreline, Laguna Beach HSA	at Main Beach	City of Aliso Viejo County of Orange City of Laguna Beach City of Laguna Woods Orange County Flood Control District South Orange County Wastewater Authority Caltrans Owners/operators of small MS4s
Aliso HSA (901.13)	Pacific Ocean Shoreline, Aliso HSA	at Aliso Beach middle	City of Aliso Viejo City of Laguna Beach City of Laguna Hills City of Laguna Niguel City of Laguna Woods City of Lake Forest City of Mission Viejo County of Orange
		at Aliso Creek mouth	
	Aliso Creek		

Watershed	Waterbody	Segment or Area	Responsible Parties
	Aliso Creek (mouth)		Orange County Flood Control District South Orange County Wastewater Authority Caltrans Owners/operators of small MS4s El Toro Water District
Dana Point HSA (901.14)	Pacific Ocean Shoreline, Dana Point HSA	at Aliso Beach at West St.	City of Dana Point City of Laguna Beach City of Laguna Niguel County of Orange Orange County Flood Control District South Orange County Wastewater Authority Caltrans Owners/operators of small MS4s Moulton Niguel Water District South Coast Water District
		Dana Point Harbor at Baby Beach	County of Orange South Orange County Wastewater Authority City of Dana Point South Coast Water District
Lower San Juan HSA (901.27)	Pacific Ocean Shoreline, Lower San Juan HSA	at North Beach Creek	City of San Juan Capistrano City of Mission Viejo City of Laguna Hills City of Laguna Niguel City of Dana Point City of Rancho Santa Margarita County of Orange Orange County Flood Control District South Orange County Wastewater Authority Caltrans Owners/operators of small MS4s Moulton Niguel Water District Santa Margarita Water District South Coast Water District
		at North Doheny State Park Campground	
		at San Juan Creek	
		at South Doheny State Park Campground	
	San Juan Creek		
	San Juan Creek (mouth)		
San Clemente HA (901.30)	Pacific Ocean Shoreline, San Clemente HA	at Poche Beach	City of San Clemente County of Orange Orange County Flood Control District South Orange County Wastewater Authority City of Dana Point Caltrans Owners/operators of small MS4s South Coast Water District
		at San Clemente City Beach at Pier	
		at South Capistrano Beach at Beach Road	
		at South Capistrano County Beach	
		at South Poche Beach at Capistrano Shores	

Watershed	Waterbody	Segment or Area	Responsible Parties
San Luis Rey HU (903.00)	Pacific Ocean Shoreline, San Luis Rey HU	at San Luis Rey River Mouth	City of Oceanside City of Vista County of San Diego Caltrans Owners/operators of small MS4s Controllable nonpoint sources Buena Sanitation District San Diego County Sanitation District San Luis Rey Municipal Water District Vallecitos Water District Vista Irrigation Yuima Municipal Water District
Scripps HA (906.30)	Pacific Ocean Shoreline, Scripps HA	at Children's Pool	City of San Diego UC San Diego Owners/operators of small MS4s
		at Pacific Beach Point at Pacific Beach	
Tecolote HA (906.50)	Tecolote Creek		City of San Diego Owners/operators of small MS4s
Mission San Diego HSA (907.11) & Santee HSA	Forrester Creek		City of El Cajon City of Santee County of San Diego Caltrans Owners/operators of small MS4s Helix Water District
	San Diego River, Lower		City of El Cajon City of La Mesa City of San Diego City of Santee County of San Diego Caltrans Owners/operators of small MS4s Padre Dam Water Treatment Facility Helix Water District San Diego County Sanitation District
	Pacific Ocean Shoreline, San Diego HU	at San Diego River Mouth at Dog Beach	
Point Loma HA (908.10)	San Diego Bay Shelter Island Shoreline Park		City of San Diego San Diego Unified Port District
Chollas HSA (908.22)	Chollas Creek		City of La Mesa City of Lemon Grove City of San Diego San Diego Unified Port District Caltrans Owners/operators of small MS4s Helix Water District San Diego County Sanitation District

Table 7-2 and **Table 7-3** summarize the responsible parties for delisted waterbody segments and waterbodies without current recreation beneficial use impairments. Responsible parties to these waterbody segments will only be responsible for implementing Tier 1 receiving water monitoring in accordance with **Section 7.2** to ensure that impairments are identified in the future. If these waterbodies are listed in the future, the other monitoring tiers and implementation requirements will become applicable.

Table 7-2. TMDL Responsible Parties for Delisted Waterbodies

Watershed	Waterbody	Segment or Area	Responsible Parties
San Joaquin Hills HSA (901.11) & Laguna Beach HSA (901.12)	Pacific Ocean Shoreline, San Joaquin Hills HSA	at Emerald Beach	City of Laguna Beach County of Orange Orange County Flood Control District South Orange County Wastewater Authority Caltrans Owners/operators of small MS4s
	Pacific Ocean Shoreline, Laguna Beach HSA	at Bluebird Canyon	City of Aliso Viejo County of Orange City of Laguna Beach City of Laguna Woods Orange County Flood Control District South Orange County Wastewater Authority Caltrans Owners/operators of small MS4s
		at Laguna Beach at Cleo Street	
		at Laguna Hotel	
		at Dumond Drive at Victoria Beach	
Aliso HSA (901.13)	Pacific Ocean Shoreline, Aliso HSA	at Aliso Beach north	City of Aliso Viejo City of Laguna Beach City of Laguna Hills City of Laguna Niguel City of Laguna Woods City of Lake Forest City of Mission Viejo County of Orange Orange County Flood Control District South Orange County Wastewater Authority Caltrans Owners/operators of small MS4s El Toro Water District
		At Blue Lagoon	
Dana Point HSA (901.14)	Pacific Ocean Shoreline, Dana Point HSA	at Dana Strands Surfzone at Dana Strands Rd.	City of Dana Point City of Laguna Beach City of Laguna Niguel County of Orange Orange County Flood Control District South Orange County Wastewater Authority Caltrans Owners/operators of small MS4s Moulton Niguel Water District South Coast Water District
		at South of Salt Creek Outlet at Salt Creek Service Rd.	
		at Table Rock Drive	
		at Thousand Steps Beach	
San Clemente HA (901.30)	Pacific Ocean Shoreline, San Clemente HA	at Capistrano Shores at North Ole Hanson Beach	City of San Clemente County of Orange Orange County Flood Control District South Orange County Wastewater Authority City of Dana Point Caltrans Owners/operators of small MS4s South Coast Water District
		at Riviera Beach	
		at San Clemente City Beach at Linda Lane	
		at San Clemente City Beach at Mariposa Lane	
		at San Clemente City Beach at South Trafalgar St. Beach	
		at San Clemente City Beach at Trafalgar Canyon Outlet	
San Dieguito HU (905.00)	Pacific Ocean Shoreline, San Dieguito HU	at San Dieguito Lagoon Mouth at Seascape Beach Park	City of Del Mar City of Escondido City of Poway City of San Diego City of Solana Beach County of San Diego Caltrans Owners/operators of small MS4s

Watershed	Waterbody	Segment or Area	Responsible Parties
			Rincon del Diablo Municipal Water District 22nd District Agricultural Association Controllable nonpoint sources San Diego County Sanitation District

Table 7-3. TMDL Responsible Parties for Watersheds Included in the TMDL, but with no Listed Segments for Recreation

Watershed	Waterbody	Responsible Parties
Batiquitos HSA (904.51)	Pacific Ocean Shoreline, Batiquitos HSA	City of Carlsbad City of Encinitas City of Escondido City of San Marcos County of San Diego Caltrans Buena Sanitation District Owners/operators of small MS4s Controllable nonpoint sources Carlsbad Municipal Water District Leucadia Wastewater District Olivenhain Municipal Water District Rincon del Diablo Municipal Water District San Diego County Sanitation District Vallecitos Water District Carlsbad Municipal Water District Leucadia Wastewater District Olivenhain Municipal Water District Rincon del Diablo Municipal Water District San Diego County Sanitation District Vallecitos Water District
Miramar Reservoir HA (906.10)	Pacific Ocean Shoreline Miramar Reservoir HA	City of Del Mar City of Poway City of San Diego County of San Diego Caltrans Owners/operators of small MS4s San Diego County Sanitation District

7.2 Monitoring Requirements

An essential component of implementation is water quality monitoring. Monitoring is needed to evaluate progress toward attainment of the TMDLs and protection of the beneficial uses in the receiving waters. Monitoring will serve several purposes. First, it will be used to evaluate receiving water quality for comparison to the TMDL numeric targets. Second, it will be used to trigger implementation actions focused on the reduction of human sources of bacteria. Third, it may be used to assess progress in reducing human sources of bacteria. Finally, monitoring data may be used to support removal of a waterbody from the 303(d) list. Monitoring will be used to assess compliance via one of the three compliance pathways shown in **Figure 7-2**. Each pathway requires collection of different types of monitoring data:

1. Pathway 1: FIB data
2. Pathway 2: FIB data and HF183 data

3. Pathway 3: Epidemiological study or QMRA and demonstration that bacteria sources for the receiving water are similar to waterbodies used for the epidemiological study/QMRA and FIB for trend evaluation

Because any of the pathways can be used for compliance, there is no requirement to collect all types of data. However, if the necessary data for a given pathway are not collected, that pathway cannot be used for compliance purposes until the required data are available.

The San Diego Water Board adopted Resolution No. 2012-0069 in December 2012 endorsing a report prepared by board staff entitled *A Framework for Monitoring and Assessment in the San Diego Region* (Regional Monitoring Framework). The Regional Monitoring Framework was written to outline an approach to monitoring in the San Diego Region, shifting from a discharge-oriented monitoring approach, focused on determining whether discharges are in compliance with regulatory requirements, to evaluating water body conditions, the sources of stressors causing unsatisfactory conditions, and the effectiveness of management actions to address those sources. The TMDL monitoring requirements were developed to be consistent with the Regional Monitoring Framework. The Regional Monitoring Framework complements modifications to the TMDL which focus on evaluating and reducing human health risk rather than focusing on simply quantifying bacteria loads in discharges.

The Regional Monitoring Framework identifies four categories of monitoring, each designed to answer specific questions:

- M1: Conditions Monitoring
    - Question: Are conditions protective of beneficial uses? For example, is water quality safe for swimming?
- M2: Stressor Identification Monitoring
    - Question: What are the primary stressors causing unsatisfactory conditions?
- M3: Source Identification Monitoring
    - Question: What are the major sources of the primary stressors?
- M4: Performance Monitoring
    - Question: Are management actions effective?

Monitoring questions specific to the TMDL follow a 4-tiered approach outlined in **Figure 7-3**. TMDL monitoring will include compliance monitoring at TMDL waterbodies and upstream monitoring aimed at assessing and eliminating high-risk human sources of bacteria. Monitoring data collected at high-use recreational locations will be used to assess attainment of the TMDL and will trigger assessment monitoring upstream if exceedances occur, in accordance with the compliance pathways in **Figure 7-2.**

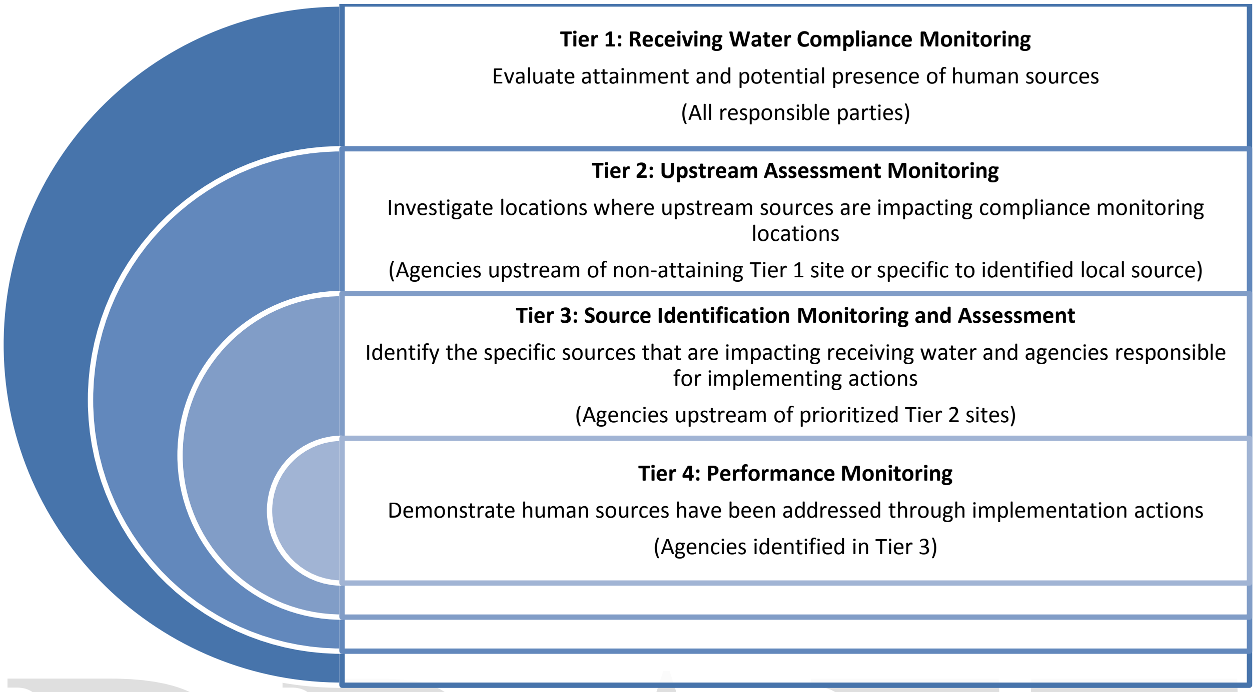

Figure 7-3. 4-Tiered Monitoring Approach

All responsible parties to the TMDL are responsible for participating in a monitoring program that meets the requirements of this section. Responsible parties shall submit a monitoring plan that includes procedures for implementing all monitoring tiers in accordance with the compliance schedule in Section 7.5. Responsible parties are encouraged to develop coordinated monitoring programs for all tiers of monitoring, with an acknowledgement that certain tiers (particularly Tiers 3 and 4) may need to vary based on the source or the responsible parties program (i.e., MS4s may need to approach source investigations differently than sanitary sewer agencies). The monitoring plan may cover the entire TMDL area, or separate monitoring plans may be developed for the hydrologic subareas listed in **Table 7-1**. Developing coordinated monitoring plans that include all responsible parties will result in consistent collection, analysis, reporting and follow-up in response to the monitoring by all responsible parties.

Tier 1 receiving water compliance monitoring will be conducted at delisted waterbodies included in the TMDL; however, Tiers 2, 3, and 4 monitoring will not be triggered for these waterbodies unless the waterbodies are listed on a future 303(d) list. Tier 1 monitoring is required for all compliance pathways, but Tiers 2, 3, and 4 are not required for compliance pathway 3.

7.2.1 Tier 1: Receiving Water Compliance Monitoring

The purpose of the Tier 1 monitoring is to assess the monitoring question: Is the water quality safe for swimming? The question will be assessed through collection and analysis of FIB at designated compliance monitoring locations for all compliance pathways. If compliance Pathway 2 is being considered, HF183 monitoring will be added at designated discharge monitoring locations. For compliance Pathway 3, enterococcus data should be collected at receiving water compliance locations to evaluate trends that would indicate potential changes in sources that would trigger a sanitary survey evaluation and support implementation actions, but the data will not be used for assessing compliance.

7.2.1.1 Selection of Receiving Water Compliance Monitoring Locations

In March 2017, the San Diego Water Board adopted a resolution supporting the use of key beneficial uses and key areas for prioritization of Water Board efforts. Key beneficial uses are the beneficial uses that are most critical to protecting human and environmental health. Key areas are the places where protection and restoration of the chemical, physical, and biological integrity of waters is most important for a key beneficial use. The key beneficial use/key area concept allows for prioritization of the work that contributes most to protection and restoration of the integrity, or health, of waters. Recreation has been identified as a key beneficial use for the Water Board and the key waterbodies identified for REC-1 were 1) Ocean 2) Mission Bay and 3) San Diego Bay and Dana Point Harbor. In the staff report for the resolution, Table 2 includes potential applications of the key beneficial uses/key areas concept that includes “inform decisions about which beneficial uses, places & parameters to focus on in monitoring and assessment of the status & trends of water body conditions”. The approach to selecting receiving water monitoring compliance locations is designed to focus on the key areas for the REC-1 beneficial use. In addition, the CBA demonstrated that costs are reduced without significant loss of benefit if compliance points are moved to beach locations downstream of the discharges to the beach. Moving compliance locations will reduce compliance costs as less exceedances will be observed due to dilution, and was determined not to contribute significantly to increased illness rates or loss of recreational opportunities. Recreational activity within creeks in the region is generally limited in the region, especially during wet weather conditions that can be hazardous. Observations of beachgoers after storms show that moving monitoring locations will be more representative of concentrations at points of exposure. Surfers are the predominant group of beachgoers after wet weather events. As surfing occurs offshore in the surf zone (region where waves break before they reach shore), it can be concluded that water contact recreation is unlikely to occur at point zero locations after wet weather events. This is evidenced by a recent Ocean Beach recreational study that indicated there were no head immersion activities observed in the lower San Diego River segment (Zone B) during the wet weather events studied (Baker, 2017).

To reflect the key beneficial uses document and the CBA, the receiving water compliance points for all listed beaches and creeks with a REC-1 beach at the coastal mouth, compliance monitoring is now moved to the beach downstream of the outfall or creek discharge location. For unique cases where creeks do not have a REC-1 beach downstream (e.g. Chollas Creek), monitoring will be conducted in the ocean (or bay) at a location outside the mixing zone for the creek discharge or in the creek above the tidal prism as appropriate.

Receiving water compliance monitoring locations for FIB will be defined to be representative of human health risk, and thus will be chosen at high recreational use locations, as appropriate. Beach segments identified in **Table 7-1** may be combined and one representative monitoring location determined if all segments are part of the same beach and one location can adequately represent the expected average exposure conditions for the other beach segments.

Under compliance Pathway 2, representative discharges corresponding to the FIB compliance monitoring location will be monitored for HF183 concurrently with compliance monitoring for FIB to determine if FIB exceedances are attributable to human sources. HF183 should be collected at a discharge location rather than at the FIB receiving water compliance monitoring location, as levels of the human marker can fluctuate near the limit of detection in saltwater receiving waters, often due to dilution. The HF183 monitoring location may be co-located if the receiving water is a freshwater waterbody.

Dischargers will have two options for analyzing the collected HF183 samples:

1) Sample and process for FIB and HF183 concurrently.
2) Sample and process for FIB only, store and archive samples for HF183 analysis and process only if deemed necessary (when FIB exceedances are observed at the beach).

Responsible parties may opt to filter and freeze discharge samples to preserve them until a later time. This provides the opportunity to evaluate if FIB at the beach is below the numeric targets, and to conserve monitoring resources. However, if exceedances do occur, archived samples can be thawed and processed for HF183 to determine if exceedances are due to human sources.

In either case, monitoring at the beach and discharge should be conducted so that the samples can be considered to be “paired”, that is, taken at the same time and date, to the extent practical. If preserved, samples can be filtered and archived (when properly stored) for up to one year.

7.2.1.2 Monitoring Frequency

At least two wet weather monitoring events should be conducted within 24 hours of the end of a storm event that occurs during the wet season (October 1 through April 30). Wet weather is defined as days with at least 0.1 inches of rainfall and the 72 hour period following the storm event. Dry weather, therefore, is defined as days with less than 0.1 inches of rainfall of each of the previous three days. Dry weather monitoring should occur at least on a monthly basis during the wet season, and weekly during the dry season (May 1 through September 30) when the REC- 1 beneficial uses occur most frequently at the beaches.

For delisted waterbodies, continue current monitoring frequency consistent with the delisted status.

7.2.2 Tier 2: Upstream Assessment Monitoring

Tier 2 upstream assessment monitoring is only required for compliance Pathways 1 and 2 if both targets and allocations are not being attained in a waterbody as shown in **Figure 7-2**. Tier 2 monitoring will utilize HF183 or another marker shown to be reliable for identifying human fecal contamination in discharges or creeks discharging near the beach compliance monitoring location to detect locations of human sources that may be impacting beach water quality. Tier 2 monitoring will be conducted under weather conditions that triggered assessment monitoring, i.e. if the trigger was met during wet weather compliance monitoring, then Tier 2 assessments would be conducted in wet weather. The locations identified in the Tier 2 monitoring with the highest HF183 concentrations will be identified for Tier 3 source identification monitoring.

Tier 2 assessment monitoring location selection should consider locations isolating contributions from sub-drainage areas, particularly areas with known human sources of bacteria, such as OWTS and homeless encampments.

Tier 2 assessments will be phased to allow for required follow-up Tier 3 source identification monitoring and implementation of the required actions to address identified sources. Tier 2 assessments have already been conducted for the Lower San Diego River, San Diego River Mouth at Dog Beach; the beach at Stub Jetty; South of the San Diego River outlet, near Cape May Avenue and Tourmaline Surf Park through the SHS. As part of the monitoring plan, the remaining waterbodies in the TMDL, for which exceedances of receiving water targets based on the procedures in Section 7.2.6, will be prioritized for Tier 2 assessment. The assessment schedule will result in all waterbodies that require Tier 2 assessments based on the compliance pathways being assessed within five years of the effective date of the TMDL. The prioritization schedule should include all waterbodies that have exceedances of receiving water targets at the time of development of the monitoring plan, but the need for Tier 2 monitoring will be determined after two years of receiving water monitoring based on the assessment in **Figure 7-2**. In developing the assessment schedule, the following factors should be considered:

- FIB and HF183 exceedance frequency and exceedance magnitude
- Risk to human health
- Presence of known human sources
- Implementation actions planned for the waterbody, including the potential to address human sources of bacteria through multi-pollutant control measures

The monitoring plan shall include a method for using the Tier 2 assessment monitoring results to determine if repeat assessment monitoring events or additional phases of assessment monitoring at additional locations are required to progress to Tier 3 monitoring.

If human sources of bacteria have already been identified and responsible parties are currently in the process of abating those sources, additional receiving water exceedances will not trigger further Tier 2 or Tier 3 monitoring until after the sources have been abated.

7.2.3 Tier 3: Source Identification Monitoring and Assessment

Source identification monitoring will attempt to identify the specific human sources of bacteria leading to downstream exceedances of human marker thresholds, and may be conducted following assessment monitoring or concurrently. However, source identification field efforts for wet weather sources may not necessarily need to be conducted during wet weather. The approach to identifying sources will likely include a combination of field assessments and desktop analysis of areas identified through Tier 2 assessment monitoring and may involve the following:

- Inspections, targeted monitoring or outreach based on probable high risk sources within the watershed:
  - Reported sanitary sewer leaks and overflows
  - Homeless population data
  - Locations with OWTS
  - Recreational areas
  - Areas of known sanitary sewer infrastructure issues
- Additional monitoring within the storm drain or sanitary systems
- Coordination with commerical and industrial inspection programs
- Coordination with sanitation agencies on leak detection and maintenance efforts

7.2.4 Tier 4: Performance Monitoring

After sources are identified, dischargers responsible for the identified sources will conduct implementation actions, as outlined in Section 7.4. Monitoring of the effectiveness of the implementation actions will primarily be based on the Tier 1 receiving water compliance monitoring. However, follow-up creek assessment or source identification monitoring may be conducted to demonstrate the source has been addressed if the compliance locations are still exceeding targets.

7.2.5 Sanitary Survey Assessment to Determine Applicability of Pathway 3

Compliance Pathway 3 differs from the first two pathways in that an epidemiological study or QMRA is utilized to demonstrate that human health risk is below the target thresholds. Waterbodies included in the SHS are considered to be in compliance using Pathway 3. However, the study results may be applicable to more waterbodies. To determine the applicability of a study conducted in a different waterbody, an assessment must be conducted to determine if the waterbodies contain similar sources and therefore have a similar risk level. The method for conducting this assessment will be a sanitary survey.

A sanitary survey is a method of investigating the sources of fecal contamination to a water body. The USEPA has published guidelines and tools for conducting sanitary surveys for marine waters (Marine Beach Sanitary Survey User Manual (USEPA, 2013)). The annual sanitary survey procedures outlined in the manual should be utilized for the assessment. The sanitary survey will be conducted by filling out the Annual Sanitary Survey form, which includes information on watershed and local sources, waterbody characteristics, and monitoring information. The following portions of the annual sanitary survey form will be used to assess the similarity of sources for application of Pathway 3:

- 2. Description of land use in the watershed
- 5. Bather load
- 6. Beach cleaning
- 11. Potential pollution sources
- 12. Description of sanitary facilities
- 13. Description of other facilities

These survey results will be analyzed to assess bacteria sources to determine if the results from an epidemiological or QMRA study demonstrating an acceptable level of human health risk are applicable to the waterbody in question.

7.2.6 Assessment of Monitoring Data

The methods discussed in this section will be used to compare monitoring data to the FIB and HF183 thresholds during compliance monitoring. FIB data will be assessed in comparison to numeric targets to determine compliance with Pathways 1 and 2 using the following methods.

7.2.6.1 Dry Weather

The process described in this section will be used for the purposes of evaluating data to assess attainment with the TMDL. During dry weather, seasonal geometric means for FIB concentrations will be calculated for comparison to the geometric mean numeric targets on an annual basis. The summer season dry weather geometric mean will be calculated using all dry weather samples collected during the period from May 1st through September 30th. Winter season dry weather geometric means will be calculated from additional dry weather samples collected between October 1st and April 30th. A minimum of five samples collected during the season are necessary to calculate the geometric mean. If an insufficient number of samples are collected for calculating a geometric mean, then samples will be compared to the STV. The waterbody will be considered to be attaining targets if less than 10% of the samples exceed the STV. The STV will not be used for the assessment if sufficient samples are available to calculate a geometric mean, as discussed in Section 3.

Under Pathway 1, if the FIB targets are met based on the assessment for both dry weather seasons, the waterbody is considered to be attaining targets for the year. If targets are not met during a season, the waterbody is not attaining targets for that season during dry weather.

Under Pathway 2, in addition to the FIB assessment, the dry weather HF183 results for samples exceeding the FIB targets will be compared to the HF183 assessment threshold. If less than 10% of the HF183 samples exceed the assessment thresholds during the season, the waterbody is considered to be attaining targets. Note: development of a dry weather H183 threshold value is currently being evaluated and may be incorporated to help support dry weather compliance assessments.

7.2.6.2 Wet Weather

Each year, all samples collected during wet weather will be compared to the STV target for assessment of attainment during wet weather conditions.

Under Pathway 1, the waterbody will be considered in attainment for the year if less than 22% (AEF) of samples collected during wet weather for the year exceed the STV numeric target.

Under Pathway 2, the waterbody will be considered in attainment for the year if less than 10% of paired FIB and HF183 samples exceed the STV and HF183 threshold, respectively.

7.3 Human Source Reduction Program

As discussed in Section 4, sewage collection systems, illicit connections, failing onsite wastewater treatment systems, transient encampments, vessel waste, and illegal discharges are all potential sources of human waste that can reach receiving waters. To protect human health, a goal of the TMDL is to reduce or eliminate discharges of human sources to receiving waters to the extent feasible. Development and implementation of a Human Source Reduction Program will target human sources for implementation and more effectively address human health risk. Human Source Reduction Programs can be developed by individual responsible parties or can be developed jointly for a waterbody.

The key elements to be included in a human source reduction program are:

- Identification of potential human sources
- Identification of existing strategies that are in place to address human sources and other sources of FIB
- Identification of strategies that could be implemented to address the potential human sources
- Prioritized schedule for implementation of strategies to address potential sources and commitment to maintain implementation of effective existing strategies.
- Optionally, a schedule and methods for conducting a study to identify human sources can be included.

For most of the responsible parties, the San Diego Water Board has identified required plans and implementation actions in the following section. These plans will be considered to be a Human Source Reduction Program if all the elements identified above are included in the plan unless other specific requirements are identified in the following section.

7.4 San Diego Water Board Actions

This section describes the actions the San Diego Water Board will take to implement the TMDLs using its authorities under the Porter-Cologne Water Quality Control Act (Division 7 of the Water Code), including incorporating discharge prohibitions into the Basin Plan, issuing individual or general WDRs, or issuing individual or general conditional waivers of WDRs.

The Bacteria TMDL assigned primary responsibility for monitoring and implementation of actions in response to the monitoring results to the Phase I MS4s. In response to those requirements, the Phase I MS4s conducted a number of studies (as described in Appendix B) to support identification of appropriate implementation actions. The results of those studies demonstrated that other sources are contributing to the human health risk in TMDL waterbodies. While Phase I MS4s have the ability and requirement to investigate and prevent discharges to and through their MS4, discharges of human sources to the MS4 from OWTS, collection systems, private laterals, and transients can be more effectively addressed by other agencies or through collaborative efforts. For most of these sources, MS4s are limited to identifying the problem and need to rely on other entities to address the identified source. Additionally, some of these sources discharge directly to receiving waters without passing through the MS4 and are completely outside their control.

As a result, this revised TMDL incorporates requirements for monitoring and follow-up actions for all responsible parties to the TMDL. The San Diego Water Board encourages responsible parties to work together to implement the monitoring requirements outlined in Section 7.2 and collaborate where appropriate on implementing follow-up actions to address identified human sources of bacteria. To support this collaboration, the San Diego Water Board will incorporate requirements into the applicable waste discharge requirements or utilize other regulatory authorities as appropriate to ensure all responsible parties:

1. Participate in the monitoring program.
2. Implement a human source reduction program
3. Implement actions to address identified human sources for which they are responsible when identified as part of the Tier 3 source identification monitoring

The following sections provide recommended approaches for incorporating the requirements listed above into the Phase I MS4 permit and suggestions of potential approaches for other responsible parties to the TMDL.

7.4.1 Basin Plan Waste Discharge Prohibitions

The San Diego Water Board may specify certain conditions or areas where the discharge of waste, or certain types of waste, is not permitted, known as "waste discharge prohibitions" in Chapter 4 of the Basin Plan. Waste discharge prohibitions can apply to any controllable sources, including point sources and nonpoint sources discharged to ground or surface waters. Basin Plan waste discharge prohibitions that are applicable to the implementation of these TMDLs include the following:

- The discharge of waste to the waters of the state in a manner causing, or threatening to cause a condition of pollution, contamination or nuisance as defined in Water Code section 13050, is prohibited.
- The discharge of waste to inland surface waters, except in cases where the quality of the discharge complies with applicable receiving water quality objectives, is prohibited. Allowances for dilution may be made at the discretion of the Regional Board. Consideration would include streamflow data, the degree of treatment provided and safety measures to ensure reliability of facility performance.
- The dumping, deposition, or discharge of waste directly into waters of the state, or adjacent to such waters in any manner which may permit being transported into the waters, is prohibited unless authorized by the Regional Board.
- Any discharge to a storm water conveyance system that is not composed entirely of "storm water" is prohibited unless authorized by the Regional Board. [The federal regulations, 40 CFR 122.26(b)(13), define storm water as storm water runoff, snow melt runoff, and surface runoff

and drainage. 40 CFR 122.26(b)(2) defines an illcit discharge as any discharge to a storm water conveyance system that is not composed entirely of storm water exempt discharges pursant to a NPDES permit and discharges resulting from fire fighting activities.] [Section 122.26 amended at 56 FR 56553, November 5, 1991; 57 FR 11412, April 2, 1992].

- The unauthorized discharge of treated or untreated sewage to waters of the state or to a storm water conveyance system is prohibited.

The existing Basin Plan prohibitions are consistent with the TMDLs, WLAs, and LAs. If necessary, the San Diego Water Board may amend the Basin Plan to revise current waste discharge prohibitions or include new waste discharge prohibitions.

7.4.2 Waste Discharge Requirements

The primary regulatory authority used by the San Diego Water Board to protect water resources and water quality in the San Diego Region is the issuance of WDRs. The San Diego Water Board can issue WDRs to any controllable point source or nonpoint source discharging waste to ground or surface waters of the state. WDRs impose conditions to protect water quality, implement the provisions of the Basin Plan, and when the discharge is to waters of the United States, meet the requirements of the Clean Water Act.

The San Diego Water Board will issue, or revise and re-issue, WDRs to point sources and/or nonpoint sources in the San Diego Region to be consistent with the TMDLs, WLAs, and LAs. Specific San Diego Water Board actions with regard to WDRs for point sources and nonpoint sources are discussed in the following subsections.

7.4.2.1 Point Sources

USEPA has delegated responsibility to the State and Regional Boards for implementation of the federal NPDES program which specifically regulates discharges of “pollutants” from point sources to “waters of the United States”. The San Diego Water Board regulates discharges from point sources to surface waters with WDRs that implement federal NPDES regulations (NPDES requirements).

The NPDES requirements may include numerical effluent limitations, when feasible, on the amounts of specified pollutants that may be discharged and/or specified best management practices (BMPs) designed to minimize water quality impacts. These numerical effluent limitations and BMPs or other non-numerical effluent limitations must implement both technology-based and water quality-based requirements of the Clean Water Act. Technology-based effluent limitations (TBELs) represent the degree of control that can be achieved by point sources using various levels of pollution control technology.

Although NPDES requirements must contain effluent limitations that are consistent with the assumptions and requirements of the TMDL WLAs, the federal regulations do not specifically require the effluent limitations to be identical to the WLAs. The regulations leave open the possibility that the San Diego Water Board could determine that fact-specific circumstances render something other than literal incorporation of the WLA to be consistent with the TMDL assumptions and requirements.

In order for the WDRs, NPDES requirements, and discharges from these point sources to be consistent with the TMDLs and WLAs, the San Diego Water Board will issue or revise and reissue the WDRs for these point sources as follows:

7.4.2.2 Phase I MS4s

The TMDLs and municipal MS4 WLAs, with respect to discharges from Phase I MS4s, will be implemented primarily by revising and re-issuing the existing NPDES requirements that have been issued for Phase I MS4 discharges.

In 2013, the San Diego Water Board issued new NPDES permit requirements for the MS4s that incorporated the Bacteria TMDL. The permit also incorporated a requirement to develop WQIPs. It is the expectation of the San Diego Water Board that the WQIPs will be utilized to meet Phase I MS4 responsible parties' obligation to develop a Human Source Reduction Program consistent with the requirements outlined in Section 7.3. During the first complete WQIP adaptive management cycle, but not less than 12 months after the effective date of the TMDL, Phase I MS4 responsible parties will modify their WQIPs consistent with the requirements in this section**,** including incorporation of strategies targeting the reduction of human bacteria sources. The proposed WQIP strategies should be selected from the management measures proposed in **Table 7-4**. Alternative management measures can be included in addition to those shown in **Table 7-4** subject to approval by the Executive Officer as part of the WQIP approval.

In addition, the San Diego Water Board will modify the TMDL requirements (Attachment E of the permit) to reflect the compliance structure provided in the implementation plan. The permit shall provide for final compliance with the TMDL to be determined through any of the following pathways:

(a) There is no direct or indirect discharge from the Responsible Copermittee's MS4s to the receiving water; OR
(b) TMDL targets are being attained in the receiving water at the compliance monitoring locations based on the assessment procedure in Section 7.2.6; OR
(c) Wasteload allocations are being attained at the Responsible Copermittee's MS4 outfalls; OR
(d) The pollutant load reductions for discharges from the Responsible Copermittees' MS4 outfalls are greater than or equal to the load reductions necessary to meet the wasteload allocations, as determined through an analysis in the WQIP per the procedures outlined in Section 6**;** OR
(e) The Responsible Copermittees can demonstrate that exceedances of the targets at the compliance monitoring locations are due to loads from non-human sources, AND human sources have been controlled from the MS4; OR
(f) The Responsible Copermittees can demonstrate that the risk to human health is less than 32 illnesses/1000 people, consistent with the USEPA 2012 criteria; OR
(g) The Responsible Copermittees develop and implement the Water Quality Improvement Plan that includes the elements described in this section:
    a. Strategies to address all identified human sources in the jurisdiction, as outlined in **Table 2-1** (or equivalent).
    b. Monitoring plan that contains all elements required in Section 7.2.
    c. Adaptive management program that specifies methods for modifying or adding strategies to address any human sources of bacteria contributing to receiving water exceedances within the jurisdiction.

Table 7-4. MS4 Strategy Options [a]

Proposed Category of Action	Strategy Options	Sources Addressed					
		Wastewater Collection Systems	Private Sewer Laterals	Failing OWTS	Direct Human Discharges	Other Human Sources	Non-human anthropogenic
Dry weather discharge controls	Identify priority areas and conduct proactive patrols to address irrigation runoff						X
	Continuous flow monitoring on priority drains with follow-up investigations when flows increase						X
	Escalating enforcement for observed discharges in violation of permit						X
IDDE program	Identify priority areas that could be vulnerable to human source contributions [b] to MS4 and follow-up inspections/studies and implementation of controls to address identified human sources	X	X	X			
	Leverage existing inspection programs to add evaluations of potential human sources and implement follow-up actions if sources identified	X	X	X	X	X	X
Human Source Targeted outreach/ inspection programs	Implement programs targeting RVs					X	
	Implement programs targeting septic pumpout services industry					X	
	Implement programs to ensure adequate restroom facilities are available in recreational areas				X		
	Provide outreach/incentives for maintaining private sewer laterals (e.g. City of San Diego private lateral insurance program partnership)	X					
Human Source Targeted Storm drain inspection and maintenance	Identify areas of known transient populations encamped within the MS4 footprint and implement clean ups of direct human discharges prior to rainy season				X		
	Ensure adequate cleanup procedures are in place to address sanitary sewer overflows that reach the MS4	X	X				
	Conduct inspections and cleanups as needed in areas or after large events where inadequate restroom facilities are available				X		
Coordination activities	Coordinate with water agencies to maintain drought programs/inspections						X
	Coordinate with owners of recreational areas to ensure adequate restroom facilities are available				X		

Proposed Category of Action	Strategy Options	Sources Addressed					
		Wastewater Collection Systems	Private Sewer Laterals	Failing OWTS	Direct Human Discharges	Other Human Sources	Non-human anthropogenic
	Coordinate with wastewater collection agencies to develop programs to minimize sanitary sewer discharges to MS4s	X					
	Coordinate with wastewater and collection agencies to implement investigative procedures when monitoring indicates the potential presence of human sources in discharges from the MS4	X	X	X			
	Consider methods for coordinating with and/or supporting wastewater agency with developing programs to reduce leakage and overflows from private sewer laterals [c]	X	X				
	Identifying opportunities within each jurisdiction to better coordinate water quality improvement activities	X		X			X
Studies	Conduct study to investigate potential contributions from failing on-site wastewater treatment systems and implement education/outreach, inspection, and repair/replacement program if found to be a significant source			X			
Implement Multi-pollutant structural BMPs as funding becomes available		X					X

a. Strategies included in the table may already be implemented at some level within the jurisdictions. To be incorporated in the WQIP as expanded actions to address the TMDL, the strategies will be implemented on a broader scale or in additional areas prioritized through the implementation process.

b. Priority areas would be determined through a GIS or other desktop analysis that identified locations of collection systems or private sewer laterals that may be more likely to contribute bacteria to the MS4 (older than 50 years, clay tile pipes, collection system pipes located above storm drain pipes, etc.).

c. Support/coordination could include activities such as, evaluating options for requirements for inspections during permit/plan checks that MS4 programs cover or supporting program to require inspections of private sewer laterals during change of ownership/property upgrades.

7.4.2.3 Phase II MS4s

The TMDLs and municipal MS4 WLAs, with respect to discharges from Phase II MS4s, will be implemented primarily by requiring compliance with the general WDRs and NPDES requirements that have been issued for Phase II MS4 discharges as modified to incorporate the TMDL provisions. Phase II MS4s are subject to regulation under the State Water Board general WDRs implementing NPDES requirements.

Under these general WDRs and NPDES requirements, Phase II MS4s are required to develop and implement a Stormwater Pollution Prevention Plan (SWPPP). The SWPPPs specify what BMPs will be used to address certain program areas. The program areas include public education and outreach; illicit discharge detection and elimination; construction and post-construction; and good housekeeping for municipal operations. Phase II MS4 dischargers will be required to incorporate BMPs addressing human sources of bacteria into their SWPPPs. Additionally, Phase II MS4s will be required to participate in the monitoring program, either through modifications of the general WDRs or a separate investigative order. SWPPPs that contain information to meet the requirements of Section 7.3 will be considered a Human Source Reduction Program.

Any owners and operators of Phase II MS4s not yet covered under the Phase II MS4 general WDRs will be required to submit a Notice of Intent to comply with the NPDES requirements in the State Water Board general WDRs as soon as possible. The San Diego Water Board will also request that the TMDL provisions be incorporated into the State Water Board general WDRs. Pathways for compliance with TMDLs will be consistent with those discussed in Section 7.1.1.

For any individual Phase II MS4s that are identified as a significant source of pollutants, the San Diego Water Board may also issue individual WDRs requiring the implementation of WQBELs that are consistent with the Municipal MS4 WLAs. Upon issuance of such individual WDRs by the San Diego Water Board, the State Water Board general WDRs for Phase II MS4s shall no longer regulate the affected individual Phase II MS4s.

Similarly, for any category of Phase II MS4s that are identified as a significant source of pollutants, the San Diego Water Board may issue general WDRs requiring the implementation of WQBELs that are consistent with the Municipal MS4 WLAs. Upon issuance of such general WDRs by the San Diego Water Board, the State Water Board general WDRs for Phase II MS4s shall no longer regulate the affected category of Phase II MS4s.

7.4.2.4 Caltrans

The TMDLs and Caltrans WLAs will be implemented primarily by revising and re-issuing the existing NPDES requirements that have been issued for Caltrans discharges.

Caltrans is regulated under a State Water Board WDR that implement NPDES requirements. Under these general WDRs and NPDES requirements, Caltrans is required to develop and implement a Stormwater Management Plan (SWMP). Caltrans will be required to incorporate procedures and practices to address human sources of bacteria in discharges to the storm drain system into the SWMP. The San Diego Water Board will request the State Water Board to revise and re-issue the WDRs and NPDES requirements to incorporate the TMDL provisions, including the pathways for compliance, consistent with Section 7.1.1. A SWMPs that contain information to meet the requirements of Section 7.3 will be considered a Human Source Reduction Program. Additionally, Caltrans will be required to participate in the monitoring program, either through modifications of the general WDRs or a separate investigative order.

7.4.2.5 Publicly Owned Treatment Works and Wastewater Collection Systems

Because POTWs and wastewater collection systems have been assigned WLAs of zero, no discharges of bacteria are expected or allowed under the wet weather TMDLs or dry weather TMDLs.

The TMDLs, with respect to discharges from POTWs and wastewater collection systems, will be implemented primarily by requiring compliance with any existing individual and/or general WDRs and NPDES requirements that have been issued. POTWs are subject to regulation under individual WDRs that implement NPDES requirements. Wastewater collection systems are subject to regulation under general WDRs issued by the State Water Board and San Diego Water Board. Individual WDRs for POTWs and/or the San Diego Water Board WDRs, for wastewater collection systems will be revised to require participation in monitoring activities consistent with Section 7.2. Required monitoring activities can be met by coordinating with other responsible parties.

Implementation of actions to eliminate sanitary sewer system leaks is supported by the Basin Plan's prohibition of discharges of raw sewage or any waste failing to meet waste discharge requirements to any waters of the region. In addition, a regulatory program is in place to address sanitary collection system releases, the Statewide General WDR for Sanitary Sewer Systems, WQ 2013-0058-EXEC. All public entities that own or operate sanitary sewer systems greater than one mile in length and that collect and/or convey untreated or partially treated wastewater to a publicly owned treatment facility in the State of California are required to apply for coverage under the WDR and comply with its requirements.

The WDR contains provisions for SSO prevention and reduction measures, including the following:

- Development and implementation of sanitary sewer system management plans (SSMPs)
- Prohibition of any SSO that results in a discharge of untreated or partially treated wastewater to waters of the United States, or creates a nuisance as defined in California Water Code Section 13050(m).
- Requirement for dischargers to take all feasible steps to eliminate SSOs and to properly manage, operate, and maintain all parts of the collection system.
- Requirement for a monitoring and reporting plan.

In short, sewer collection system authorities are responsible for finding and repairing leaks and overflows of sanitary waste, regardless of the existence of an applicable TMDL.

The San Diego Water Board will require responsible parties to amend their SSMPs (or other sewer collection system Operations and Maintenance Plans required by applicable permits or orders) as needed to prioritize the investigation and repair of faulty sewer pipes, pumps, and other infrastructure according to their proximity to the beach, the magnitude of leak or overflow risk, and similar considerations. The radii of initial and expanded implementation efforts are based on the likelihood of sewer leakage impacting the beach and are intended to focus efforts on those areas, while considering what is reasonably achievable by implementing agencies. One quarter mile of the beach refers to a quarter mile radius centered at the beach sampling location that has experienced the bacteria water quality objectives exceedances.

In order for the modified SSMP to be considered a Human Source Reduction Program for the purposes of this TMDL, it must include the elements included in Section 7.3 and incorporate strategies to address the following situations:

- Where publically owned portions of the sewer collection system have been shown to be in good repair and sewer-related sources of bacteria persist, strategies to address private sewer laterals will be incorporated into the SSMP. Private lateral replacement programs may be a necessary element in achieving the TMDL's numeric targets and may be required under adaptive implementation if beach water quality continues to exceed targets after SSOs and other major sources of bacteria have been minimized.

- Strategies to coordinate with inspectors for the municipal stormwater entity to identify cross-connections between sewer and storm water piping and take action to eliminate them, using effective methods such as tracers to identify and quantify sources of FIB as described in analyses by the Urban Water Resources Council (UWRRC, 2014) and the City of Santa Barbara (Izbicki et al., 2009).

7.4.2.6 Construction and Industrial Discharges

The TMDLs, with respect to construction activities and industrial dischargers, will be implemented primarily by requiring compliance with statewide general WDRs and NPDES permit requirements. Both the Construction and Industrial General Permits require dischargers to develop and implement Stormwater Pollution Prevention Plans (SWPPPs). Dischargers will be required to incorporate best management practices (BMPs) to address human sources of bacteria into their SWPPPs.

7.4.2.7 Concentrated Animal Feeding Operations

The TMDLs, with respect to discharges from CAFOs, will be implemented primarily by requiring compliance with any existing individual and/or general WDRs and NPDES requirements that have been issued. CAFOs that discharge to surface waters are subject to regulation under general WDRs that implement NPDES requirements.

If necessary, the general WDRs and NPDES requirements for CAFOs can be revised to require more aggressive monitoring, maintenance, and repair schedules to ensure discharges of bacteria loads from high risk sources, such as cattle, to surface waters are minimized and/or eliminated.

7.4.2.8 Other Unidentified Point Sources

The TMDLs, with respect to discharges from unidentified point sources to surface waters, will be implemented primarily by issuing WDRs implementing NPDES requirements with provisions to address human sources of bacteria in those discharges, or requiring the point sources to cease their discharges.

7.4.3 Nonpoint Sources

Unlike discharges from point sources to surface waters, discharges from nonpoint sources to surface waters are not subject to regulations under the federal Clean Water Act. Discharges from nonpoint sources, however, are subject to regulation under the California state Porter-Cologne Water Quality Control Act. The San Diego Water Board can regulate discharges from controllable nonpoint sources to surface waters with individual or general WDRs.

The persons identified as responsible for controllable nonpoint source discharges causing or contributing to impairments at the compliance locations include the owners and operators of the following:

- Agricultural facilities,
- Nurseries,
- Dairy/intensive livestock facilities,
- Horse ranches,
- Manure composting and soil amendment operations not regulated by NPDES requirements, and

- Individual septic systems

The California Non-Point Source Implementation and Enforcement Policy requires that controllable nonpoint sources be regulated via individual or general WDRs, conditional waivers of WDRs, or Basin Plan waste discharge prohibitions.

7.4.3.1 Commercial Agricultural Operations

The TMDLs, with respect to commercial agricultural operations, will be implemented primarily by requiring compliance with general WDRs adopted by the San Diego Water Board in November 2016. Two sets of WDRs were developed by the San Diego Water Board: one that applies to agricultural operations enrolled in Third-Party Group approved by the San Diego Water Board to assist members in carrying out the terms of the WDRs, and one that applies to agricultural operations that are not members of a Third-Party Group. The San Diego Water Board will incorporate LAs for agricultural dischargers into both orders as Surface Water Quality Benchmarks.

Under these WDRs, all individual dischargers are required to prepare and implement a Water Quality Protection Plan (WQPP) to identify the type and location of management practices to minimize or prevent discharge of waste to waters of the State. Dischargers will be required to incorporate management measures and practices into their WQPPs to address human sources of bacteria, as necessary.

If a Surface Water Quality Benchmark is exceeded, Third-Party Groups or individual agricultural operations not enrolled in a Third-Party Group are required to prepare a Water Quality Restoration Program Plan (WQRP) management practices being implemented or improved management practices that will be implemented to prevent or minimize the discharge of waste that is causing or contributing to the exceedance or trend of water quality degradation. Third-Party Groups will identify members suspected of causing or contributing to the exceedance, and will identify management practices to be implemented by designated members as necessary. The results of the source identification process as part of the regional monitoring program and additional or management practices addressing high-risk bacteria sources will be incorporated into WQRPs developed in response to exceedances of Surface Water Quality Benchmarks for bacteria. WQPPs or WQRPs that meet the requirements of Section 7.3 will be considered Human Source Reduction Programs.

7.4.3.2 Conditional Waivers of Waste Discharge Requirements

There are several types of point source, as well as nonpoint source discharges that may not have an adverse effect of the quality of waters of the state, and/or are not readily amenable to regulation under WDRs. For these types of discharge, the San Diego Water Board has the authority to issue conditional waivers of WDRs. The types of discharge which may be eligible for a waiver only include discharges to land and groundwater, and discharges to surface waters that are not otherwise subject to NPDES regulations. NPDES regulations are federal regulations, there are no federal or state regulations that allow NPDES regulations to be waived.

In general, the San Diego Water Board utilizes conditional waivers of WDRs to address discharges from controllable nonpoint sources, such as horse ranches, and dairies/intensive livestock. Currently, discharges from these controllable nonpoint sources may be eligible for one of the general conditional waivers of WDRs, which are provided in the Basin Plan. For controllable nonpoint sources identified as contributing to human health risk, the San Diego Water Board will amend the Basin Plan to incorporate measures to address high risk sources of bacteria from human and bovine sources into these conditional waivers of WDRs.

7.4.4 Delegation of Authority

Water Code section 13282 allows Regional Water Quality Control Boards to delegate regulatory authority for OWTS. For example, the San Diego Water Board has authorized the County of San Diego Department of Environmental Health to issue conventional OWTS permits throughout the County (DEH, 2010), however the authority to issue permits for unconventional OWTS systems that will have a subsurface discharge remains with the San Diego Water Board. The San Diego Water Board will require OWTS authorities to incorporate actions to address contamination of receiving waters into permits, including requiring proactive maintenance or routine inspections of OWTS.

7.4.5 Investigative Orders

The San Diego Water Board has the authority to require any state or local agency to investigate and report on any technical factors involved in water quality control or to obtain and submit analyses of water. The San Diego Water Board has the authority to require technical or monitoring program reports from persons who have discharged or are discharging waste that could affect the quality of the waters in the San Diego Region. The San Diego Water Board also has the authority to establish monitoring and recordkeeping requirements for discharges regulated under NPDES requirements.

The San Diego Water Board may issue an investigative order requiring all responsible parties to collaborate to develop and conduct regional monitoring plans as described in Section 7.2 or may include requirements in individual orders as they are modified.

7.4.6 TMDL Evaluation

The proposed implementation and compliance approach to the TMDL incorporates emerging science and information to target sources that are most likely to impact human health and recreational beneficial uses. As a result, a TMDL Evaluation has been included as an explicit part of the TMDL to ensure that the compliance structure and focus on human sources is sufficient to protect human health and recreational beneficial uses in the TMDL areas. While available information indicates that the proposed compliance structure is sufficient to protect recreational beneficial uses, additional ongoing studies and work may provide better mechanisms for assessing human health protection or determine that additional actions are needed to ensure waterbodies are safe to swim (e.g. addressing areas with large quantities of non-human sources).

The San Diego Water Board will initiate the TMDL evaluation within 5 years from the effective date of this Basin Plan amendment and complete the assessment within 7 years of the effective date. The results of the assessment will be utilized to determine if a TMDL modification is needed and if Phase II actions are required. Phase II actions will not be initiated prior to the San Diego Water Board issuing the findings of the TMDL evaluation and making any necessary modifications to the TMDL resulting from the findings that necessitate Phase II actions.

The San Diego Water Board will work with the project proponents to ensure that the data and documentation will be adequate for the TMDL evaluation. The San Diego Water Board will be responsible for taking the Basin Plan amendment project through the administrative and regulatory processes for adoption by the San Diego Water Board, and approval by the State Water Board, OAL, and USEPA.

7.4.7 Basin Plan Amendments

The TMDL includes a number of elements that may require the development of Basin Plan Amendments. The San Diego Water Board will develop Basin Plan Amendments as needed to address any or all of the following components:

- The numeric targets are based on the State Water Board's Bacteria Provisions. Should the State Water Board not adopt the Bacteria Provisions, the San Diego Basin Plan may need to be updated to reflect the revised water quality objectives proposed by the State Water Board.
- The TMDL incorporates provisions allowing the use of HFS and LFS/seasonal suspensions as authorized under the State Water Board's bacteria provisions. The San Diego Water Board will evaluate if Basin Plan Amendments are required to implement these provisions or if the bacteria provisions provide sufficient authorization assuming the technical requirements for developing the suspensions are approved by the Executive Officer.
- Designation of a waterbody with a Limited REC-1 beneficial use would require a Basin Plan Amendment.
- It is the intention of the TMDL to use the compliance pathways for evaluating attainment of waterbodies with water quality objectives and eventually delisting waterbodies. The San Diego Water Board will evaluate the Listing Policy to assess whether any Basin Plan Amendments are required to authorize use of the compliance pathways for making listing/delisting decisions.

Additionally, the San Diego Water Board may decide to modify water quality objectives, implementing procedures for water quality objectives, targets, allocations, or other aspects of the Basin Plan to reflect a focus on human health risk, rather than FIB. These modifications would necessitate a Basin Plan Amendment.

7.4.8 Other Actions

In addition to the regulatory authorities and actions that the San Diego Water Board can use to implement these TMDLs, the San Diego Water Board may take other actions to help the regulated community implement measures to comply with the regulatory actions above.

For these TMDLs, the San Diego Water Board shall recommend that the State Water Board assign a high priority to awarding grant funding[10] for projects to implement the bacteria TMDLs. Special emphasis will be given to projects that can achieve quantifiable bacteria load reductions consistent with the specific bacteria TMDLs, WLAs, and LAs.

Implementation of these TMDLs by the San Diego Water Board should not require any special studies to be conducted by the dischargers or other entities. The San Diego Water Board, however, will continue to encourage and support any special studies proposed and undertaken by the dischargers or other entities that will provide information to refine and improve the implementation of these TMDLs. This would include development of approved HFS/LFS thresholds and LREC-1 criteria for incorporation into the San Diego Basin Plan to enable identification of specific creeks (or creek segments) that may qualify under these provisions. The San Diego Water Board may develop agreements (e.g., a Memorandum of Understanding) with one or more entities to support and use the findings from any special studies that may be conducted. Proposing a special study project and initiating an agreement with the San Diego Water Board to use the results of the study to modify this TMDL Implementation Plan is the responsibility of the project proponent(s).

[10] The State Water Board administers the awarding of grants funded from Proposition 13, Proposition 50, Clean Water Act section 319(h) and other federal appropriations to projects that can result in measureable improvements in water quality, watershed condition, and/or capacity for effective watershed management. Many of these grant fund programs have specific set-asides for expenditures in the areas of watershed management and TMDL project implementation for non-point source pollution.

7.5 TMDL Compliance Schedule and Implementation Milestones

Phase I MS4s have been actively working to implement the TMDLs since the effective date in 2010. Implementation actions have included the development of comprehensive implementation plans that have been incorporated into WQIPs, source control activities to reduce dry weather runoff and control anthropogenic sources of bacteria, and source investigations to address human sources of bacteria. In particular, in response to the SHS, responsible parties undertook a watershed assessment to determine potential human sources of bacteria. In areas where large amounts of HF183 were found as part of the watershed assessment, responsible parties conducted follow-up source investigations and source remediation activities that led to significant reductions in the discharge of human sources of bacteria in the targeted areas. These efforts are continuing in the SHS watersheds.

The modifications made to the TMDL require an extension of the compliance schedule to account for regulatory changes in response to advancing scientific information, changes in the implementation actions and level of effort needed to address human sources, and new requirements for some responsible parties. A schedule extension is warranted for the following reasons:

1. The TMDL incorporates targets based on new water quality objectives that are more stringent (both in the risk level and FIB concentration) than the Bacteria TMDL.

2. The TMDL incorporates information on the latest science and modifies the focus of the TMDL from addressing all FIB to focusing on human sources of FIB. The switch in focus requires modifications to the implementation requirements for the MS4 dischargers and includes new and additional requirements for sanitary agencies.

3. The modified implementation requirements for the MS4 dischargers include additional monitoring and source abatement obligations that will take additional time to implement. The revised schedule has been developed in part to reflect the time that will be necessary to identify and abate human sources in the follow-up actions to the SHS as these are likely to be typical of the actions taken by the MS4s and other responsible parties to address human sources of bacteria.

4. Due to the focus on human sources, it is anticipated that addressing wastewater collection system infrastructure will be a component of the implementation actions required by the TMDL. As such, additional time is required for sanitary agencies to assess areas of concern and implement actions to address any identified infrastructure issues. Additionally, time is needed to set up structures that allow sanitary agencies to coordinate monitoring and follow-up source identification and abatement efforts consistent with Section 7.2 with other responsible parties.

5. Finally, the preliminary Financial Capability Analysis developed as part of the CBA demonstrates that the cost burden associated with the current TMDL exceeds USEPA-established affordability thresholds. Extending the schedule will allow responsible parties to reduce the financial burden on ratepayers to more affordable levels and provides a more cost-effective approach to achieving compliance.

The TMDLs are being established and implemented as phased TMDLs, consistent with USEPA guidance. Implementing the TMDL as a phased TMDL allows for adaptive management of the system based on the additional information gathered as part of TMDL implementation. Adaptive management is a structured iterative implementation process that offers flexibility for responsible parties to monitor implementation actions, determine the success of such actions and ultimately, base future management decisions upon the measured results of completed implementation actions and the current state of the system. This process enhances the understanding and estimation of predicted outcomes and ensures refinement of necessary activities to better guarantee desirable results. In this way, understanding of the resource can be enhanced over time, and management can be improved.

Adaptive management entails applying the scientific method to the TMDL. A National Research Council review of USEPA's TMDL program strongly suggests that the key to improving the application of science in the TMDL program is to apply the scientific method to TMDL implementation. For a TMDL, applying the scientific method involves 1) taking immediate actions commensurate with available information, 2) defining and implementing a program for refining the information on which the immediate actions are based, and 3) modifying actions as necessary based on new information.

The implementation effort can be divided into two phases for this TMDL, as described below:

Phase I consists of implementing actions to achieve compliance through one of the compliance pathways shown in **Figure 7-2** at the defined receiving water compliance locations. It is anticipated that this approach will provide protection of recreation beneficial uses for the waterbodies in the TMDL. However, because the proposed approach uses new techniques and focuses on the beaches, it is possible that modifications to the compliance pathways, assessment thresholds or compliance points may be necessary to ensure protection of beneficial uses in all TMDL waterbodies. A TMDL evaluation will be conducted after X years of implementation actions under Phase I to determine if additional actions are necessary that would require additional time to implement. If the TMDL evaluation confirms the approach and thresholds, the final compliance dates will be at the end of Phase I (Y years for dry weather and Z years for wet weather). If the TMDL evaluation results in modifications to the approach that require additional implementation actions or compliance locations in the creeks, the Phase II compliance schedules will become the final compliance date of the TMDL, unless modified by a Basin Plan Amendment. The phased TMDL schedule is shown in **Figure 7-4.**

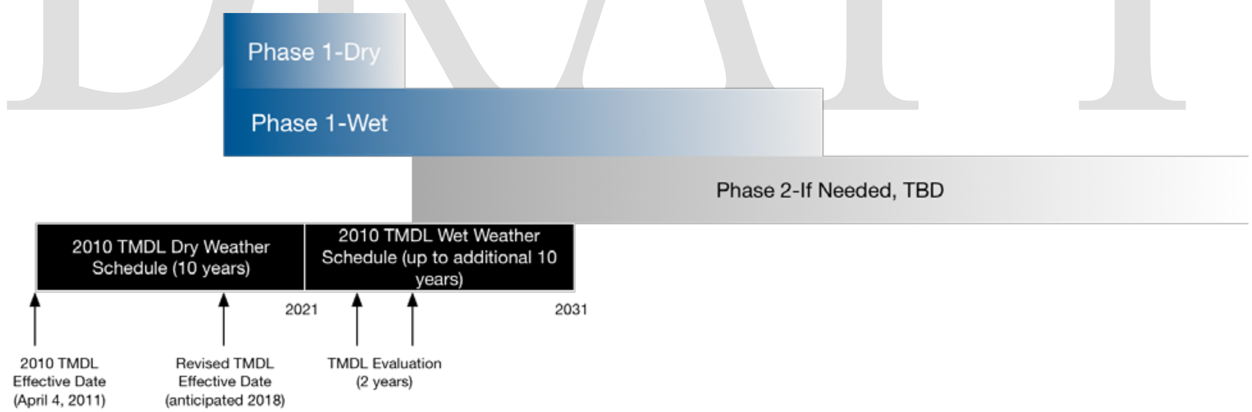

Figure 7-4. Phased Compliance Schedule (Dates to be filled in)

7.5.1 Implementation Milestones

Accomplishing the goals of the implementation plan will be achieved by cooperative participation from all responsible parties, including the San Diego Water Board. Major milestones are described in **Table 7-5**.

Table 7-5. TMDL Implementation Milestones (Dates to be filled in consistent with the phased schedule)

Item	Implementation Action	Responsible Parties	Date
1	Obtain approval of Beaches and Creeks Indicator Bacteria TMDLs from the State Water Board, OAL, and USEPA.	San Diego Water Board	
2	Issue investigative orders to all responsible parties requiring the development and implementation of monitoring programs acceptable to the Regional Board and consistent with Section 7.2 within 12 months of effective date.	San Diego Water Board	
3	Issue an investigative order to incorporate actions to address human sources of bacteria in SWMPs, SWPPPs and WQRPs to comply with TMDL requirements for Phase II, Caltrans, Construction, Industrial, and Irrigated Agricultural responsible parties.	San Diego Water Board	
4	Issue, reissue, or revise general WDRs and NPDES requirements for the Phase I MS4s to incorporate the requirements for complying with the TMDLs and MS4 WLAs.	San Diego Water Board	
5	Issue, reissue, or revise general WDRs and NPDES requirements for Phase II, Construction and Industrial permits to incorporate the requirements for complying with the TMDLs and WLAs.	San Diego Water Board, State Water Board	
6	Issue, reissue, or revise general WDRs and NPDES requirements for Caltrans to incorporate the requirements for complying with the TMDLs and Caltrans WLAs.	San Diego Water Board, State Water Board	
7	Issue, reissue, or revise the WDRs and NPDES requirements for POTWs and wastewater collection systems to incorporate new requirements for sewer line surveillance and maintenance, consistent with the zero WLA.	San Diego Water Board	
8	Modify WQIP to incorporate Phase I implementation actions and adaptive management program	Municipal Dischargers	
9	Submit an enhanced Sewer System Management Plan that prioritizes sewer system inspections and repairs in areas within 1⁄4 mile of beach or otherwise connected to the beach. Include a diagram of prioritized infrastructure, a time schedule for implementing short- and long-term plans, and, as necessary, a schedule for developing the funds needed for the capital improvement plan.	POTWs and wastewater collection system operators	
10	Complete inspections and repairs identified in enhanced SSMP	POTWs and wastewater collection system operators	
11	Prioritize watersheds for source assessment	Municipal Dischargers, Caltrans, Agriculture/Livestock Dischargers, POTWs and wastewater collection system operators	
12	Attain TMDL targets at receiving water compliance monitoring locations during dry weather using one of the compliance pathways shown in Figure 7-2	Municipal Dischargers, Caltrans, Agriculture/Livestock Dischargers, POTWs and wastewater collection system operators	
13	Attain TMDL targets at beach compliance monitoring locations during wet weather using one of the compliance pathways shown in Figure 7-2	Municipal Dischargers, Caltrans, Agriculture/Livestock Dischargers, POTWs and wastewater collection system operators	
14	Conduct TMDL Evaluation and determine need for Phase II	San Diego Water Board	

Item	Implementation Action	Responsible Parties	Date
15	Amend discharge conditions of appropriate waivers to be consistent with the requirements for complying with the TMDLs and Agriculture LAs.	San Diego Water Board	
16	Issue individual or general WDRs or Basin Plan prohibitions consistent with the TMDLs and LAs for controllable nonpoint source discharges not eligible conditional waivers.	San Diego Water Board	
17	Enroll Phase II MS4s identified as significant sources of bacteria to receiving waters under State Water Board general WDRs and NPDES requirements.	San Diego Water Board	
18	Issue individual or general WDRs and NPDES requirements consistent with the TMDLs and WLAs for specific Phase II MS4s or category of Phase II MS4s.	San Diego Water Board	
19	Amend the Basin Plan and/or provisions of these TMDLs based on the TMDL evaluation to trigger Phase II implementation actions	San Diego Water Board, Municipal Dischargers, Caltrans, Agriculture/Livestock Dischargers, POTWs and wastewater collection system operators	
20	Meet Phase II TMDL targets, if needed, at beach compliance monitoring locations during dry weather	Municipal Dischargers, Caltrans, Agriculture/Livestock Dischargers, POTWs and wastewater collection system operators	
21	Meet Phase II TMDL targets, if needed, at beach compliance monitoring locations during wet weather	Municipal Dischargers, Caltrans, Agriculture/Livestock Dischargers, POTWs and wastewater collection system operators	
22	Meet Phase II TMDL targets, if needed, at creek compliance monitoring locations during wet weather	Municipal Dischargers, Caltrans, Agriculture/Livestock Dischargers, POTWs and wastewater collection system operators	

Note the effective date = date of approval by OAL
Municipal Dischargers = Phase I and Phase II MS4s

8. References

Arnold, B.F., Schiff, K.C., Griffith, J.F., Gruber, J.S., Yau, V., Wright, C.C., Wade, T.J., Burns, S., Hayes, J.M., McGee, C., Gold, M., Cao, Y., Weiseberg, S.B. and J.M. Colford, 2013. Swimmer illness associated with marine water exposure and water quality indicators: Impact of widely used assumptions. *Epidemiology* 24(6): 845-53.

Arnold, B.F., Schiff, K.C., Ercumen, A., Benjamin-Chung, J., Steele, J.A., Griffith, J.F., Steinberg, S.J., Smith, P., McGee, C.D., Wilson, R., Nelsen, C., Weisberg, S.B. and Colford, J.M., Jr., 2017. Acute Illness Among Surfers After Exposure to Seawater in Dry- and Wet-Weather Conditions. *American Journal of Epidemiology*, 1-10.

Arnold, B.F., Wade, T.J., Benjamin-Chung, J., Schiff, K.C., Griffith, J.F., Dufour, A.P., Weisberg, S.B. and Colford, J.M., Jr., 2016. Acute Gastroenteritis and Recreational Water: Highest Burden Among Young US Children. *American Journal of Public Health* 106(9): 1690-1697.

Badgley B.D., Thomas F.I.M., Harwood, V.J. 2010. Quantifying environmental reservoirs of fecal indicator bacteria associated with sediment and submerged aquatic vegetation. *Environmental Microbiology* 13: 932 – 942.

Baker (Michael Baker International). 2017. Recreational Observations at Ocean Beach, San Diego after Rain Events. September 6, 2017. Prepared for the County of San Diego.

Boehm, A.B., Soller, J. and O. Shanks, 2015. Human-Associated Fecal Quantitative Polymerase Chain Reaction Measurements and Simulated Risk of Gastrointestinal Illness in Recreational Waters Contaminated with Raw Sewage. *Environmental Science & Technology Letters* 2(10): 270–275.

Brinton, W.F., Storms, P. and Blewett, C. 2009. Occurrence and levels of fecal indicators and pathogenic bacteria in market-ready recycled organic matter composts. *Journal of Food Protection* 72: 332-339.

Brown and Caldwell, 2005. Status Report of the Development of a Reporting Methodology for Subsurface Discharges of Sewage. Prepared for Orange County Sanitation District, September.

Byappanahalli, M., Fowler, M., Shively, D., and Whitman, R. 2003. Ubiquity and persistence of *Escherichia coli* in a Midwestern coastal stream. *Applied & Environmental Microbiology* 69: 4549-4555.

Byappanahalli, M., Roll, B.M., Fujioka, R.S. 2012. Evidence for Occurrence, Persistence, and Growth Potential of Escherichia coli and Enterococci in Hawaii's Soil Environments. *Microbes and Environments* 27: 164-170.

Cabelli, V.J., Dufour, A.P., McCabe, L.J. and M.A. Levin, 1982. Swimming-associated gastroenteritis and water quality. *American Journal of Epidemiology* 115(4): 606-616.

Cabelli, V.J. 1983. Health Effects Criteria for Marine Recreational Waters, Technical Report. U.S. Environmental Protection Agency, Health Effects Research Laboratory: Research Triangle Park, NC. EPA 600/1-80-031.

Calderon, R. L., Mood, E. W. and Dufour, A. P. 1991. Health effects of swimmers and nonpoint sources of contaminated water. *International Journal of Environmental Health Research* 1: 21–31.

Carroll, S. Goonetilleke, A., Thomas, E., Hargreaaves E., Frost, R., Dawes L. 2006. Integrated Risk Framework for Onsite Wastewater Treatment Systems. *Environmental Management* 38: 286 – 303.

CBA, 2017. Cost-Benefit Analysis San Diego Region Bacteria Total Maximum Daily Loads.

Center for Watershed Protection (CWP), 1999. Microbes and Urban Watersheds: Concentrations, Sources, & Pathways. *Watershed Protection Techniques* 3(1): 554-565.

CREST, 2008. Cleaner Rivers through Effective Stakeholder-led TMDLs. Los Angeles River Bacteria Source Identification Study: Final Report. November 2008.

City of San Diego, 2013. Work Plan for Tecolote Creek Quantitative Microbial Risk Assessment Study. December 2013.

Colford, J.M., Wade, T.M., Schiff, K.C., Wright, C.C., Griffith, J.F., Sukhminder, K.S., Burns, S.B., Hayes, J., Sobsey, M.D., Lovelace, G. and S.B. Weisberg, 2007. Water quality indicators and the risk of illness at beaches with nonpoint sources of fecal contamination. *Epidemiology* 18:27-35.

Corson, Chelsea M., "Transport Mechanisms for Human Fecal Indicator Bacteria in an Urban Stormwater Basin in Southeastern Wisconsin" (2015). Theses and Dissertations. 1045. http://dc.uwm.edu/etd/1045

County of San Diego Department of Environmental Health (DEH), 2010. Onsite Wastewater Treatment Systems Permitting Process and Design Criteria.

Davies, C.M., Long, J.A.H., Donald, M., and Ashbolt, N.J. 1995. Survival of fecal microorganisms in marine and fresh-water sediments. *Applied & Environmental Microbiology* 61: 1888-1896.

Devuono-powell, S. 2013. Homeless Encampments in Contra Costa County: A Report for the Contra Costa County Flood Control and Water Conservation District. Final Report. 2013.

Dickerson, J., Hagedorn, C., Hassal, A. 2007. Detection and remediation of human-origin pollution at two public beaches in Virginia using multiple source tracking methods. *Water Research* 41: 3758-3770.

Desmarais, T.R., Solo-Gabriele, H.M., and Plamer, C.J. 2002. Influence of soil on fecal indicator organisms in a tidally influenced subtropical environment. *Applied & Environmental Microbiology* 68: 1165-1172.

Dufour, AP., 1984. EPA Health Effects Criteria for Fresh Recreational Waters. United States Environmental Protection Agency, Toxicology and Microbiology Division, Cincinnati, OH, EPA-600/1-84-004.

Ervin, J., Van De Werfhorst, L., Holden, P. Arroyo Burro Beach Microbial Source Tracking Study. Undated. Conducted by the University of California Santa Barbara (UCSB) as part of the Source Identification Protocol Project (SIPP).

Ferguson D.M., Weisberg S.B., Hagedorn C., De Leon K., Mofidi V., Wolfe J., Zimmerman M., Jay J.A. 2016. Enterococcus growth on eelgrass (Zostera marina); implications for water quality. FEMS *Microbiology Ecology* 92: no. 4.

Field, R., Pitt, R., Lalor, M., Brown, M., Vilkelis, W., Phackston, E. 1994. Investigation of dry weather pollutant entries into storm drainage systems. *Journal of Environmental Engineering* 120(5): 1044–1066.

Field, K.G., and Samadpour, M. 2007. Fecal source tracking, the indicator paradigm, and managing water quality. *Water Research* 41: 3517-3538.

Griffith, J.F., Weisberg, S.B., Arnold, B.F., Cao, Y., Schiff, K.C. and J.M. Colford, Jr., 2016. Epidemiologic evaluation of multiple alternate microbial water quality monitoring indicators at three California beaches. *Water Research* 94: 371-381.

Griffith, J., D. Ferguson. 2012. San Diego County Enterococcus Regrowth Study. Final Report. SCCWRP. January 23, 2012.

Guerineau H., Dorner S., Carriere A., McQuaid N., Sauve A., Aboulfadl, K., Hajj-Mohamad M. Prevost M. 2014. Source tracking of leaky sewers: A novel approach combining fecal indicators in water and sediments. *Water Research* 58: 50 – 61.

Haile R.W., Witte J.S., Gold M., Cressey R., McGee C., Milikan R.C., Glasser A., Hatawa N., Ervin C., Harmon P., Harper J., Dermand J., Barrett K., Nides M., Wang G. 1999. *Epidemiology* 10: 355-363.

Harris, P. J. 1995. Water quality impacts from on-site waste disposal systems to coastal areas through groundwater discharge. *Environmental Geology* 26(4): 262-268

Harwood V., Staley C., Badgley B.D., Borges K., Korajkic A. 2014. Microbial source tracking markers for detecting of fecal contamination in environmental waters: relationships between pathogens and human health outcomes. *FEMS Microbiology Reviews* 38: 1-40.

Imamura G.J., Thompson R.S., Boehm A.B., Jay J.A. 2011. Wrack promotes the persistence of fecal indicator bacteria in marine sands and seawater. *FEMS Microbiology Ecology* 77: 40-49.

Ishii, S., Ksoll, W.B., Hicks, R.E., and Sadowsky, M.J. 2006. Presence and growth of naturalized *Escherichia coli* in temperate soils from Lake Superior watersheds. *Applied & Environmental Microbiology* 72: 612-621.

Izbicki, J., Swarzenski, P., Reich, C., Rollins, C., Holden, P. 2009. Sources of Fecal Indicator Bacteria in Urban Streams and Ocean Beaches, Santa Barbara, California. *Annals of Environmental Science* 3: 139-178.

Layton B.A., M.R. Raith, and J.F. Griffith. 2015. Use of dye tracers and qPCR to identify human fecal contamination at Doheny State Beach, Dana Point, CA. Southern California Coastal Water Research Project. Technical Report 860. Costa Mesa, CA. April 2015.

Lee, M. 2005. State set to tighten its septic tank rules. San Diego Tribune. August 23, 2005.

Lewis, D., E. Atwill, M. Lennox, L. Hou, B. Karle, and K. Tate. 2005. Linking on-farm dairy management practices to storm-flow fecal coliform loading for California coastal watersheds. *Environmental Monitoring and Assessment* 107: 407-425.

Liefenthaler, L., Stein, E., Schiff, K. 2011. Levels and patterns of fecal indicator bacteria in stormwater runoff from homogenous land use sites and urban watersheds. *Journal of Water and Health* 9: 279-90.

Los Angeles Regional Water Quality Control Board (LARWQCB), 2004. Malibu Watershed Bacteria TMDL.

LARWQCB, 2014. Recreation Use Reassessment (RECUR) of the Engineered Channels of the Los Angeles River Watershed. Part I: Background, Methods and Results Final Report.

Love, D.C., Rodriguez, R.A., Gibbons, C.D., Griffith, J.F., Stewart, J.R. and M.D. Sobsey, 2014. Human viruses and viral indicators in marine water at two recreational beaches in southern California, USA. *Journal of Water and Health* 12:136-150

Marsalek, J., and Rochfort, Q. 2004. Urban wet-weather flows: sources of fecal contamination impacting on recreational waters and threatening drinking-water sources. *Journal of Toxicology and Environmental Health*, Part A: Current Issues 67: 1765-1777.

McBride, G., Salmond, C., Bandaranayake, D., Turner, S., Lewis, G., Till, D. 1998. Health effects of marine bathing in New Zealand. *International Journal of Environmental Health Research* 8: 173-189.

McLellan, S.L., Daniels, A.D., and Salmore, A.K. 2003. Genetic characterization of *Escherichia coli* populations from host sources of fecal pollution by using DNA fingerprinting. *Applied & Environmental Microbiology* 69: 2587-2594.

McQuaig, S., Griffth, J., Harwood, V. 2012. Association of Fecal Indicator Bacteria with Human Viruses and Microbial source tracking markers at coastal beaches impacted by nonpoint source pollution. *Applied & Environmental Microbiology* 78(18): 6423-6432.

Paul, M.; Wolf, L.; Fund, K.; Held, I.; Winter, J.; Elswirth, M.; Gallert, C.; Hotzl, H. 2004. Microbiological condition of urban groundwater in the vicinity of leaky sewer systems. *CLEAN Soil, Water, Air.* 32(4-5): 351–360.

Power, M.L., Littlefield-Wyer, J., Gordon, D.M., Veal, D.A., and Slade, M.B. 2005. Phenotypic and genotypic characterization of encapsulated Escherichia coli isolated from blooms in two Australian lakes. *Environmental Microbiology* 7: 631-640.

Pruss, A, 1998. Review of epidemiological studies on health effects from exposure to recreational waters. *International Journal of Epidemiology* 27: 1-9.

RBF Consulting, 2003. Septic System Inventory and Assessment.

Riedel T.E., Thulsiraj, V., Zimmer-Faust, A.G., Dagit, R., Krug, J., Hanley, K.T., Adamek, K., Ebentier, D.L., Torres, R., Cobian, U., Peterson, S., Jay, J.A. 2015. Long-term monitoring of molecular markers can distinguish different seasonal patterns of fecal indicating bacteria sources. *Water Research* 71: 227 – 243.

Reeves, R., Grant, S., Mrse, R., Copil Oancea, C., Sanders, B., Boehm, A. 2004. Scaling and Management of Fecal Indicator Bacteria in Runoff from a Coastal Urban Watershed in Southern California. Environ. Sci. Technol. 38: 2637-2648.

Regional Task Force on the Homeless, 2017. 2017 WeALLCount Results, San Diego County. September 2017. http://www.rtfhsd.org/wp-content/uploads/2017/07/2017-PITC-Results-Powerpoint.pdf

Regional Task Force on the Homeless, 2017. 2017 WeALLCount Annual Report, San Diego County. September 2017. http://www.rtfhsd.org/wp-content/uploads/2017/07/comp-report-final.pdf

RWQCB, 2008. Total Maximum Daily Loads for Indicator Bacteria Baby Beach in Dana Point Harbor and Shelter Island Shoreline Park in San Diego Bay, Technical Report. California Regional Water Quality Control Board, San Diego Region.

RWQCB, 2010. Revised Total Maximum Daily Loads for Indicator Bacteria Project I – Twenty Beaches and Creeks in the San Diego Region (Including Tecolote Creek), Technical Report. California Regional Water Quality Control Board, San Diego Region. Resolution No. R9-2010-0001

Santa Monica Bay Beaches Bacterial TMDLs Coordinated Shoreline Monitoring Data (SMBBB CSM data). Provided by the City and County of Los Angeles.

Sauer, E.P., VandeWalle, J.L., Bootsma, M.J., McLellan, S.L., 2011. Detection of the human specific *Bacteroides* genetic marker provides evidence of widespread sewage contamination of stormwater in the urban environment. Water Research 45: 4081–4091.

SCCWRP, 2005. Microbiological Water Quality at Reference Beaches in Southern California During Wet Weather. Southern California Coastal Water Research Project. Technical Report 448. August 2005.

SCCWRP, 2006. Microbiological water quality at non-human impacted reference beaches in southern California during wet weather. Southern California Coastal Water Research Project. Technical Report 495. December 2006.

SCCWRP, 2007. Assessment of Water Quality Concentrations and Loads from Natural Southern California Coastal Water Research Project. Southern California Coastal Water Research Project. Technical Report 500. February 2007.

SCCWRP, 2008. Fecal Indicator Bacteria (FIB) Levels During Dry Weather from Southern California Reference Streams. Southern California Coastal Water Research Project. Technical Report 542. January 2008.

SCCWRP, 2014. Doheny State Beach Microbial Source Tracking Study, April.

SCCWRP, 2015. Wet and Dry Weather Natural Background Concentrations of Fecal Indicator Bacteria in San Diego, Orange, and Ventura County, California Streams. Southern California Coastal Water Research Program. Technical Report 862. June 2015.

SCCWRP, 2016a. The Surfer Health Study: A Three-Year Study Examining Illness Rates Associated with Surfing During Wet Weather. Southern California Coastal Water Research Project. Technical Report 943. September 2016.

SCCWRP, 2016b. Microbiological Water Quality at Reference Beaches and an Adjoining Estuary in Southern California during a Prolonged Drought. Southern California Coastal Water Research Project. Technical Report 963. July 2016.

Schiff, K., J. Griffith, G. Lyon. 2005. Microbiological Water Quality at Reference Beaches in Southern California during Wet Weather. Southern California Coastal Water Research Project. Technical Report 448.

Schoen, M.E., and Ashbolt, N.J., 2010. Assessing Pathogen Risk to Swimmers at Non-Sewage Impacted Recreational Beaches. *Environmental Science & Technology* 44(7): 2286-2291.

Schoen, M.E., Soller, J., Ashbolt, N. 2011. Evaluating the importance of fecal sources in human-impacted waters. *Water Research* 45: 2670-2680.

Sercu, B., Van De Werfhorst, L., Murray, J., Holden P. 2011. Sewage Exfiltration as a Source of Storm Drain Contamination during Dry Weather in Urban Watersheds. *Environmental Science & Technology* 45 (17): 7151–7157.

Sercu, B., Van De Werfhorst, L., Murray, J., Holden P. 2009. Storm Drains are Sources of Fecal Pollution during Dry Weather in Three Urban Southern California Watersheds. *Environmental Science & Technology* 43: 293-298.

Sieyes N.R., Yamahara K.M., Layton B.A., Joyce E.H., Boehm A.B. 2008. Submarine discharge of nutrient-enriches fresh groundwater at Stinson Beach, California is enhanced during neap tides. *Limnology Oceanography* 53: 1433-1445.

Skinner, J., J. Guzman, and J. Kappeler. 2010. Regrowth of enterococci and fecal coliform in biofilm: studies of street gutters and storm drains in Newport Beach, CA suggest causes for high bacteria levels. Stormwater July/August: 28-34.

Soller, J.A., Bartrand, T., Ashbolt, N.J., Ravenscroft, J., Wade, T.J. 2010a. Estimating the Primary Etiologic Agents in Recreational Fresh waters Impacted by Human Sources of Fecal Contamination. *Water Research* 44(16): 4736–4747.

Soller, J., Schoen, M.E., Bartrand, T., Ravenscroft, J., Wade, T.J. 2010b. Estimated Human Health Risks from Exposure to Recreational Waters Impacted by Human and Non-human Sources of Fecal Contamination. *Water Research* 44(16): 4674–4691.

Soller, J., Bartrand, T., Ravenscroft, J., Molina, M. Whelan, G., Schoen, M. and Ashbolt, N. 2015. Estimated human health risks from recreational exposures to stormwater runoff containing animal faecal material. *Environmental Modeling & Software* 72: 21-32.

Soller, J.A., Schoen, M., Steele, J.A., Griffith, J.F. and Schiff, K.C. 2017. Incidence of gastrointestinal illness following wet weather recreational exposures: Harmonization of quantitative microbial risk assessment with an epidemiologic investigation of surfers. *Water Research* 121: 280-289.

Soller J., Schoen ME, Varghese A, Ichida AM, Boehm AB, Eftim S, Ashbolt NJ, Ravenscroft JE, 2014. Human health risk implications of multiple sources of faecal indicator bacteria in a recreational waterbody. *Water Research* 1(66): 254-64.

Stein, E.D. and V.K. Yoon. 2007. Assessment of Water Quality Concentrations And Loads From Natural Landscapes. Southern California Coastal Water Research Project. Technical Report 500.

Stein, E. D., L. L. Tiefenthaler and K. C. Schiff. 2007. Sources, Patterns and Mechanisms of Stormwater Pollutant Loading from Watersheds and Land Uses of the Greater Los Angeles Area, California, USA. Southern California Coastal Water Research Project. Technical Report 510.

Stein, E.D., L.L. Tiefenthaler, and K.C. Schiff. 2008. Comparison of stormwater pollutant loading by land use type. pp. 15-27 in: S.B. Weisberg and K. Miller (eds.), Southern California Coastal Water Research Project 2008 Annual Report.

Stevenson, A.H, 1953. Studies of Bathing Water Quality and Health. *American Journal of Public Hlth. Association* 43:259.

Stewart, J.R., Boehm, A.B., Dubinsky, E.A., Fong, T.T., Goodwin, K.D., Griffith, J.F., Noble, R.T., Shanks, O.C., Vijayavel, K., and S.B. Weisberg, 2013. Recommendations following a multi-laboratory comparison of microbial source tracking methods. *Water Research* 47(18):6829-38.

SWRCB, 2017, Draft Staff Report, Including Substitute Environmental Documentation for Part 3 of the Water Quality Control Plan for Inland Surface Waters, Enclosed Bays, and Estuaries of California-Bacteria Provisions and a Water Quality Standards Variance Policy and Amendment to the Water Quality Control Plan for Ocean Waters of California-Bacteria Provisions and a Water Quality Standards Variance Policy. Draft Report. State Water Resources Control Board. June, 2017.

Tiefenthaler, L. L., S. E.D. and G. S. Lyon. 2008. Fecal Indicator Bacteria (FIB) Levels During Dry Weather from Southern California Reference Streams. Southern California Coastal Water Research Project. Technical Report 542.

Tiefenthaler, L., M Sutula, Y Cao, J Griffith, M Raith, C Beck, R Christoph, J Shrake. 2015. Wet and Dry Weather Natural Background Concentrations of Fecal Indicator Bacteria in San Diego, Orange, and Ventura County, California Streams. Southern California Coastal Water Research Project. Technical Report 862.

Underground Service Company and Electro Scan, 2015. Sanitary Sewer Investigation Baby Beach. Prepared with assistance from County of Orange, Public Works.

USEPA, 1994. Protecting Coastal Waters from Vessel and Marina Discharges: A Guide for State and Local Officials. United States Environmental Protection Agency, Office of Water. EPA 842-B-94-004.

USEPA, 2009. Review of Zoonotic Pathogens in Ambient Waters. U.S. Environmental Protection Agency, Office of Water, Health and Ecological Criteria Division, Washington, D.C. (Report EPA 822-R-09-002).

USEPA, 2010a. Report on 2009 National Epidemiologic and Environmental Assessment of Recreational Water Epidemiology Studies. United States Environmental Protection Agency, Office of Research and Development. (EPA Report Number EPA-600-R-10-168, 2009).

USEPA, 2010b. Quantitative Microbial Risk Assessment to Estimate Illness in Fresh water Impacted by Agricultural Animal Sources of Fecal Contamination. United States Environmental Protection Agency. EPA 822-R-10-005.

USEPA, 2011. Report of the Experts Scientific Workshop on Potential Human Health Risks from Exposure to Fecal Contamination from Avian and other Wildlife Sources in Recreational Waters. Report, December 21, 2011. United States Environmental Protection Agency, Office of Water.

USEPA, 2012. Recreational Water Quality Criteria. U.S. Environmental Protection Agency, Office of Water. Washington D.C. (EPA 820-F-12-058, 2012).

USEPA, 2013. Marine Beach Sanitary Survey User Manual. U.S. Environmental Protection Agency, Office of Water. Washington D.C. (EPA 820-B-13-001, March 2013).

USEPA, 2014a. Overview of Technical Support Materials: A Guide to the Site-Specific Alternative Recreational Criteria TSM Documents (EPA-820-R-14-010, December 2014).

USEPA, 2014b. Site-Specific Alternative Recreational Criteria Technical Support Materials for Alternative Indicators and Methods (EPA-820-R-14-011, December 2014).

USEPA, 20145. Review of Coliphages as Possible Indicators of Fecal Contamination for Ambient Water Quality. (EPA-820-R-15-098, April 2015).

Urban Water Resources Research Council (UWRRC), 2014. Pathogens in Urban Stormwater Systems. Prepared by Urban Water Resources Research Council Pathogens in Wet Weather Flows Technical Committee, Environmental and Water Resources Institute, American Society of Civil Engineers, August.

Wade, T. J., Pai, N., Eisenberg, J. N. S. and Colford, J. M. 2003. Do U.S. Environmental Protection Agency water quality guidelines for recreational waters prevent gastrointestinal illness? A systematic review and meta-analysis. Environmental Health Perspectives: 111: 1102-1109.

Water Environment Research Federation (WERF), 2011. Final Report: Quantification of Pathogens and Sources of Microbial Indicators for QMRA in Recreational waters. PATH2R08.

Weston Solutions, 2010. Tecolote Creek Microbial Source Tracking Summary: Phases I, II, and III. Prepared for the City of San Diego Storm Water Department.

Weston Solutions, 2013. Poche Beach Bacterial Source Identification Study, Final Report. Prepared for the City of San Clemente Public Works Department, June.

Wuertz, S., Wang D., Reischer G.H., Farnleitner A.H. Library-independent source tracking methods. In: Hagedorn C., Blanch A.R., Harwood V.J., editors. Microbial Source Tracking: Methods, Applications, and Case Studies. Springer; New York, USA: 2011. pp. 61–113.

Yamahara, K. M., S.P. Walters, and A.B. Boehm. 2009. Growth of enterococci in unaltered, unseeded beach sands subjected to tidal wetting. *Applied & Environmental Microbiology* 75: 1517-1524.

Zaleski, K.J., Josephson, K.L., Gerba, C.P. and Pepper, I.L. (2005) Potential regrowth and recolonisation of salmonellae and indicators in biosolids and biosolid-amended soil. *Applied & Environmental Microbiology* 71(7): 3701-3708.

Zmirou, D., Pena, L., Ledrans, M. and Letertre, A. 2003. Risks associated with the microbiological quality of bodies of fresh and marine water used for recreational purposes: summary estimates based on published epidemiological studies. *Archives of Environmental Health*, 58(11): 703–711.

Appendix A. 303(d) Listing Status Progression of TMDL Waterbodies

Table A-1. Progression of 303(d) Listed Waterbodies

Watershed	Waterbody	2002 Noted areas of impairment (Indicator Bacteria) [2]	2006 Noted areas of impairment (Indicator Bacteria) [2]	2010 303(d) List			2014 303(d) List		
				Segment [2]	2010 Listing Status	2010 Listed Constituents	Segment	2014 Listing Status	2014 Listed Constituents
San Joaquin Hills HSA (901.11)/ Laguna Beach HSA (901.12)	Pacific Ocean Shoreline, San Joaquin Hills HSA	Cameo Cove at Irvine Cove Dr.	Cameo Cove at Irvine Cove Dr.						
		Riviera Way Heisler Park North[1]	Riviera Way Heisler Park North						
				at Crescent Bay Beach	Delisted				
				at Emerald Beach	Not listed				
	Pacific Ocean Shoreline, Laguna Beach HSA	Laguna Beach at Ocean Ave[1]	Laguna Beach at Ocean Ave						
		Laguna Beach at Laguna Ave	Laguna Beach at Laguna Ave						
		Laguna Beach at Cleo St[1]	Laguna Beach at Cleo St	at Laguna Beach at Cleo Street	Delisted				
		Arch Cove at Bluebird Canyon Road[1]	Arch Cove at Bluebird Canyon Road	at Bluebird Canyon	Delisted				
				at Laguna Hotel	Delisted				
		Laguna Beach at Dumond Dr.[1]	Laguna Beach at Dumond Dr.	at Dumond Drive at Victoria Beach	Delisted				
							at Broadway Creek	Listed (new)	Indicator Bacteria
		Main Laguna Beach[1]	**Main Laguna Beach**	**at Main Beach**	**Listed**	**Total Coliform**	**at Main Beach**	**Delisted**	
Aliso HSA (901.13)	**Aliso Creek**	**Aliso Creek[1]**	**Aliso Creek**	**Aliso Creek**	**Listed**	**Indicator Bacteria**	**Aliso Creek**	**Listed**	**Indicator Bacteria**
	Aliso Creek mouth	**Aliso Creek mouth[1]**	**Aliso Creek mouth**	**Aliso Creek mouth**	**Listed**	**Indicator Bacteria**	**Aliso Creek mouth**	**Listed**	**Indicator Bacteria**
	Pacific Ocean Shoreline, Aliso HSA			**at Aliso Beach middle**	**Listed**	**Enterococcus, Total Coliform (SHELL)**	**at Aliso Beach middle**	**Listed**	**Indicator Bacteria**
				at Aliso Beach north	Delisted				
				at Aliso Creek mouth	**Listed**	**Enterococcus, Total Coliform, Fecal Coliform**	**at Aliso Creek mouth**	**Listed**	**Indicator Bacteria**
		Laguna Beach at Lagunita Place/ Blue Lagoon Place at Aliso Beach[1]	Laguna Beach at Lagunita Place/ Blue Lagoon Place at Aliso Beach[1]	at Blue Lagoon	Delisted				

Watershed	Waterbody	2002 Noted areas of impairment (Indicator Bacteria) [2]	2006 Noted areas of impairment (Indicator Bacteria) [2]	2010 303(d) List			2014 303(d) List		
				Segment [2]	2010 Listing Status	2010 Listed Constituents	Segment	2014 Listing Status	2014 Listed Constituents
Dana Point HSA (901.14)	**Pacific Ocean Shoreline, Dana Point HSA**			at Aliso Beach South	Not Listed				
		Aliso Beach at West St.[1]	**Aliso Beach at West St.**	**at Aliso Beach at West St.**	**Listed**	**Indicator Bacteria**			
				at Camel Point	Not listed				
		Salt Creek Beach at Dana Strands Rd.	Salt Creek Beach at Dana Strands Rd.	at Dana Strands Surfzone at Dana Strands Rd.	Delisted				
				at Laguna Lido	Not listed				
				at Salt Creek outlet at Monarch Beach	Listed (SHELL)	Indicator Bacteria	at Salt Creek outlet at Monarch Beach	Listed (new for REC-1)	Indicator Bacteria
		Salt Creek Beach at Salt Creek service road[1]	Salt Creek Beach at Salt Creek service road	at South of Salt Creek Outlet at Salt Creek Service Rd.	Delisted				
		Salt Creek outlet[1]	Salt Creek outlet						
		Aliso Beach at Table Rock Drive[1]	Aliso Beach at Table Rock Drive	at Table Rock Drive	Delisted				
		1000 Steps Beach at PCH[1]	1000 Steps Beach at PCH	at Thousand Steps Beach	Delisted				
				Dana Point Harbor at Baby Beach[1]	**Listed**	**Enterococcus, Total Coliform (SHELL)**	**Dana Point Harbor at Baby Beach**	**Listed**	**Indicator Bacteria**

Watershed	Waterbody	2002 Noted areas of impairment (Indicator Bacteria) [2]	2006 Noted areas of impairment (Indicator Bacteria) [2]	2010 303(d) List			2014 303(d) List		
				Segment [2]	2010 Listing Status	2010 Listed Constituents	Segment	2014 Listing Status	2014 Listed Constituents
Lower San Juan HSA (901.27)	San Juan Creek	San Juan Creek[1]	San Juan Creek	San Juan Creek	Listed	Indicator Bacteria	San Juan Creek	Listed	Indicator Bacteria
	San Juan Creek mouth	San Juan Creek mouth[1]	San Juan Creek mouth	San Juan Creek mouth	Listed	Indicator Bacteria	San Juan Creek (mouth)	Listed	Indicator Bacteria
	Pacific Ocean Shoreline, Lower San Juan HSA	Capistrano Beach	Capistrano Beach[1,3]						
		South Capistrano Beach at Beach Rd.	South Capistrano Beach at Beach Rd.[1,3]						
							1000 feet south of outfall	Listed (new)	Indicator Bacteria
							2000 feet south of outfall	Listed (new)	Indicator Bacteria
							3000 feet south of outfall	Listed (new)	Indicator Bacteria
							4000 feet south of outfall	Listed (new)	Indicator Bacteria
							5000 feet south of outfall	Listed (new)	Indicator Bacteria
							7500 feet south of outfall	Listed (new)	Indicator Bacteria
							10000 feet south of outfall	Listed (new)	Indicator Bacteria
							at surfzone outfall at Doheny State Beach	Listed (new)	Indicator Bacteria
		North Beach Creek	North Beach Creek	at North Beach Creek	Listed	Enterococcus, Total Coliform (SHELL), Fecal Coliform	at North Beach Creek	Listed	Indicator Bacteria
				at North Doheny State Park Campground	Listed	Enterococcus, Total Coliform (SHELL)	at North Doheny State Park Campground	Listed	Indicator Bacteria
		San Juan Creek outlet[1]	San Juan Creek outlet	at San Juan Creek	Listed	Enterococcus, Total Coliform, Fecal Coliform	at San Juan Creek	Listed	Indicator Bacteria
				at South Doheny State Park Campground	Listed	Enterococcus	at South Doheny State Park Campground	Listed	Indicator Bacteria

Watershed	Waterbody	2002 Noted areas of impairment (Indicator Bacteria) [2]	2006 Noted areas of impairment (Indicator Bacteria) [2]	2010 303(d) List			2014 303(d) List		
				Segment [2]	2010 Listing Status	2010 Listed Constituents	Segment	2014 Listing Status	2014 Listed Constituents
San Clemente HA (901.30)	**Pacific Ocean Shoreline, San Clemente HA**	San Clemente City Beach at El Portal St. Stairs[1]	San Clemente City Beach at El Portal St. Stairs,						
		San Clemente City Beach at South Linda Lane[1]	San Clemente City Beach at South Linda Lane,						
		San Clemente State Beach at Cypress Shores[1]	San Clemente State Beach at Cypress Shores						
		San Clemente City Beach at Lifeguard Headquarters[1]	San Clemente City Beach at Lifeguard Headquarters						
		Ole Hanson Beach Club Beach at Pico Drain[1]	Ole Hanson Beach Club Beach at Pico Drain	at Capistrano Shores at North Ole Hanson Beach	Delisted				
		Poche Beach[1]	**Poche Beach**	**at Poche Beach**	**Listed**	**Enterococcus, Total Coliform (SHELL)**	**at Poche Beach**	**Listed**	**Indicator Bacteria**
		San Clemente State Beach at Riviera Beach[1]	San Clemente State Beach at Riviera Beach,	at Riviera Beach	Delisted				
		San Clemente City Beach at Linda Lane[1]	San Clemente City Beach at Linda Lane	at San Clemente City Beach at Linda Lane	Delisted				
		San Clemente City Beach at Mariposa St.[1]	San Clemente City Beach at Mariposa St.	at San Clemente City Beach at Mariposa Lane	Delisted				
		San Clemente City Beach Under San Clemente Municipal Pier[1]	**San Clemente City Beach Under San Clemente Municipal Pier**	**at San Clemente City Beach at Pier**	**Listed**	**Enterococcus**	**at San Clemente City Beach at Pier**	**Listed**	**Indicator Bacteria**
				at San Clemente City Beach, 450 ft North of Pier	Not listed				
				at San Clemente City Beach at Projection of Las Palmeras	Not listed				
				at San Clemente City Beach at South Trafalgar St. Beach	Delisted				
				at San Clemente City Beach at Trafalgar Canyon Outlet	Delisted				
				at San Clemente City Beach, North Beach	Listed (SHELL)	Total Coliform	at San Clemente City Beach, North Beach	Listed (SHELL)	Indicator Bacteria
				at San Clemente City Beach at Trafalgar Street Beach	Not listed				

Watershed	Waterbody	2002 Noted areas of impairment (Indicator Bacteria) [2]	2006 Noted areas of impairment (Indicator Bacteria) [2]	2010 303(d) List			2014 303(d) List		
				Segment [2]	2010 Listing Status	2010 Listed Constituents	Segment	2014 Listing Status	2014 Listed Constituents
				at San Clemente State Beach at Projection of Avenida Calafia	Not listed				
				at South Capistrano Beach at Beach Road [3]	**Listed**	**Enterococcus**	**at South Capistrano Beach at Beach Road**	**Listed**	**Indicator Bacteria**
				at South Capistrano County Beach [3]	**Listed**	**Enterococcus, Total Coliform (SHELL)**	**at South Capistrano County Beach**	**Listed**	**Indicator Bacteria**
				at South Poche Beach at Capistrano Shores	Not listed				
San Luis Rey HU (903.00)	**Pacific Ocean Shoreline, San Luis Rey HU**	**at San Luis Rey River mouth[1]**	**at San Luis Rey River Mouth**	**at San Luis Rey River Mouth**	**Listed**	**Enterococcus, Total Coliform (SHELL)**	**at San Luis Rey River Mouth**	**Listed**	**Indicator Bacteria**
				at Oceanside Pier and Pier View Way	Not listed				
				at Pier at Surfrider Way	Not listed				
				at Pier at Tyson Way	Not listed				
Batiquitos HSA (904.50)	**Pacific Ocean Shoreline, Batiquitos HSA**	San Marcos HA at Moonlight State Beach[1]	San Marcos HA at Moonlight State Beach	at Moonlight State Beach (Cottonwood Creek outlet)	Listed (SHELL)	Total Coliform	at Moonlight State Beach (Cottonwood Creek outlet)	Listed (SHELL)	Indicator Bacteria
				at South Carlsbad State Beach (Batiquitos Lagoon outlet)	Not listed				
				at Swami's Beach	Not listed				
San Dieguito HU (905.00)	**Pacific Ocean Shoreline, San Dieguito HU**	San Dieguito Lagoon Mouth, Solana Beach[1]	San Dieguito Lagoon Mouth, Solana Beach	at San Dieguito Lagoon Mouth at San Dieguito River Beach	Listed (SHELL)	Total Coliform	at San Dieguito Lagoon Mouth at San Dieguito River Beach	Listed (SHELL)	Indicator Bacteria
				at San Dieguito Lagoon Mouth at Seascape Beach Park	Delisted				
Miramar Reservoir HA (906.10)	**Pacific Ocean Shoreline, Miramar Reservoir HA**	at Torrey Pines State Beach at Del Mar (Anderson Canyon)[1]	Not Listed						
				at Los Penasquitos River Mouth	Listed (SHELL)	Total Coliform	at Los Penasquitos River Mouth	Listed (SHELL)	Indicator Bacteria

Watershed	Waterbody	2002 Noted areas of impairment (Indicator Bacteria) [2]	2006 Noted areas of impairment (Indicator Bacteria) [2]	2010 303(d) List			2014 303(d) List		
				Segment [2]	2010 Listing Status	2010 Listed Constituents	Segment	2014 Listing Status	2014 Listed Constituents
Scripps HA (906.30)	Pacific Ocean Shoreline, Scripps HA	at La Jolla Beach at El Paseo Grande[1]							
		La Jolla Shores Beach at Caminito Del Oro[1]							
		Windansea Beach at Palomar Ave.[1]							
		Pacific Beach at Grand Ave.[1]							
		La Jolla Shores Beach at Ave. de la Playa[1]		at Avenida De la Playa at La Jolla Shores Beach	Listed (SHELL)	Total Coliform	at Avenida De la Playa at La Jolla Shores Beach	Delisted	
		Windansea Beach at Bonair St.[1]		at Bonair St at Windansea Beach	Not listed				
		Casa Beach/Childrens Pool[1]	**at Childrens Pool Beach**	**at Childrens Pool**	**Listed**	**Enterococcus, Total Coliform (SHELL), Fecal Coliform**	**at Childrens Pool**	**Listed**	**Indicator Bacteria**
				at Coastal Blvd. Gazebo	Not listed				
				at Crystal Pier	Not listed				
				at El Paseo Grande at La Jolla Shores Beach	Not listed				
				at Grand Ave. At Pacific Beach	Not listed				
				at La Jolla Cove	Listed (SHELL)	Total Coliform	at La Jolla Cove	Delisted	
				at Pacific Beach Point at Pacific Beach	**Listed**	**Enterococcus, Total Coliform (SHELL), Fecal Coliform**	**at Pacific Beach Point at Pacific Beach**	**Listed**	**Indicator Bacteria**
		Windandsea Beach at Playa Del Norte[1]		at Playa Del Norte at Windansea Beach	Not listed				
		Whispering Sands Beach at Ravina St.[1]		at Ravina	Listed (SHELL)	Total Coliform	at Ravina	Delisted	
				at Scripps Pier at La Jolla Shores Beach	Not listed				
		South Casa Beach at Coast Blvd[1]		at South Casa Beach	Not listed				
		Tourmaline Surf Park[1]		at Tourmaline Surf Park at Pacific Beach	Not listed				
		La Jolla Shores Beach at Vallecitos[1]		at Vallecitos Court at La Jolla Shores Beach	Listed (SHELL)	Total Coliform	at Vallecitos Court at La Jolla Shores Beach	Listed (SHELL)	Indicator Bacteria
		Windansea Beach at Vista de la Playa[1]		at Vista de la Playa at Windansea Beach	Not listed				
				at Whispering Sands Beach at Nicholson Point at La Jolla	Not listed				

Watershed	Waterbody	2002 Noted areas of impairment (Indicator Bacteria) [2]	2006 Noted areas of impairment (Indicator Bacteria) [2]	2010 303(d) List			2014 303(d) List		
				Segment [2]	2010 Listing Status	2010 Listed Constituents	Segment	2014 Listing Status	2014 Listed Constituents
Tecolote HA (906.50)	**Tecolote Creek**	**Tecolote Creek[1]**	**Tecolote Creek**	**Tecolote Creek**	**Listed**	**Indicator Bacteria**	**Tecolote Creek**	**Listed**	**Indicator Bacteria**
Mission San Diego HSA (907.11)/ Santee HSA (907.12)	**Forester Creek**	**Forester Creek[1]**	**Forester Creek**	**Forester Creek**	**Listed**	**Fecal Coliform**	**Forester Creek**	**Listed**	**Indicator Bacteria**
	San Diego River (Lower)	**San Diego River (Lower)[1]**	**San Diego River (Lower)**	**San Diego River (Lower)**	**Listed**	**Enterococcus, Fecal Coliform**	**San Diego River (Lower)**	**Listed**	**Indicator Bacteria**
	Pacific Ocean Shoreline, San Diego HU			at Stub Jetty, South of the San Diego River outlet, near Cape May Avenue	Not listed		at Stub Jetty, South of the San Diego River outlet, near Cape May Avenue	Listed (SHELL)	Indicator Bacteria
		at San Diego River mouth (Dog Beach)[1]	**at San Diego River mouth (Dog Beach)**	**at San Diego River Outlet at Dog Beach**	**Listed**	**Enterococcus, Total Coliform (SHELL)**	**at San Diego River Outlet at Dog Beach**	**Listed**	**Indicator Bacteria**
Point Loma HA (908.10)	**San Diego Bay Shoreline, Shelter Island Shoreline Park**	**San Diego Bay Shoreline, Shelter Island Shoreline Park[1]**	**San Diego Bay Shoreline, Shelter Island Shoreline Park**	**San Diego Bay Shoreline, Shelter Island Shoreline Park**	**Listed**	**Enterococcus, Total Coliform (SHELL), Fecal Coliform**	**San Diego Bay Shoreline, Shelter Island Shoreline Park**	**Listed**	**Indicator Bacteria**
Chollas HSA (908.22)	**Chollas Creek**	**Chollas Creek[1]**	**Chollas Creek**	**Chollas Creek**	**Listed**	**Indicator Bacteria**	**Chollas Creek**	**Listed**	**Indicator Bacteria**

Notes: "Not Listed" refers to considered segments with sufficient justification against placing on the 303(d) list. Blank cells indicate no information available on the 303(d) list under that year for the referenced segment.

1. Listed in Attachment E of the 2013 MS4 Permit (Order No. R9-2012-0001)
2. In the 2002 and 2006 303(d) lists, the waterbodies were all listed as the entire Pacific Ocean shoreline within the HSA with a note in the potential sources portion of the list that identified specific areas of impairment along the shoreline. In the 2010 303(d) listing process, the Regional Water Board considered the previous listings to be inclusive of the entire HSA, HA, or HU and broke the listings into individual segments. As a result, the 2002 and 2006 columns are noted areas of impairment for the Pacific Ocean Shoreline listings and the 2010 listings are specific waterbody segment listings. This led to the clarification that several areas of the shoreline were considered to be not listed (rather than delisted) because impairments had not been observed within the specific segment. Segment descriptions are consistent with the 2010 303(d) list and may slightly differ from the R9-2013-0001 permit.
3. In the 2002 and 2006 303(d) lists, South Capistrano Beach at Beach Road and South Capistrano County Beach were incorrectly listed as being in the Lower San Juan HSA. The error was corrected in the 2010 303(d) list and the waterbodies moved to the San Clemente HA.

Appendix B: Surfer Health Study Results and Role in the Revised Bacteria TMDL

This appendix provides a summary of the Surfer Health Study (SHS), as well as the rationale for using the findings from the SHS within the context of the Bacteria TMDL. A detailed comparison of the SHS is made against the 2012 USEPA Recreational Water Quality Criteria (2012 RWQC). Similarities and differences in study design and results are examined. The appendix also discusses the benefit of using an additional indicator, the human-associated HF183 *Bacteroidales* genetic marker (HF183) to assess water quality. The HF183 marker provides a mechanism for an alternative pathway for demonstrating compliance with final targets and allocations. The advantages of using the human marker in addition to traditional fecal indicators (*Escherichia coli* and *Enterococcus*) are detailed below. In the second half of the appendix, a summary of the use of the HF183 marker in the TMDL, the uncertainties around its use, and potential challenges in implementation are further examined.

1. Background of Surfer Health Study (SHS)

The SHS was a large study that included an epidemiological component and a Quantitative Microbial Risk Assessment (QMRA) component (SCCWRP, 2016, Arnold et al., 2017, Soller et al., 2017). The following is a summary of the study results from the published report and the two peer-reviewed articles. The study was designed to compare illness rates following ocean exposure during dry versus wet weather in southern California beaches. The SHS is one of the only epidemiological studies thus far to evaluate enterococci levels associated with incident illness during wet weather periods where stormwater runoff is the main source of human-influenced contamination. Limited information suggested that fecal indicator bacteria concentrations are higher at beaches in southern CA during wet weather conditions, which could mean a greater risk of incident illness during those conditions (Arnold et al., 2017). The goal of the SHS was to answer the following hypothesis/research questions: “1) Is surfing associated with an increased rate of illness? 2) Are illness rates higher when surfing following wet weather compared to dry weather? 3) What is the association between water quality and illness following wet weather events? 4) What level of water quality corresponds to the same risk illness as current water quality objectives?”(SCCWRP, 2016).

Surfers were selected as the test population because they are known to engage in ocean exposure (immersion) during storm conditions in the winter. A total of 654 surfers participated (33,377 days of observation; 10,081 surf sessions). They reported surf activity along with illness (gastrointestinal illness, sinus infections, ear infections, infected wounds) every 7 days using a web-based app. Exposure during wet weather was defined as surf sessions within 3 days of rainfall (>0.25 cm in 24 hours). The study period included two winter seasons: Jan 14, 2014 – Mar 18, 2014 and Dec 1, 2014 – Mar 22, 2015.

Surf sessions reporting daily surfing activity and illness symptoms were recorded for multiple beaches within the San Diego region. Water quality samples for human markers and pathogens were collected from Tourmaline Surfing Park and Ocean Beach. These representative beaches were selected because they are frequented year-round and receive storm water runoff. Tourmaline Surfing Park water quality was sampled at two locations at the beach and discharge samples were collected within Tourmaline Creek. Ocean Beach water quality was sampled at four locations along the shore at the beach and discharge samples were collected from San Diego River. Both sites receive stormwater inputs from the MS4 system.

Enrollees were recruited in-person, or online. The eligibility criteria required that participants were: >18 yrs. old, speak and read English, surf in study region during the study period, have valid email address or cell number, and access to internet via smartphone or computer. Participants self-reported surfing activity (location, date, time of entry and exit) and illness symptoms. A participant was excluded (open cohort design) if surfing took place outside the study region during that reporting/follow up period (Arnold et al., 2017).

The study enrolled 654 individuals (162 in year 1, 492 in year 2) who contributed on average 51 days of follow-up post surfing activity surveys (range: 6 to 139 days). The population was 73% male, 63% college educated, and 75% employed. The median age was 34 years old. Surfers entered the ocean an average of two times per week. The median ocean entry time was 08:00 and median time spent in the water was 2 hours (Arnold et al., 2017).

There were 10 rainstorms >0.25 cm during the study period. Field staff collected 1,073 beach water samples and 92 wet weather discharge samples for fecal indicator bacteria analysis. Across all weather conditions, the study found that ocean exposure in the three days during and following the wet weather event was associated with increased incidence of all outcomes except for upper respiratory illness. SHS results found an increased rate of GI illness due to ocean exposure, following a wet weather event. An excess risk of 12 GI Illnesses per 1,000 surfers who entered the ocean within 3 days after a storm event, compared to unexposed surfers (those who did not enter the ocean), was observed.

The SHS also examined illness rates for six non-GI symptoms – skin rashes, open wound infections, earache/infections, sinus pain/infections, fever, and upper respiratory infections. Nearly all of the illness rates for these symptoms increased when surfers entered the ocean compared to when they didn't go in the ocean, although not all of these symptoms could be directly related to water quality. Cumulatively, across all infectious symptoms, there was an excess risk of 19 surfers per 1,000 on average who became ill when they entered the ocean in wet weather, compared to when they did not enter the ocean (Arnold et al., 2017).

With the exception of fever and skin rash, there was an increase in incidence rates between unexposed periods (not exposed to ocean), exposure during dry weather (ocean exposure during dry events, in winter), and exposure during wet weather (ocean exposure during rainstorm events, in winter) (SCCWRP, 2016). For most types of illnesses, shortening the wet weather window increased the difference in incidence rates between exposed periods during dry and wet weather. Increased illness was most pronounced within 24 hours of storm events. A 0-3 day window captured most illnesses due to wet weather exposure and was used in the SHS analysis as the exposure period (**Figure 1**). *Enterococcus*, total coliforms, and fecal coliforms were positively associated with increased incidence of almost all outcomes (e.g., GI, earache, infection etc). Elevated levels of *Enterococcus* (>35 and >104 CFU per 100 ml) had no association with illness during dry conditions. In addition, log10 concentrations of total coliforms and fecal coliforms similarly had no association with illness during dry conditions. However, all fecal indicators showed strong positive associations following wet weather.

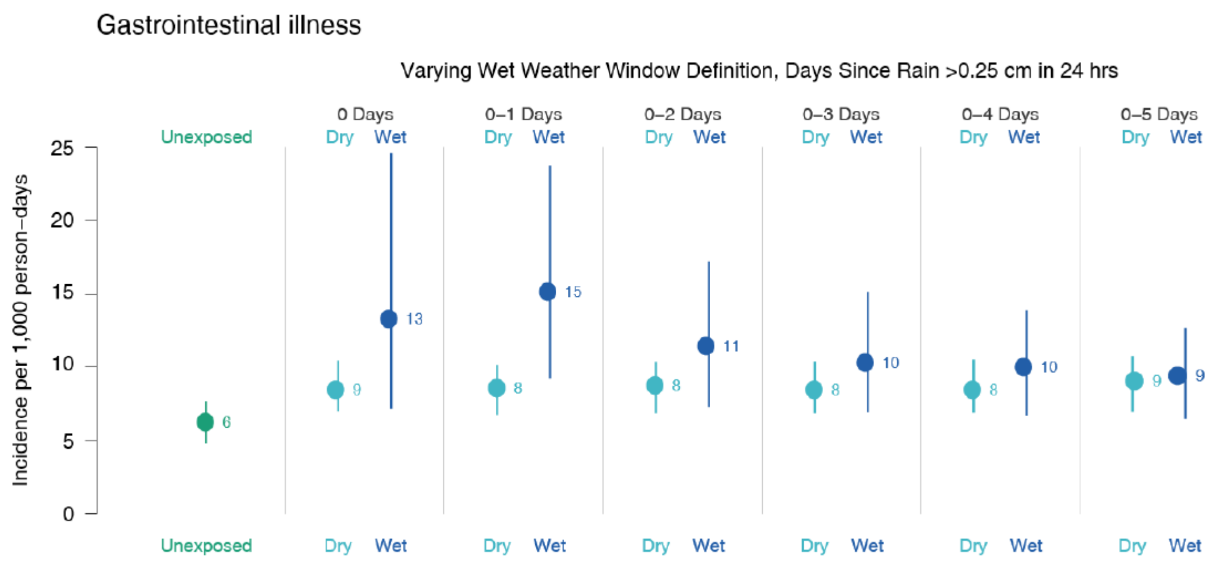

Figure 1. Sensitivity analysis of exposure period on incidence rates of GI illness. Incidence rates were calculated by dividing incidence episodes by person-days in the unexposed and exposed periods during follow-up. Incidence of GI illness per 1,000 person-days are reported in the figure above for each wet weather window definition. Reproduced from Chapter 1, Figure 3 at p. 23. from SHS Report (SCCWRP 2016).

Overall, ocean exposure increased the incidence of acute illness. Rainstorms led to higher levels of fecal indicator bacteria at sentinel beaches. Seawater exposure within three days of rain further increased the incidence of a broad set of infectious outcomes. Fecal indicator bacteria concentrations were strongly associated with subsequent illness only during wet weather periods. During the window of highest risk in the sensitivity analysis, which was 0-1 days within the rain event, the risk difference was 25 per 1,000 recreators.

The relative increase in gastrointestinal illness associated with ocean exposure (adjusted IRR = 1.33, 95% CI: 0.99, 1.78) was similar in magnitude to relative increases in risk measured in marine swimmer cohorts in California and in other studies in the U.S. A 3-fold increase in rates of earache or infection (adjusted IRR = 3.28, 95% CI: 1.96, 5.50) and 5-fold increase in infected open wounds (adjusted IRR = 4.96, 95% CI: 2.18, 11.29) associated with exposure following rainstorms were observed in the SHS (SCCWRP, 2016).

While the SHS was a very comprehensive study, there are several limitations (SCCWRP, 2016). These include:

- Self-reporting: over-reporting illness by participants;

- Illness reporting period: some pathogens have longer incubation periods (>3 days). Illnesses due to some pathogens may not have been captured although the vast majority of expected waterborne illnesses for this study result from <3 day incubation time (Soller et al., 2017);
- Online enrollment: This did not allow for physical verification of surfers who completed surveys as actually surfing within beach limits included in the study sites. The SHS enrolled adult surfers because there was no guarantee of adequate consent for minors through online enrollment, therefore individuals (people < 18 years old) were excluded from the study;
- The two study winters took place during a drought in Southern California (13% of surf sessions took place within 3 days of rain). It is possible that storms of greater size and frequency could have resulted in greater excess illness levels.

In summary, the SHS reported an average excess risk of gastrointestinal illness following wet weather exposure of 12 excess GI per 1,000. The QMRA component of the SHS estimated an average illness level of 15 excess GI illnesses per 1,000. These findings present important empirical and estimated measures of illness associated with stormwater discharges in Southern California. Assessing health risks through a comprehensive health study, such as the SHS provides important context for public health protection and regulatory decision making (SCCWRP, 2016).

1.1 Comparison of the SHS results to the 2012 RWQC

1.1.1 2012 RWQC

The 2012 RWQC described EPA's "recommended final recreational water quality criteria for the protection of primary contact recreation in both coastal and non-coastal waters, based upon consideration of all available information relating to the effects of fecal contamination on human health, including the studies conducted under CWA §104(v)". Thus, "EPA's 2012 RWQC recommendations describe the desired ambient water quality conditions to support the designated use of primary contact recreation". The 2012 RWQC recommends that states make a risk management decision regarding illness rate which will determine which set (based on illness rate selected) of criteria values are most appropriate for their waters. The document also indicates that the designated use of primary contact recreation would be protected if either set of their specified criteria (including a GM and related STV) is adopted into state WQS. The specified estimated *average illness rates* are 32 and 36 NGI illnesses per 1,000 primary contact recreators (USEPA, 2012).

1.1.2 Comparing the SHS Results to the 2012 RWQC Recommendations

From a policy implementation perspective, a key question is whether the SHS results are indicative of water quality conditions that are protective of the primary contact recreation use. To answer that question, it is necessary to compare the SHS results to the criteria set forth as protective in the 2012 RWQC.

Both the SHS and the 2012 RWQC use a metric of excess illness attributable to recreational activities: the SHS reported a "risk of 12 surfers per 1,000 on average who will become ill when they enter the ocean in wet weather, compared to when they do not enter the ocean" and the 2012 RWQC specifies estimated (average) illness rates of 32 or 36 NGI per 1,000 primary contact recreators. However, there are several factors that limit a direct comparison between the SHS and the 2012 RWQC. These factors include:

- Duration – the time period for which the SHS results are reported are different (shorter time period during and following wet weather) than those specified in the 2012 RWQC;
- Risk of population – the population included in the SHS did not include children, whereas the studies that underpin the 2012 RWQC measured risk of the general population that included children and adults;
- Exposed population – the exposed population engaging in REC-1 activities during wet weather conditions, similar to storm conditions recorded in the SHS, is likely comprised of a smaller fraction of children than the 2012 RWQC;
- Source of contamination and the associated spectrum of expected illnesses – wastewater effluent was the presumed predominant source in the 2012 RWQC compared to untreated human sources in the SHS. These sources could result in a different mixture of pathogens and therefore, different illness rates;
- Geographical extent of SHS study area – water quality data were collected at two sentinel watersheds and there is uncertainty associated with extrapolating the SHS water quality - health relationships to other watersheds within the SHS area;
- Water quality sampling location compared to exposure locations – SHS water quality sampling occurred in near shore areas whereas most of the exposures occurred off shore during the study. The 2012 USEPA RWQC were based on water quality sampling throughout a given beach including near shore and deeper (waist depth) locations where swimmers were present.

- The relationships between enterococci and GI illness include a substantial amount of model uncertainty – The SHS relationship between enterococci and GI illness includes a substantial amount of model uncertainty (i.e. the confidence bounds of SHS water quality – health relationship are broad). The 2012 USEPA RWQC also included substantial variability in the enterococcus-GI illness relationship.

A short discussion of each of these factors is provided below followed by a synthesis of this information.

Duration – The 2012 RWQC specify an average risk for a given 30-day time period. That duration is intended to include all relevant hydrologic conditions including wet weather. The SHS evaluated recreation during storm days plus three days following storms. Furthermore, the SHS reported that dry days had lower risks than wet periods (within 72 hrs of storm), and risks are predicted to be highest on storm days and within ~24 hours of a storm and then decrease (Arnold et al., 2017). This trend of increased risk on storm days, followed by decreased risk on subsequent days is consistent with the long-standing County health policy to advise the public to stay out of the water until 72 hours after a rain event. Given California's climate of sporadic and sometimes intense rainfall followed by periods of clear, dry weather, it is reasonable to infer that a 30-day risk would likely be lower than the observed wet weather risk from the SHS (and somewhat higher than the observed dry weather risk, provided that some rain occurs during that 30-day period). Although the duration examined in the SHS was shorter than that used to derive the 2012 RWQC, the fact that exposure and illness rates were only examined during and immediately following wet weather events in the SHS (which is when indicator bacteria concentrations are generally much higher than during dry weather), enhances confidence that the SHS results are indicative of water quality conditions that are protective of the primary contact recreation use.

Risk of Population – As in previous EPA epidemiological studies, children were well represented in EPA's NEEAR study population. At West Beach, the proportion of children aged ten years and under made up 20 percent of the study sample. A similar representation of children is true for studies at the other NEEAR beaches, including Huntington (20 percent of the study sample), Washington Park (22 percent), Silver Beach (22 percent), Edgewater (17 percent), Fairhope (30 percent), and Goddard (20 percent). The population included in the SHS did not include children (Arnold et al., 2017).

Children, especially those less than 5 years, exhibit greater illness rates from recreational exposures than adults. For example, in a meta-analysis of previously conducted epidemiological studies, Arnold et al. (2016) report that children aged 5 to 10 immersed their bodies at a greater rate than younger children or those older than 10 yrs, and spent more time in the water than other age groups. Swallowing water was more common among children than older beachgoers. Arnold et al. (2016) also present evidence that children 0-4 yrs are more susceptible than beachgoers aged 5 and above, however, children aged 5-10 did not exhibit substantially different susceptibility than those of ages 10 and over.

Thus, it may be inferred that children aged 5-10 appear to be more highly exposed (i.e. swallow more water) and children 0-4 yrs appear to be more susceptible (higher rate of illness for a given level of exposure) than older individuals. It is also noteworthy that new data have recently become available to quantitatively characterize the differences in exposure between children and adults (Dufour et al., 2017); however, little quantitative data are available to characterize differences in susceptibility. Nevertheless, it is reasonable to infer that if children were included in the SHS, that the observed rates of illness likely would have been higher than were reported. Thus, this factor would reduce confidence that the SHS results indicate that the SHS conditions represent water quality conditions that are protective of the primary contact recreation use.

Exposed Population – As described above, children were well represented in EPA's NEEAR study population. However, the surfer health study focused on adult surfers, as surfers routinely enter the ocean year round and are known to recreate during and after wet weather events when surfing conditions tend to improve (SCCWRP, 2016). At southern California beaches, the majority of individuals who frequent the ocean during rain events and within 72 hours of a rain event are adults. **(Data provided by San Diego County).** Thus, the data collected and reported by the SHS seems highly relevant to actual conditions in Southern California. Nevertheless, considering the total recreating population is appropriate within the TMDL context.

Limited data collected by San Diego County (from three storm events in 2017 indicate that approximately 75% of the beach population during the 3 days following a wet weather event engaged in activities that did not (or would not be expected to) result in water ingestion. Of those that did engage in activities that reasonably could result in water ingestion (25% of the total), one third (8% of the total) participated in likely head immersion activities. Twelve percent of those who participated in likely head immersion activities were under 18 years of age (~1% of the total) – 2% of were in the 0-4 year age group (0.16% of the total) and 10% were in the 5-17 year old group(0.8% of the total).

Continued efforts are being made to refine survey protocols and obtain additional data on exposure population (difference age groups) and types of recreation (body immersion) during wet weather events.

Given the relatively low percentage of children potentially exposed during wet weather time periods at southern California beaches and the small change in relative susceptibility of children aged 5-10 compared to those 10 and over (Arnold et al., 2016), it is reasonable to infer that the observed rates of illness in the SHS would likely not have changed dramatically if children were included in the SHS. Thus, even though the target population examined in the SHS did not include children, the available information suggests that the SHS results are likely indicative of water quality conditions that are protective of the primary contact recreation use.

Source of contamination and the associated spectrum of expected illnesses – Wastewater effluent was the presumed predominant source in the 2012 RWQC. In fact, the NEEAR study design required the presence of wastewater effluent (i.e., "The range of indicator density was related to occasional contamination by an identified human source of pollution (point-source)"; USEPA 2012) as one of several characteristics that were used to select the seven beaches studied between 2003 and 2007 (USEPA, 2012). Recent QMRA studies indicate that human enteric viruses are likely the etiologic agents of primary concern in the NEEAR study waters (Soller et al., 2010).

In comparison, the SHS beaches had no point sources of treated human contamination. Rather they are predominately influenced by stormwater runoff. Stormwater influenced areas may not necessarily have the same mixture of human pathogens as point sources. In recreational waters impacted by runoff, other disease causing agents such as pathogenic bacteria and parasitic protozoans could also be agents of concern. In addition to GI illness, these non-viral pathogenic microbes could result in other adverse health outcomes such as respiratory illness, ear infection, and skin infections. Also, FIB from non-human sources (e.g., birds and pets) are likely to be more prevalent in runoff. These sources of FIB generally have lower infectivity than those associated with human sources (Soller et al, 2010).

Results from the NEEAR study, and previous epidemiological studies, indicate that criteria based on protecting the public from GI illness will also prevent most types of recreational waterborne illnesses (Fleisher et al., 1996, Haile et al., 1999, McBride et al., 1998, Wade et al., 2008). Typically, these other illnesses occur at a lower rate than GI illness (as defined by any widely accepted definition). For example, Wade et al. (2008) reported a mean overall GI illness incidence of 7.3 percent, upper respiratory infection incidence of 5.7 percent, rash incidence of 2.7 percent, and eye irritations and infections of 2.9 percent. Kay et al. (1994) and Fleisher et al. (1998) reported 14.8 percent GI illness in swimmers and 9.7 percent in non-swimmers, 4.7 percent incidence of respiratory infection in swimmers and three percent in non-swimmers, and 4.2 percent incidence of ear ailments in swimmers and 4.8 percent and non-swimmers.

Given the above information, and that the 2012 RWQC are based on a GI illness endpoint, it is reasonable to infer that current water quality conditions suggest conditions that are protective of the primary contact recreation use, as indicated by the SHS.

Geographical extent of SHS study area – The 2012 RWQC were derived based on epidemiological studies conducted in seven locations. Those results are presumed to apply nationwide. The SHS illness levels associated with ocean exposure were based on all surf sessions reported in the SHS. Compared with unexposed periods, ocean exposure increased the risk of gastrointestinal illness during dry weather (Risk Difference = 7 per 1,000, 95% CI: 0.9, 13) and during wet weather (Risk Difference = 12 per 1,000, 95% CI: 0.3, 24).

SHS water quality data were collected at two sentinel watersheds. These sentinel watershed water quality data were used to develop a relationship between the density of enterococcus and GI illness. In these analyses, Arnold et al. (2016) matched the subset of individual surf sessions at the two sentinel beaches with fecal bacteria indicator levels by date and beach. Surf sessions at non-sentinel beaches were not included in this analysis of fecal indicator bacteria and subsequent illness.

Given that the water quality indicator (enterococci) – exposure analysis was limited in its geographic extent to the two sentinel beaches, there is uncertainty associated with using that relationship to characterize the risk associated with exposures in other watersheds within the SHS area. Although the overall illness rate applies to the whole SHS area, additional information (such as comparison of fecal contamination sources) may be needed to understand the limitations of using the reported enterococcus/GI illness relationship in other SHS watersheds. Thus, it is not known whether this uncertainty significantly affects the use of the SHS results to confirm whether current water quality conditions are supporting the primary contact recreation use.

Water quality sampling location compared to exposure locations – The 2012 RWQC relied on NEEAR water quality data collected in the near-shore (ankle to waist depth) and exposures that generally occurred in the near-shore. The SHS characterized health risks associated with surfing exposures, which typically occur off-shore. However, water quality sampling occurred just below the water surface in near-shore areas. It is possible that the near shore sampling was not representative of the typical Enterococcus exposure that occurred during the study and is likely to occur in the future during storm events and post-storm events. The illness rates reported for surfers could correlate to a different (i.e., lower) Enterococcus concentration than what was used in the SHS analyses. Thus, near-shore exposures could result in higher illness rates than those reported in the SHS. As noted above, the number of near-shore exposures of surfers may be lower than off-shore exposures during wet weather time periods. This factor would reduce confidence that the SHS results are indicative of water quality conditions that are protective of the primary contact recreation use, assuming near-shore primary contact recreation is of significant concern during and within 72 hours of winter rain events.

The relationships between enterococci and GI illness include a substantial amount of model uncertainty – As with any epidemiological relationship between fecal indicator bacteria and adverse human health effects, there is substantial uncertainty in the reported indicator-health relationship for the NEEAR studies. USEPA reported a weak association with relatively wide confidence intervals between illness and water quality for culturable enterococci (**Figure 2**, top two panels) and the exposure-response relationship was not statistically significant over the entire range of observed water quality measured by culturable enterococci (USEPA, 2012).

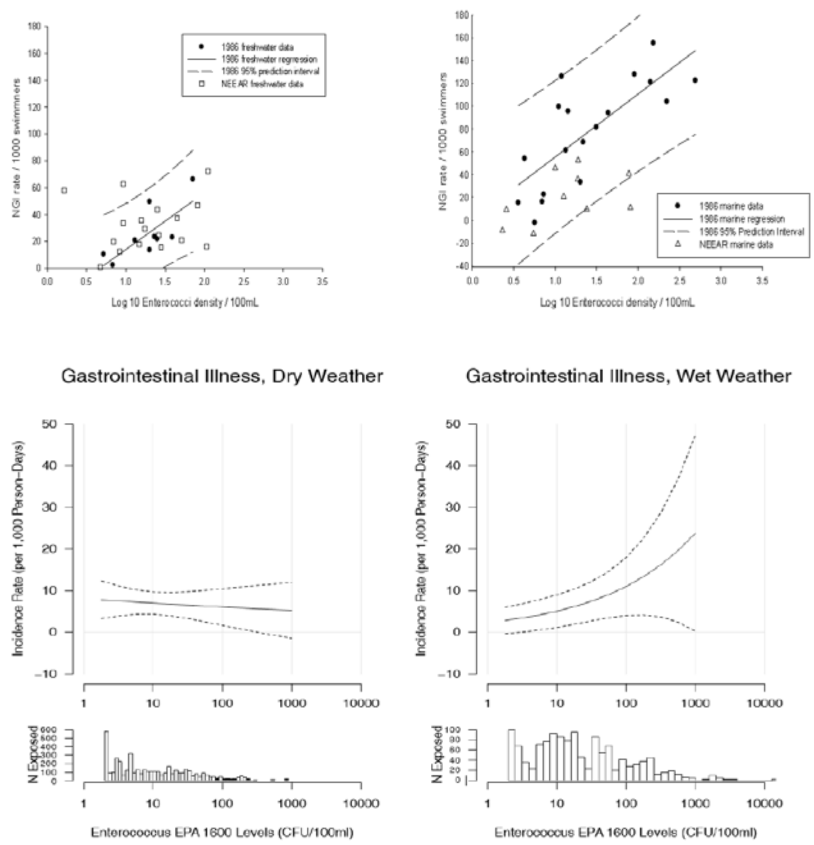

Figure 2. Relationship between enterococci and GI illness. Top two panels reproduced from USEPA, 2012. Bottom two panels are reproduced from Chapter 1, Figure S9 at p. 45 from SHS Report (SCCWRP 2016).

Similarly, the confidence bounds of SHS enterococci – health relationship are broad. As shown in **Figure 2** (bottom two panels) and similar to the NEEAR study results, the magnitude of the uncertainty bounds increases as the level of enterococcus increases. The implication of this factor is that the "true" risk of GI illness at any given level of enterococcus could be either higher or lower than is apparent by only considering a point estimate value. For example, during wet weather, the predicted excess risk that corresponded to the current regulatory guideline of 35 CFU/100ml was 16 episodes per 1,000 (95% CI: 5-27/1000) (Arnold et al., 2017). This is an inevitable consequence of large epidemiological studies such as the SHS, which involved many participants and reliance on self-reporting.

Given this information, the enterococci- GI illness relationship reported in the SHS neither increases nor decreases the confidence in whether the SHS results are indicative of water quality conditions that are protective of the primary contact recreation use as defined by the 2012 RWQC.

1.1.3 Follow up analyses

Given the information described above, an additional analysis was conducted to determine if further information could be used to quantify the uncertainties inherent in the SHS study design described above and determine whether the SHS results can be useful for evaluating the extent to which current water quality conditions are protective of the primary contact recreation use. As indicated above, the major uncertainties in this regard are the population studied and the water quality sampling locations used in the SHS. The population studied in the SHS (adults over 18 years of age) was of particular interest because data are now available to characterize differential exposure between children and adults (Dufour et al., 2017). As mentioned previously, data are not available to quantitatively characterize differential susceptibility for the 0-4 yr age group versus other age groups within a QMRA context.

To facilitate this analysis, the published SHS QMRA model (Soller et al., 2017) was modified by replacing the incidental water ingestion (exposure) distribution (which represents the general population; median 19mL) with a children specific ingestion distribution (median 38 mL) based on recently published data from Dufour et al. (2017). The result of this modification in the QMRA is an increase in the estimated risks of GI illness from a median of 15/1000 (as reported in Soller et al., 2017) to 29/1000. Assuming that 25% of the exposed population is children (consistent with the previously reported proportions in the NEEAR studies and an over-representation of that reported by San Diego County), the normalized estimated risk of GI illness for the general population (including children) would be ~18-19/1000. This calculation is simplistic but is a reasonable first cut estimate at a population level risk which assumes that the proportion of the population that recreates during wet weather time periods in Southern California is similar to (slightly greater than) the recreating population during the NEEAR study. The finding that the GI illness rate is still lower than that recommended by USEPA, even with children included, increases confidence that current water quality conditions are protective of the primary contact recreation use.

1.1.4 Summary of Uncertainties

This summary provides a holistic and comprehensive consideration of the salient factors associated with comparing the SHS results to the 2012 RWQC. Using the reported SHS results as a starting point and considering these factors cumulatively, this summary provides a basis to reasonably infer that the SHS results appear to represent water quality conditions that are protective of the primary contact recreation use as defined by the 2012 RWQC.

2. Application of the SHS Results within the TMDL

There are several possibilities for incorporating the SHS results into the TMDL, including establishing a regional water quality objective for indicator bacteria. One of the most important inferences from the SHS is that fecal contamination from human sources likely contributed a significant portion of the observed human health risk during the SHS and that those risks are not always correlated to fecal indicator bacteria densities (because indicator bacteria derive from both human and non-human sources). In other words, there can be times when fecal indicator bacteria (enterococci) are high, but health risks are not similarly elevated. These important findings from the SHS highlight the need to carefully consider how WQOs are developed so that they ensure the protection of human health. WQOs based solely on fecal indicator bacteria are not likely to achieve this goal in these particular waterbodies, whereas WQOs based on human markers (which to our knowledge has not yet been successfully completed anywhere) may be premature at this point.

The genetic marker HF183 is the most accurate indicator of human source contribution that is currently available (Boehm et al., 2013). Therefore it is suggested that the human source marker HF183 be used as an implementation and verification tool within the TMDL context. As exceedances of FIB can result from both human and non-human sources, it is proposed that the HF183 marker be used to provide verification that high enterococci densities are the result of high risk human sources - since the reduction and elimination of high risk sources are a key goal of this TMDL to ensure protection of REC beneficial uses. Optional monitoring of HF183 and compliance determination via HF183 numeric thresholds are proposed as a key component of the revised TMDL implementation section and associated compliance monitoring. The following summary provides information on HF183 and the compliance thresholds that were derived from the SHS QMRA.

2.1 Benefits of the HF183 Genetic Marker in Compliance Monitoring

Fecal indicator bacteria (FIB), such as *Escherichia coli (E. coli)* and *Enterococcus*, are natural inhabitants of the gastrointestinal tract of humans and other animals, making up a large portion of intestinal microflora. FIB, although generally harmless themselves, are used as proxies to indicate the presence of pathogens associated with fecal contamination. Although some studies have shown a general link between high levels of FIB and an increased human health risk, other studies have been equivocal (Cabelli et al., 1982; Wade et al., 2010; Arnold et al., 2013). Since, FIB can originate from both human and non-human sources, the detection of generic indicator bacteria (such as culturable enterococci) in water quality monitoring does not provide specific information on the origin of the bacteria source.

As detailed in Section 4 Source Analysis of the Bacteria TMDL Technical Report, indicator bacteria are currently used to measure water quality and can originate from a number of human and non-human sources. Some possible sources contributing to the exceedance of FIB numeric targets include human sewage (including infiltration and exfiltration, leaking infrastructure, and/or human feces from transient human populations), wildlife, domestic pets, livestock, and even regrowth in soil and the MS4 conveyance system. To better understand sources contributing indicator bacteria and the associated potential health risk they pose, microbial source tracking (MST) methods can be employed. In recent years, MST techniques have been used to help detect fecal inputs from specific sources (e.g., human, dog, bird) of contamination (Seurinck et al., 2005; Kildare et al., 2007). Molecular-based genetic markers that distinguish between sources of contamination such as *Bacteroidales* are being applied to support monitoring efforts and TMDL compliance (SCCWRP, 2016). *Bacteroidales* make up a large fraction of the human gut microbiota, are abundant in sewage, require anaerobic conditions and are therefore not expected to persist for long periods when released into the environment, are source-specific (can distinguish between human and non-human sources), and can easily be detected using molecular-based techniques, making them an ideal alternative indicator for fecal contamination. Detection methods using quantitative Polymerase Chain Reaction (qPCR) and digital PCR for measuring the host-associated *Bacteroidales* genetic markers, are highly repeatable, specific, and sensitive methods of tracking human and animal pollution back to its source (Boehm et al., 2013; Cao et al., 2015; Ahmed et al., 2016).

Identification of sources is critical for targeted remediation action to ensure the protection of human health. Other methods to determine sources and health risk include direct monitoring of pathogens, assessment of swimming related illness via epidemiology studies, and estimating risk levels using Quantitative Microbial Risk Assessment (QMRA) models (**Figure 3**). Human fecal contamination is known to be associated with greater human health risk than most non-human sources (Soller et al., 2010). QMRA models have shown that waste streams dominated by mixtures of non-human sources posed a substantially lower risk to human health than mixtures dominated by human sources (Lim, 2016; Schoen et al., 2011; Soller et al., 2014). Future monitoring efforts are trending toward inclusion of a human-associated *Bacteroidales* genetic marker (i.e., HF183[1]) when possible, to detect and quantify presence of human waste, especially at monitoring sites with chronically high levels of traditional indicator bacteria (fecal coliforms, *Enterococcus*). Utilizing genetic markers such as HF183 at monitoring sites is important to better understand trends and associated risk of human and non-human fecal contamination within a watershed.

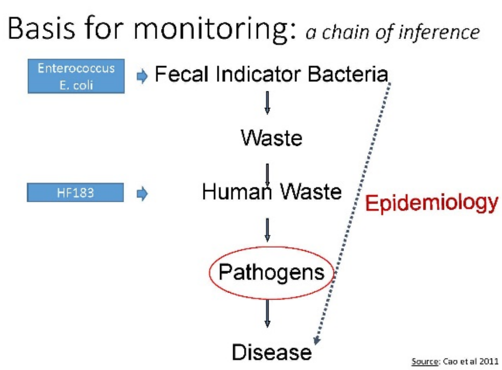

Figure 3. Connection between fecal indicators and the chain of inference of disease (Cao et al., 2011).

2.2 Implementation and Compliance Monitoring

Multiple compliance pathways can be utilized within this TMDL to demonstrate compliance and attainment of final targets. Details regarding all three pathways can be found in Section 3.4 and Section 7 of the TMDL Technical Report. The results of the SHS were used to derive compliance thresholds for the HF183 marker, as detailed below.

The human-associated HF183 *Bacteroidales* genetic marker (HF183) is being proposed as an implementation tool for one of the pathways (Pathway 2) described in the TMDL technical report. In this case, HF183 could be optionally monitored in addition to the required monitoring of *Enterococcus*. This implementation option utilizes HF183 as a verification tool to help determine if exceedances of *Enterococcus* are the result of human sources of contamination. The justification for this approach is that human sources are known to contain pathogens that can result in GI illness, whereas fecal contamination from wildlife and other non-controllable sources correspond to risk levels that are substantially lower than those from humans. By using the HF183 marker in addition to FIB, prioritization of efforts can be focused on reduction and elimination of human sources that are considered high risk and are of greatest concern.

3. SHS Derived Compliance Threshold for HF183

3.1 Derivation of the HF183 Compliance Threshold

The SHS QMRA model (Soller et al., 2017) was the foundation for deriving an HF 183 compliance threshold. The SHS model used SHS norovirus (NoV) data in the discharge point prior to each sentinel beach (San Diego River for Ocean Beach and Tourmaline Creek for Tourmaline Beach), concurrent *Enterococcus* monitoring data from various locations at the two beaches to estimate dilution of NoV between the discharge and beaches, estimates of ingestion from the literature (water ingestion rates used were based on a study conducted by Dufour and colleagues (2006), where average volume of water swallowed by a general population (adults and children) was measured and reported for individuals swimming in a pool), and dose-response relationships from the literature. With these data, the SHS QMRA estimated an excess GI illness rate of 15/1000 for the current conditions observed during the SHS.

[1] HF183 is the human-associated *Bacteroidales* genetic marker hereafter referred to as HF183

These results are in excellent agreement with the SHS epidemiological component which reported an excess illness rate of 12/1000. Norovirus was identified to be the pathogen most associated with GI illness in the SHS – other pathogens contributed very low levels of illness in the QMRA modeling.

The objective of this work component was to calculate an HF183 threshold that would be associated with a specified risk level using the SHS data and conditions as the study foundation. This work extends the SHS QMRA to consider "what if" scenarios, based on the reported correspondences between norovirus and HF183 in the discharges evaluated in the SHS, and also in raw sewage (which is assumed to be the source of contamination).

As part of the SHS, HF183 was monitored at the discharge point (above each beach - San Diego River for Ocean Beach and Tourmaline Creek for Tourmaline Beach). However, HF183 is known to attenuate at different rates than norovirus and other pathogens of health concern (Green et al., 2011; Holden, 2012; SCCWRP, 2016[2]). Therefore to derive an HF 183 level that would correspond to a specific level of illness risk (i.e. 15/1000), extension of the QMRA model was required.

In addition to data used in the SHS QMRA model and the HF183 data collected as part of the SHS, HF183 data in raw wastewater from San Diego County, and NoV levels in raw sewage in San Diego County and a meta -analysis of data from the US (Eftim et al., 2017) were used. The process involved two basic steps.

- First, a distribution describing the differential attenuation between NoV and HF183 between the release of contamination and the discharge point was derived. Numerical simulation was used to complete this step. NoV and HF183 values were numerically sampled from the reported statistical distributions from raw wastewater and the discharge point. Then attenuation values were computed for each iteration in the numerical simulation. The differential attenuation values and the corresponding statistical distribution of differential attenuation were then computed from those computed values.

- The second step uses the differential attenuation distribution to estimate risk associated with specific levels of HF183 in the discharge. This step starts by computing the HF183 reduction between raw wastewater and the HF183 in the discharge. That distribution is converted to estimated NoV densities in the discharge using the differential attenuation distribution and the NoV density in raw wastewater. That resulting distribution of NoV density in the discharge is converted to estimated NoV density at the recreation site using the data from the SHS. Then, those NoV densities are converted subsequently to "doses" and then infection and illness risk through QMRA techniques developed specifically for the SHS. This approaches provides a methodology to estimate risks associated with any HF183 value in the discharge. For example, using this approach one could determine the risk that would be associated a median HF183 density in the discharge of 100 copies /100 mL, or 500 copies / 100mL, or 750 copies /100mL.

Through a series numerical simulations and calculations, it was determined that a median value of 250 copies / 100mL with a 90th percentile of 2655 copies/100 ml corresponds to 15[3] excess GI illnesses/1000 surfers, respectively during wet weather. The USEPA statistical threshold value (STV) for Enterococcus is 110 organisms/100 ml for an illness level of 32 NGI / 1000 recreators. This STV is the 90th percentile value of the water quality distribution at the specified risk level. In this current work component, QMRA was used to derive an HF183 level in a manner that is parallel to the methodology that USEPA used for deriving its 2012 Recreational Water Quality Criteria (RWQC). In this case, however, the 90th percentile HF183 concentration corresponds to the reported SHS QMRA results of 15 illnesses / 1000 recreation events. That HF183 level is 2655 copies/100ml.

In summary, these results suggest that if the HF183 density in the discharge exceeds 2655 copies/100 ml more than 10% of the time, the 12 excess GI illnesses/1000 observed from the SHS epidemiology study is likely to be exceeded during wet weather.

3.1.1 Justification of HF183 Thresholds

The foundational justification for using the HF183 threshold of 2655 copies/100 ml (as a 90th percentile value) is that it corresponds to a similar risk level as that observed in the SHS. Setting the HF183 compliance threshold to be consistent with the current condition risk level ensures that risks are not greater than those observed during the SHS, and thus, for reasons describe previously, provides protection of REC-1 beneficial use. As described previously, the recommended approach is to use HF183 as a supplement to culturable enterococci. Used in this way, HF183 can be a flexible, specific, and resource efficient tool to augment the 2012 RWQC-based WQOs with local study results that accurately reflect the microbial conditions in the local waterbodies.

[2] QMRA chapter in the SHS

[3] Site-specific QMRA-estimated risk in the SHS; note that the site-specific observed risk rate is 12 excess GI illness/1000 surfers in the SHS epidemiology study

3.2 Uncertainties with the HF183 Compliance Threshold

There are several sources of uncertainties related to the HF183 threshold. First, the threshold was derived by considering both SHS discharge sites (OBDIS and TDIS) examined in the SHS as a single case. The two beaches were very different with respect to FIB and HF183 measurements as well as dilution. While there is some indication that the two sites represent potential book-ends of the distribution that may exist in terms of dilution and human sources for southern California beaches, this is not known at this time. Combining the two sites in the analysis may increase the uncertainty associated with the potential risks at any particular site.

Another potential source of uncertainty is related to storm size. HF183 data were available at the discharge sites for five storm events (Dec 2014 – Feb 2015), which ranged in size from 0.19 to 2.53 inches. The HF183 concentrations for the five storm events are summarized in Table 1.

Table 1. HF183 concentrations (gene copies per 100 ml) for five storm events; based on values reported at p. 67 of the SHS report (SCCWRP, 2016).

Location	Range of Individual Storm Geometric Means	Grand Geometric Mean (Arithmetic mean of the Individual Storm Geometric Means)
Tourmaline Creek	281.6 – 904.4	525.5
San Diego River	19.5 – 175.1	82.4

As can be seen from **Table 1** above and **Figure 4**, Tourmaline Creek had consistently higher HF183 concentrations than the San Diego River. There is also a wide range of concentrations at each location. No relationship between HF183 concentrations and storm size was observed for either watershed, however small sample size was a factor as noted in the SHS report. Figure S7 of Chapter 1*: Epidemiology* of the SHS Report presents excess GI illness rates by storm size, and suggests that incidence rates for large storms (>49 mm) are greater than for medium (25-49 mm) and small storms (<25 mm) (though this is based on the limited number of five storm events). The QMRA could not evaluate HF183 thresholds associated with storm size due to small sample size.

Insufficient data are available to adequately address this - it is possible that the HF183 threshold corresponding to a risk level of 12 - 15/1000 might be different depending on the magnitude of the wet weather event and available dilution.

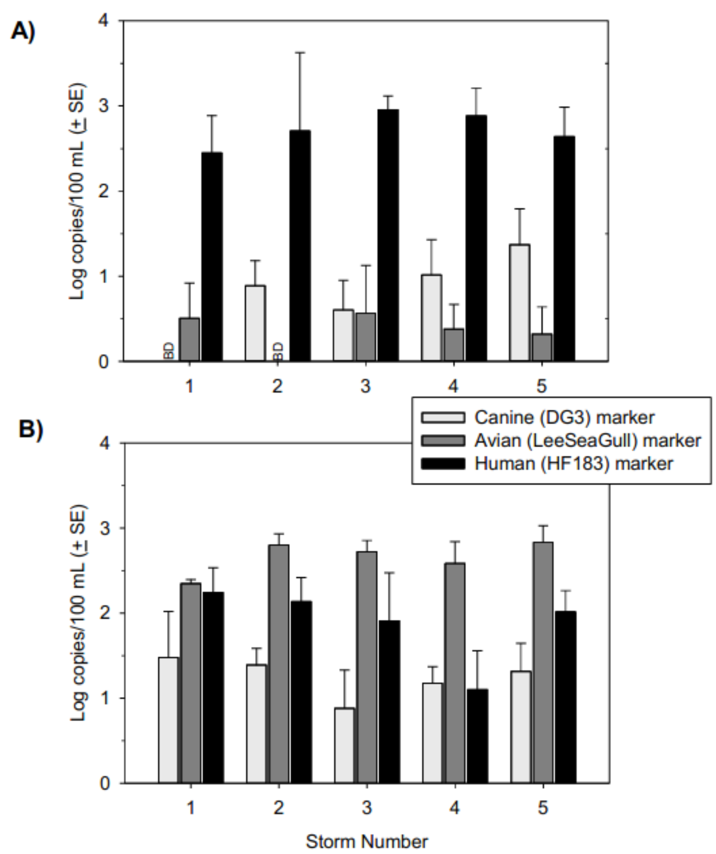

Figure 4. Concentrations of Source Markers for Canine, Avian, and Human Hosts Measured by Digital PCR in Stormwater Discharges from (A) Tourmaline Creek and (B) San Diego River. BD=below detection limit. Reproduced from Chapter 2, Figure 5 at p. 70 from SHS Report (SCCWRP, 2016).

3.3 Challenges of HF183 Implementation

Although many benefits may be associated with use of the HF183 genetic marker in the TMDL context described above, certain challenges exist in incorporating this new indicator and methodology into TMDL monitoring. Currently there is no standard method approved by the US EPA for measuring and quantifying the human-associated HF183 genetic marker. The USEPA is actively working to publish a standard method, but it has yet to be released. There is no standardization of holding time for samples prior to molecular analysis, of reference materials, or of primer probe sets. Although certain primers are easy to access, others require a license from USEPA for use.

Lack of accreditation for laboratory facilities, as well as a certification program for trained technicians is also a concern. Continuous training is important because deterioration of skill can result in unreliable data. Building performance checks on a routine basis by existing Public Health labs or other entity is an important factor for successful incorporation of the HF183 marker into compliance monitoring.

Decisions regarding equipment requirements are also important as different platforms vary in sensitivity (detection limits). Quantifiable measurements of the HF183 marker can be made using digital PCR or real-time PCR. Digital PCR is an emerging technology, has not been as widely tested and currently very few laboratories have access to this equipment in Southern California. The financial burden may be felt by some municipalities if required to upgrade from a qPCR machine to digital PCR, as the field continues to rapidly evolve.

With qPCR, current technology leverages indirect quantification by comparing unknown sample quantities to known reference material. Again, lack of certified reference material can influence molecular results, leading to incorrect quantification of the genetic marker in collected samples. Although several different vendors supply reference material and it is generally easy to purchase, a skilled technician is required to prepare standards and quantify starting material accurately as each lot of standards can vary by orders of magnitude (Cao et al., 2015). A certain minimum level of quality assurance and quality control of the data produced, and the analysis from raw data output of the amplification machine should be required and maintained. For the human-associated HF183 genetic marker to be utilized in TMDL monitoring and implementation to achieve compliance of regulatory WQOs, these logistics must be carefully considered and addressed.

4. References

Ahmed, W., B. Hughes, V. J. Harwood. 2016. Current Status of Marker Genes of Bacteroides and Related Taxa for Identifying Sewage Pollution in Environmental Waters. *Water* 8(6): 231.

Arnold, B.F., Wade, T.J., Benjamin-Chung, J., Schiff, K.C., Griffith, J.F., Dufour, A.P., Weisberg, S.B. and Colford, J.M., Jr. 2016. Acute Gastroenteritis and Recreational Water: Highest Burden Among Young US Children. *American Journal of Public Health* 106(9): 1690-1697.

Arnold, B.F., Schiff, K.C., Ercumen, A., Benjamin-Chung, J., Steele, J.A., Griffith, J.F., Steinberg, S.J., Smith, P., McGee, C.D., Wilson, R., Nelsen, C., Weisberg, S.B. and Colford, J.M., Jr. 2017. Acute Illness Among Surfers After Exposure to Seawater in Dry- and Wet-Weather Conditions. *American Journal of Epidemiology*, 1-10.

Arnold, B.F., Schiff, K.C., Griffith, J.F., Gruber, J.S. Yau, V., Wright, C.C., Wade, T.J., Burns, S., Hayes, J.M, McGee, C., Gold, M., Cao, Y., Weisber, S.B., Colford, J.M. Jr. 2013. Swimmer Illness Associated with Marine Water Exposure and Water Quality Indicators: Impact of Widdely Used Assumptions. *Epidemiology* 24(6): 845-853.

Boehm, A. L. Van De Werfhorst, J. Griffith, P. Holden, J. Jay, O. Shanks, D. Wang, S. B. Weisberg. 2013. Performance of forty-one microbial source tracking methods: a twenty-seven lab evaluation study. *Water Research* 47: 6812- 6828.

Cabelli, V.J., Dufour, A.P., McCabe, L.J. and M.A. Levin, 1982. Swimming-associated gastroenteritis and water quality. *American Journal of Epidemiology* 115(4): 606-616.

Cao, Y.; Wu, C.H.; Andersen, G.L.; Holden, P.A. Community analysis-based methods. In Microbial Source Tracking: Methods, Applications, and Case Studies, Hagedorn, C.; Blanch, A.; Harwood, V., Eds. Springer: New York, NY, 2011; pp 251-282.

Cao, Y., M. R. Raith, J. F. Griffith. 2015. Droplet digital PCR for simultaneous quantification of general and human-associated fecal indicators for water quality assessment. *Water Research* 70: 337- 339.

Dufour, A.P., Behymer, T., Cantu, R., Magnusun, M. and Wymer, L. 2017. Ingestion of swimming pool water by recreational swimmers. *Journal of Water and Health* (In Press).

Dufour, A.P., O. Evans, T. Behymer, and R. Cantu. 2006. Water ingestion during swimming activities in a pool: a pilot study. *Journal of Water and Health* 4(4): 425-430.

Eftim, S.E., Hong, T., Soller, J., Boehm, A., Warren, I., Ichida, A., Nappier S.P. 2017. Occurrence of Norovirus in Raw Sewage - A systematic literature Review and Meta-Analysis. *Water Research* 111, 366-374.

Fleisher, J.M., Kay, D., Salmon, R.L., Jones, F., Wyer, M.D. and Godfree, A.F. 1996. Marine waters contaminated with domestic sewage: nonenteric illnesses associated with bather exposure in the United Kingdom. *American Journal of Public Health* 86(9): 1228-1234.

Fleisher, J.M., Kay, D., Wyer, M.D. and Godfree, A.F. 1998. Estimates of the severity of illnesses associated with bathing in marine recreational waters contaminated with domestic sewage. *Int. J. Epidemiology 27(4): 722-726.*

Green, H., O. Shanks, M. Sivaganesan, R. Haugland, and K. Field. 2011. Differential decay of human fecal Bacteroides in marine waters. *Environental Microbiology* 13:3235-3249.

Haile, R.W., Witte, J.S., Gold, M., Cressey, R., McGee, C., Millikan, R.C., Glasser, A., Harawa, N., Ervin, C., Harmon, P., Harper, J., Dermand, J., Alamillo, J., Barrett, K., Nides, M. and Wang, G.Y. 1999. The health effects of swimming in ocean water contaminated by storm drain runoff. *Epidemiology* 10(4): 355-363.

Holden, P. 2012. Human indicator persistence in the environment. State-of-the-Science: Fecal Source Identification and Associated Risk Assessment Tools, November 28-29, 2012. Workshop held at the Southern California Coastal Water Research Project, Costa Mesa, CA.

Kay, D., Fleisher, J.M., Salmon, R.L., Jones, F., Wyer, M.D., Godfree, A.F., Zelenauch-Jacquotte, Z. and Shore, R. 1994. Predicting likelihood of gastroenteritis from sea bathing: results from randomized exposure. *Lancet* 344(8727): 905-909.

Kildare, B.J, Leutenegger, C.M., McSwain, B.S., Bambic, D.G., Rajal, V.B., Wuertz, S. 2007. 16S rRNA-based assays for quantitative detection of universal, human-, cow-, and dog-specific fecal Bacteroidales: a Bayesian approach. *Water Research* 41:3701–3715.

Lim, Keah-Ying. 2016. Microbial risk assessment of sustainable urban stormwater management practices. UC Irvine: Engineering. Retrieved from: http://escholarship.org/uc/item/19h6w7h2

McBride, G.B., Salmond, C.E., Bandaranayake, D.R., Turner, S.J., Lewis, G.D. and Till, D.G. 1998. Health effects of marine bathing in New Zealand. *International Journal of Environmental Health Ressearch* 8(3): 173-189.

SCCWRP, 2016. The Surfer Health Study: A Three-Year Study Examining Illness Rates Associated with Surfing During Wet Weather. Southern California Coastal Water Research Project. Technical Report 943. September 2016.

Schoen, M.E., Soller, J., Ashbolt, N. 2011. Evaluating the importance of faecal sources in human-impacted waters. *Water Research* 45: 2670-2680.

Seurinck, S., T. Defoirdt, W. Verstraete, S. Siciliano. Detection and quantification of the human-specific HF183 Bacteroides 16S rRNA genetic marker with real-time PCR for assessment of human faecal pollution in freshwater. 2005. *Environmental Microbiology* 2: 249-259.

Soller, J.A., Bartrand, T., Ashbolt, N.J., Ravenscroft, J. and Wade, T.J. 2010. Estimating the primary etiologic agents in recreational freshwaters impacted by human sources of faecal contamination. *Water Research* 44(16): 4736-4747

Soller, J.A., M. Schoen, A. Varghese, A. Ichida, A. Boehm, S. Eftim, N. Ashbolt, J. Ravenscroft. 2014. Human health risk implications of multiple sources of faecal indicator bacteria in a recreational waterbody. *Water Research* 66:254-64.

Soller, J.A., Schoen, M., Steele, J.A., Griffith, J.F. and Schiff, K.C. 2017. Incidence of gastrointestinal illness following wet weather recreational exposures: Harmonization of quantitative microbial risk assessment with an epidemiologic investigation of surfers. *Water Research* 121: 280-289.

USEPA, 2012. Recreational Water Quality Criteria, 820-F-12-058. Office of Water (ed), Washington, D.C.

Wade, T.J., Calderon, R.L., Brenner, K.P., Sams, E., Beach, M., Haugland, R., Wymer, L. and Dufour, A.P. 2008. High sensitivity of children to swimming-associated gastrointestinal illness: results using a rapid assay of recreational water quality. *Epidemiology* 19(3): 375-383.

Wade T.J., Sams, E., Brenner, K.P., Haugland, R., Chern, E., Beach, M., Wymer, L., Rankin, C.C., Love, D., Li, Q., Noble, R., Dufour, A.P. 2010. Rapidly measured indicators of recreational water quality and swimming-associated illness at marine beaches: a prospective cohort study. *Environmental Health* 966; doi:10.1186/1476-069X-9-66 [Online 31 October 2010].