State of California
California Regional Water Quality Control Board, Los Angeles Region

Final Technical Staff Report

Evidence in support of an Amendment to the *Water Quality Control Plan for the Coastal Watersheds of Los Angeles and Ventura Counties*

to Prohibit On-site Wastewater Disposal Systems in the Malibu Civic Center Area

Technical Memorandum #3: *Pathogens in Wastewaters that are in Hydraulic Connection with Beaches Represent a Source of Impairment for Water Contact Recreation*

By
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November 5, 2009

Technical Memorandum #3: ***Pathogens in Wastewaters that are in Hydraulic Connection with Beaches Represent a Source of Impairment for Water Contact Recreation***[1]

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1. Purpose

The purpose of the memorandum is (a) to document the discharge of enterococcus, total coliform and fecal coliform, bacteria used to indicate risk of recreational waterborne illness, from on-site wastewater disposal systems (OWDS) in the Malibu Civic Center onto adjacent surface waters and beaches, and (b) to determine human health impacts on beach users from exposure to pathogens given observed levels of enterococcus in beach water.

2. Study Design and Data

The study sought to examine the distribution of bacteria in groundwater beneath the Malibu Civic Center area and surface water around Malibu Civic Center area. Fecal-indicator-bacteria are quantified in OWDS discharge, in leachfields/seepage pits, in groundwater, and in streams and beaches. OWDS performance data from permitted commercial facilities, groundwater monitoring data and beach monitoring data at the Malibu Civic Center are studied for the presence of enterococcus bacteria, which can originate in the human gut, have been used as indicators of pathogens, and are the basis of marine recreational criteria for the protection of human health.

Of the twenty permitted commercial facilities in the Malibu Civic Center under the Regional Water Quality Control Board's (Regional Board) oversight, four provided end-of-pipe measures and ten submitted groundwater monitoring results. End-of-pipe discharge reports from permitted systems document effluent quality as it enters the leachfield/seepage pit. Enterococcus densities were also examined in groundwater monitoring wells surrounding the leachfields.

The City of Malibu measures groundwater quality periodically throughout the Malibu Valley Basin which receives the effluent from the OWDS in the Malibu Civic Center area The groundwater monitoring of 20 such wells in the Malibu Civic Center area completed by the City of Malibu in 2004 and summarized by Stone Environmental, Inc. (Stone, 2004) are used for this study.

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[1] The area subject to the proposed prohibition is referred to as the Malibu Civic Center area (Figure 1). The area was defined using topographic features and drainage patterns, and encompasses the hydrologic areas of Malibu Valley (also referred to as the lower Malibu Creek watershed), Winter Canyon, and adjacent coastal strips including Amarillo Beach, Malibu Beach, Malibu Lagoon, and Malibu Lagoon Beach (aka Surfrider Beach, including First, Second, and Third Points at Surfrider). For more discussion on the prohibition boundaries defining the Malibu Civic Center area, refer to the Technical Staff Report Overview and the Environmental Staff Report.

Beach data collected as part of the Coordinated Shoreline Monitoring Plan for Santa Monica Bay beaches were used for this study. The "Santa Monica Bay Beaches Bacteria Total Maximum Daily Load Coordinated Shoreline Monitoring Plan, April 7, 2004" (CSMP) went into effect on April 28, 2004. The sites cover 44 beaches that were identified as impaired due to high fecal-indicator-bacteria and/or beach closures and therefore placed on the California Clean Water Act 2002 section 303(d) list. Detailed descriptions of standardized sampling and testing procedures can be found at http://ladpw.org/wmd/npdes/beachplan.cfm. Attachment 3-A contains a complete list of the beaches in the CSMP.

The study sought to determine if enterococcus bacteria were present continuously along likely hydrological transport paths, such as those documented for the Civic Center area or at other beaches described in the literature, from the OWDSs in the Civic Center area to the adjacent beaches. Beach enterococcus densities, and their frequency distributions, were compared to variables such as watershed size, urban acreage, beach visitor population, wave strength, setting such as lagoon or estuary, number of roofs seen on air photo (where indicative of a septic system), preceding winter weather as rainfall, and annual variation, to identify correlations with the highest Pearson's Correlation coefficients. Although the study design does not eliminate all possible alternative bacteria sources, it focused on bacteria delivered to the beach via groundwater by examining the beaches during the summer months (May to the end of October) when other bacteria sources, such stormwater and overland urban runoff, are known to be at a minimum. Further, examining bacteria during storm-free dry conditions minimizes other transport mechanisms, such as rainfall or heavy wave action, which could move bacteria onto the beach face.

Compilations of the data reviewed have been provided for public review. Over 8000 records collected for CSMP were compiled and released with a summary of the beach characteristics on August 24, 2009 on the Regional Water Quality Control Board Website www.waterboards.swrcb/los angeles. Among these records, the Civic Center beaches sampled by CSMP are Malibu Colony Beach labeled as MC-1, Malibu Surfrider Beach labeled as MC-2, and the beach near Malibu Pier Beach labeled as MC-3. Sweetwater Canyon at Carbon Beach, labeled as SMB 1-13, is the Civic Center beach which lies furthest to the southeast. Marie Canyon, labeled as SMB 1-12, is the beach which lies furthest to the northwest and just outside the Malibu Civic Center Prohibition area. Attachment 3-B contains an expanded reference list including those documents cited here. Attachment 3-C contains a list of selected correlation coefficients between the Civic Center Beaches.

Early Technical Review

An Early Technical Review (ETR) of this work was conducted between June 8, 2009, and the public release of this document. The ETR resulted in recommendations from the reviewers (a) to enhance the confidence of the conclusions using statistics, (b) to recommend additional studies to confirm and extend the results shown here, (c) to emphasize the complexity of the subsurface hydraulic and microbiological environment between OWDS discharge and the ocean, and (d) to verify the relationship between human illness from marine recreational activities and coastal OWDS use. In response to these comments, additional statistical results were generated and human health risks estimates were based on a site-specific study. The Early Technical Reviewers were Dr. Mark Gold (Heal the Bay), Mr. Steve Weisberg and Dr. John Griffith (Southern California Coastal Water Research Project or SCCWRP), Dr. Alexandria Boehm

(Stanford University) and Dr. John Izbicki (US Geological Survey), all of whom have completed research on microbial water quality at beaches.

Peer Review

Independent Peer Review was also conducted through a contract with the University of California at Berkeley and the State Water Resources Control Board, with the comments and response to comments released to the public and considered with this document by the Regional Board.

Integration with Ongoing Studies

An epidemiology study of Surfrider Beach by SCCWRP is ongoing with fieldwork conducted during the summer of 2009. Groundwater assessment was conducted during a ten-day period in July 2009 by Dr. John Izbicki of the USGS. The City of Malibu reports that Richard Ambrose and Jenny Jay of UCLA conducted a study of *Bacteroides* in Malibu Lagoon in 2009. General descriptions of the ongoing studies are available from the Regional Board.

3. Results

Hydrological Connection

The existence of a hydrological connection between the beaches and the groundwater underlying the Malibu Civic Center area has been well established in existing literature, by groundwater models (Stone, 2005; Questa, 2003), by surface water models (Malibu Creek and Lagoon nutrient TMDL 2003; Malibu Creek and Lagoon bacteria TMDL, 2004), and as described in the 2004 Memorandum of Understanding between the City of Malibu and the Regional Board. The City of Malibu's ongoing hydrology study, as expressed in the planning documents provided to Board staff in September, 2008, seeks to quantify and model the groundwaters of the Civic Center and their hydrological connection with the ocean.

Enterococcus is found all along hydrological transport paths from the Onsite Wastewater Disposal Systems in the Civic Center Area to the beaches.

Bacteria in Groundwater

End-of-pipe bacteria measurements are reported for four permitted commercial sites in the Malibu Civic Center. Disinfection has failed in each example except Malibu Beach Inn. The enterococcus values are considered to be typical for non-disinfection systems like most residential OWDSs. A more complete description of the extent of enterococcus in the groundwater basin is included as part of Technical Memo #2.

Table 1: End-of-Pipe Effluent Bacteria Densities (MPN/100mL) reported for permitted Malibu Civic Center Commercial Facilities where Disinfection has failed.

Site	Total	Fecal	Enterococcus
Malibu Creek Preservation	1,600	350	46
	1,600	140	110
Malibu Beach Inn[2]	Not measured	2	2
	Not measured	2	2
Malibu Colony Plaza	105	2	2
	4,000	2	2
	1,600	1,600	2,419
	1,600	1,600	2,419
Fire Station 88	1,600	1,600	2,419
	9,000	Not available	90,000
	24,000	24,000	24,000
	30,000	2,400	50,000
	240,000	Not available	240,000
	300,000	50,000	1,600,000

Shaded measures on the chart show where fecal-indicator-bacteria values are above the water quality objectives for protection of body contact recreation (REC-1)). The end-of-pipe data were provided to document that enterococcus is discharged from OWDSs into groundwater. Staff notes the values are higher than 'average' enterococcus ranges reported in raw sewage or natural waters. Enterococcus values in wells and at end-of-pipe have been reported ranging to 1 X 10^8, suggesting that high values are not computational, sampling or reporting errors.

Elevated bacteria levels were found throughout the Malibu Valley groundwater basin, which underlies the Malibu Civic Center area, and are also reported in 2004 by Stone Environmental's "Final Report-Risk Assessment of Decentralized Wastewater Disposal Systems in High Priority Areas in the City of Malibu, CA". Figure 1 shows the locations of monitoring wells in Stone's study. Elevated subsurface enterococcus densities are seen adjacent to the receiving waters. Fifteen out of 20 City wells, and 16 out of 27 permit monitoring wells, located at the edge of leachfields, contained a maximum enterococcus density exceeding the single sample maximum water quality objective of 104 MPN/100ml for protection of the beneficial use of REC-1, i.e., 31 out of the total 47 wells (76%) have an exceedance (Figure 2 and 3). Importantly, the occurrence of enterococcus in groundwater at these wells illustrates that enterococcus is present in the groundwater at the study site.

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[2] Disinfection had not failed at Malibu Beach Inn, but end-of-pipe data were submitted.

Figure 1. The maximum enterococcus measures in wells in the Civic Center area after Stone 2004.

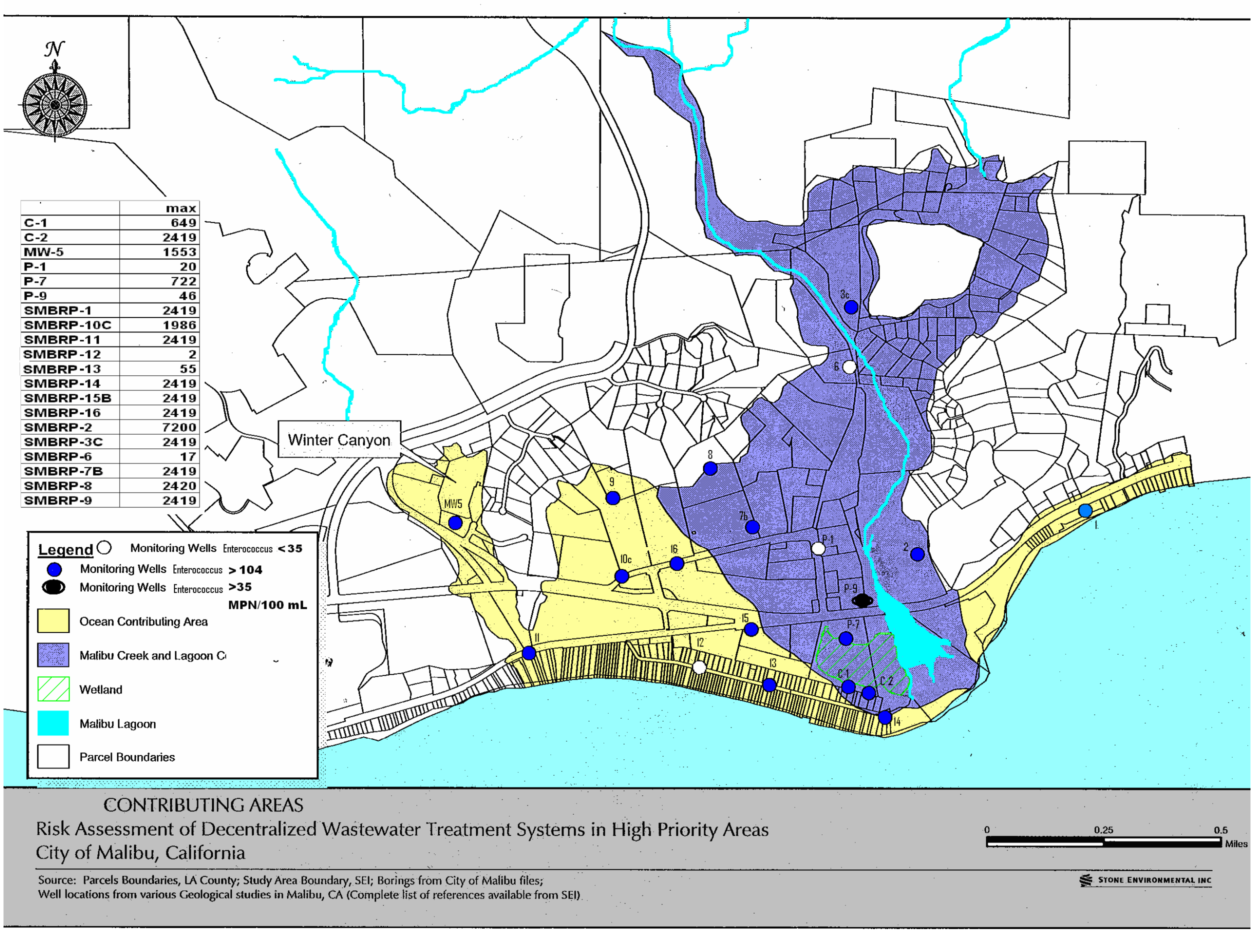


Figure 2: Chart of Maximum Enterococcus Density (MPN/100 mL) for 20 groundwater wells in the Civic Center area from Stone 2004 Study (well locations are shown in Figure 1).

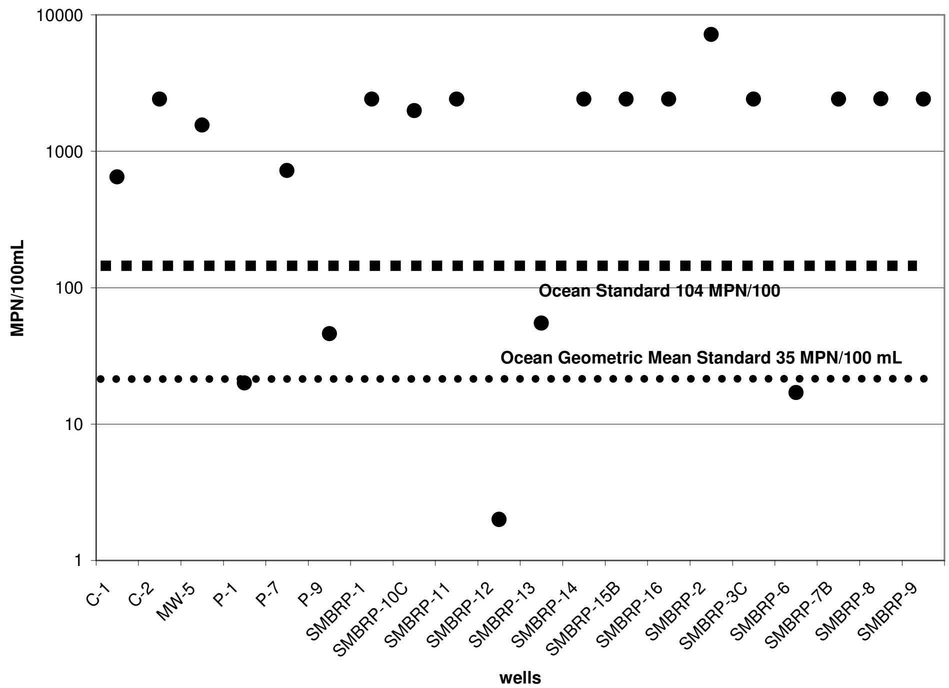
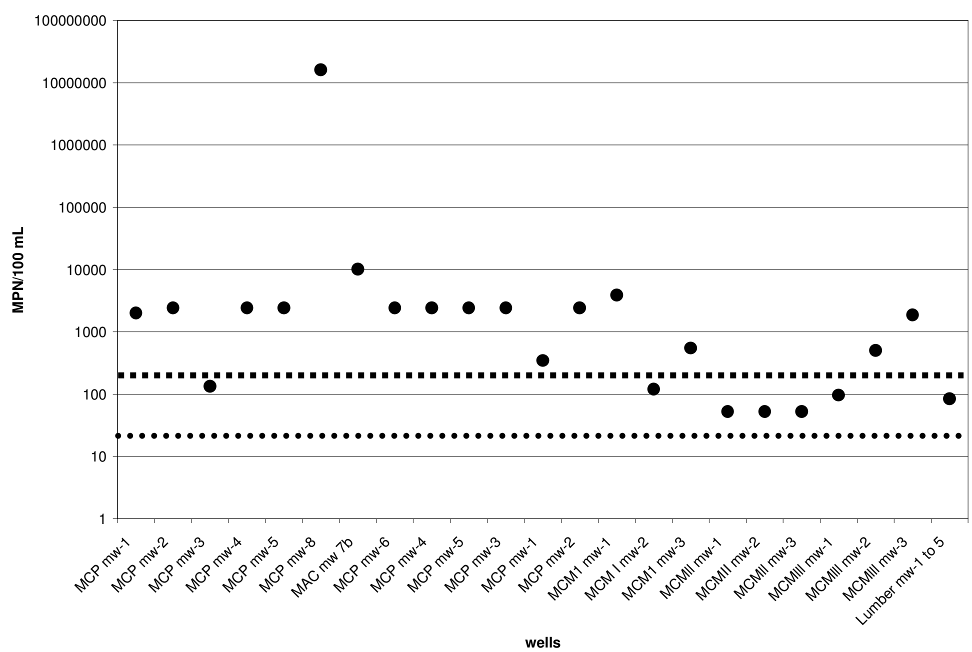


Figure 3: Chart of Maximum Enterococcus Density (MPN/100 mL) for 27 permit monitoring wells in the Civic Center area (well locations are shown in Technical Memorandum #2).



Bacteria in Surface Water: Malibu Creek and Lagoon

Several public and not-for-profit agencies measure water quality on Malibu beaches, in Malibu Creek, in the lagoon and in the ocean. This data were not collected simultaneously, may not be sampled, transported or tested with consistent protocols, and is often not compiled. Recent data from 2 of many sample sites show that last summer's levels of enterococcus are lower in the water entering Malibu Lagoon from the Malibu Creek watershed (see HTB-1 in Figure 4), than downstream of the Malibu Civic Center area (MCW-1). The contrast can be seen at Lower Malibu Creek sampling station HTB-1 and Lagoon sampling station MCW-1.

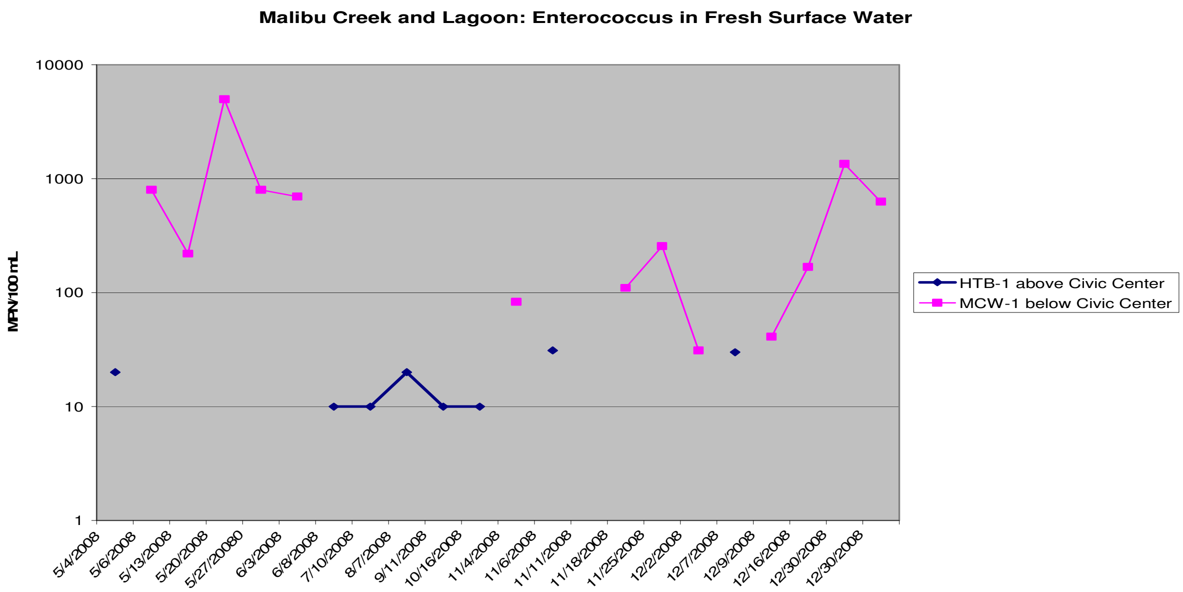
Researchers have recently released data, but not interpretations, of water quality in the lagoon and creek that may ultimately lead to a better understanding of the temporal relationship between bacteria sources and transport mechanisms such as tides, creek flow volumes, groundwater discharge volumes, and rainfall. The recent data provided in Figure 5 demonstrate that periods have been observed when Malibu Creek is not the only source of bacteria in the lagoon. Given the elevated concentrations of enterococcus observed in the groundwater beneath the civic center, and Stone's (2004) conclusion that about half of groundwater is supplied by OWDSs and most of the groundwater makes it way to the ocean, the existence of Malibu Civic Center groundwater discharge is considered a possible source of increased levels of enterococcus in the Lagoon. Typically during the summer, bacteria from any source must travel via groundwater beneath the Surfrider Beach berm before discharging into the wave zone at MC-2, as seen in Figure 4, because the beach is not broken by overland flow.

Figure 4: Malibu Civic Center Surface Water and Beach Sampling Points.

Sampling Point HTB-1 can be seen in Figure 4 where surface water from Malibu Creek watershed enters the Lagoon, MCW-1 where Malibu Creek enters Malibu Lagoon after receiving groundwater discharge from the Malibu Civic Center. The groundwater contains enterococcus which increases in concentration in the Lagoon, as shown in Figure 5. Also seen are beach sampling points MC-1 at the beach adjacent to

Malibu Colony, MC-2 at the breach point of Malibu Lagoon on Surfrider Beach, MC-3 at the beach adjacent to Malibu Pier and SMB-1-13 at Carbon Canyon Beach where Sweetwater Canyon discharges.

Figure 5: Summer 2008 Enterococcus above and below Malibu Civic Center in the Lagoon[3]



Bacteria in Surface Water: Beaches

The frequencies with which bacteria at Surfrider Beach, Malibu Colony Beach, adjacent to Malibu Pier and Sweetwater Canyon, and Marie Canyon Beach exceed the water quality objectives for enterococcus in the summers of 2005, 2006 and 2008 are listed here. A figure comparing these violations of the water quality standards for the protection of contact recreation beneficial use (REC-1) are displayed in Figure 6.

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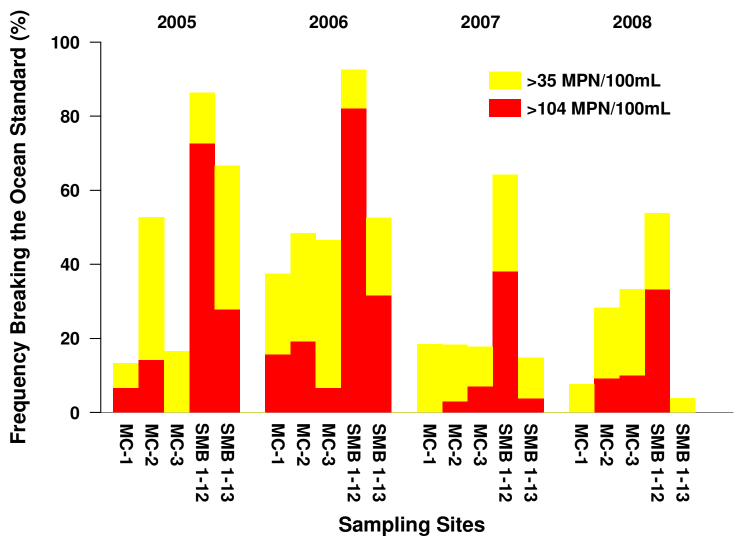
[3] Data have been collected at these locations for additional dates, but these data are the most recent and documents simultaneous measurements at upstream and downstream locations in the lagoon.

Table 2: Exceedences of single sample Enterococcus water quality standard[4].

Days/Frequencies with Enterococcus >104 MPN/100mL	2005	2006	2007	2008
Adjacent to Malibu Pier (MC 3)	0 (0)	2 (6.7%)	2 (7.1%)	0 (0)
Surfrider Beach (MC-2)	10 (14.3%)	25 (19.2%)	4 (3.1%)	12 (9.2%)
Malibu Colony (MC-1)	1 (6.7%)	5 (15.6%)	0 (0)	0 (0)
SMB 1-13 Sweetwater Canyon at Carbon Beach (southeast)	5 (27.8%)	12 (31.6%)	1 (3.7%)	0 (0)
SMB 1-12 Marie Canyon(northwest)	16 (72.7%)	55 (82.1%)	16 (38.1%)	13 (33.3%)

[4] The data summarized here were collected at each site four times a month from April through October

Figure 6: Cumulative frequencies of enterococcus concentrations that failed to meet the ocean discharge standards in Malibu Civic Center beaches



On the beaches, bacteria are typically present at levels above water quality objectives at Malibu Colony (MC-1), Surfrider Beach (MC-2), and adjacent to Malibu Pier (MC-3). The pollution on beaches has been quantified in the 2002 303(d) list, Heal the Bay's beach report cards, and the Regional Board's Santa Monica Bay Beaches Bacteria TMDLs. Further, the Regional Board issued a Notice of Violation (NOV) for bacteria adjacent to the Malibu Civic Center beaches in March 2008. It identified violations of the waste discharge requirements established in Board Order No. 01-182, as amended by Order No. R4-2006-0074 and Order No. R4-2007-0042, pertaining to the Los Angeles MS-4 Permit controlling urban runoff and stormwater discharges. Tables 3, 4 and 5 show the water quality measures upon which the NOV was based for Malibu Civic Center Beaches.

Table 3: Surfrider beach: Fecal-Indicator Bacteria Violations[5]

Surfrider Beach MC-2 Date of Violation(s)	Single Sample Result (MPN/100 ml)			
	Total Coliform	Fecal Coliform	Enterococcus	Total Coliform (Fecal:Total Coliform Ratio > 0.1)
Basin Plan Limit	**10,000**	**400**	**104**	**1,000**
9/14/2006		1,100		6,800
9/15/2006		1,100		7,900
9/16/2006				
9/17/2006				
9/18/2006				
9/19/2006				
9/20/2006				
9/21/2006				
9/22/2006				
9/23/2006				
9/24/2006				
9/25/2006				
9/26/2006				
9/27/2006				
9/28/2006		500		
9/29/2006		430		2,200
9/30/2006				1,400
10/1/2006				
10/2/2006				
10/3/2006	>13,000	6,300		>13,000
10/4/2006				
10/5/2006	13,000	7,300	1,400	13,000
10/6/2006				
10/7/2006		740		
10/8/2006				
10/9/2006				
10/10/2006		1,000	530	5,500
10/11/2006				
10/12/2006				
10/13/2006				
10/14/2006				
10/15/2006				
10/16/2006				

[5] Data listed here were gathered for enforcement purposes and does not represent all the information gathered in a particular year. The geometric mean calculations were incompletely documented in an 9/9/09 draft and have been deleted.

10/17/2006		1,300		6,300
10/18/2006			110	1,100
10/19/2006				
10/20/2006		500		
10/21/2006				
10/22/2006				
10/23/2006				
10/24/2006				
10/25/2006		3,200	160	3,200
10/26/2006				
10/27/2006		430	110	3,400
10/28/2006				
10/29/2006				
10/30/2006				
10/31/2006				
4/6/2007		580		3,400
4/7/2007	>13,000	1,600		>13,000
4/24/2007	11,000	740		
4/25/2007	11,000	7,300		11,000
4/27/2007		430		1,600
5/18/2007		430	190	
5/19/2007		430		
6/2/2007			270	
6/16/2007		8,700	310	9,600
10/19/2007		500		1,300
10/20/2007	>13,000	830		
10/24/2007	11,000	500		
10/30/2007		580	120	
10/31/2007		910		5,900
Total Violations	**7**	**25**	**9**	**18**

Table 4: Malibu Colony: Fecal-Indicator Bacteria Violations

MC-1 Malibu Colony Date of Violation(s)	Single Sample Result (MPN/100 ml)			
	Total Coliform	Fecal Coliform	Enterococcus	Total Coliform (Fecal:Total Coliform > 0.1)
Basin Plan Limit	**10,000**	**400**	**104**	**1,000**
9/14/2006				
9/15/2006				
9/16/2006				
9/17/2006				
9/18/2006				
9/19/2006				
9/20/2006				
9/21/2006				
9/22/2006				
9/23/2006				
9/24/2006				
9/25/2006				
9/26/2006				
6/4/2007		419		
Total Violations	**0**	**1**	**0**	**0**

Table 5: Adjacent to Malibu Pier: Fecal-Indicator Bacteria Violations

Malibu Pier MC-3 Date of Violation(s)	Single Sample Result (MPN/100 ml)			
	Total Coliform	Fecal Coliform	Enterococcus	Total Coliform (Fecal:Total Coliform > 0.1)
Basin Plan Limit	**10,000**	**400**	**104**	**1,000**
10/10/2006			422	
10/11/2006				
10/12/2006				
10/13/2006				
10/14/2006				
10/15/2006				
10/16/2006				
10/17/2006				
10/23/2006				
10/24/2006				
10/25/2006				

10/26/2006				
10/27/2006				
10/28/2006				
10/29/2006				
10/30/2006				
10/31/2006				
6/4/2007			131	
10/29/2007			109	2,046
Total Violations	**0**	**0**	**3**	**1**

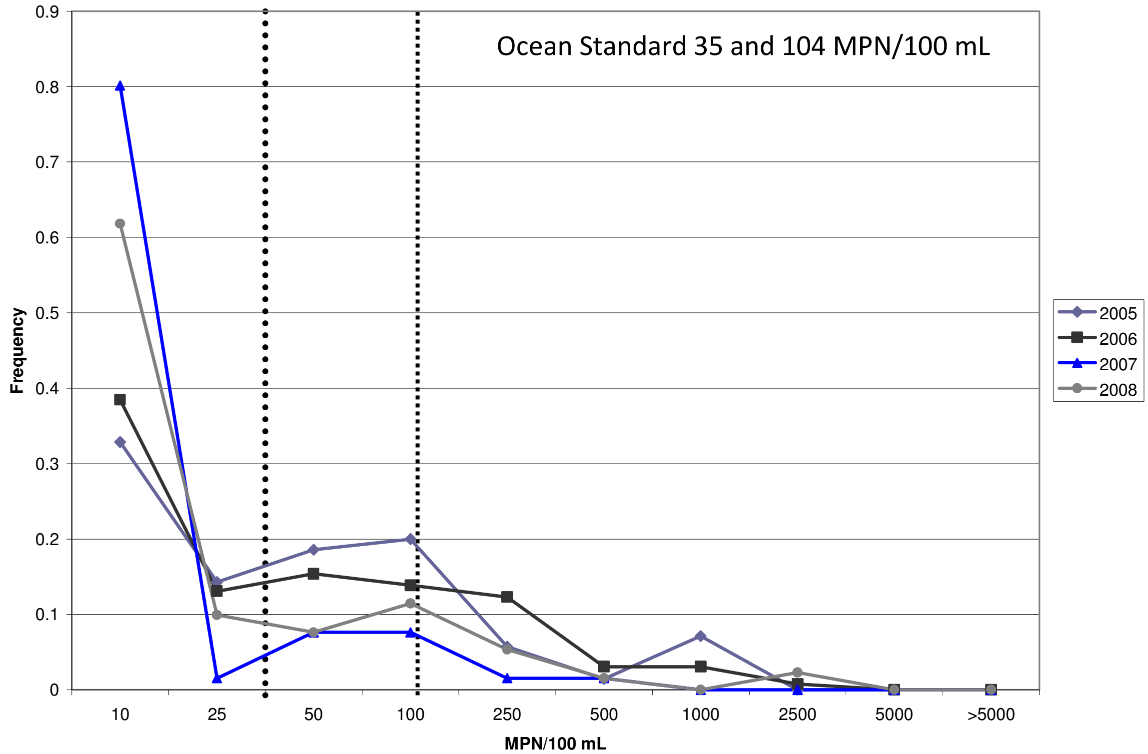
Correlations of Enterococcus with Beach Variables.

Staff did not include the results comparing beach enterococcus densities, and their frequency distributions, with other beach variables when no correlation was found. The variables examined include watershed size, urban acreage, beach visitor population, wave strength, setting such as lagoon or estuary, and number of roofs seen on air photo (where indicative of a septic system). The Pearson's Correlation Coefficient between enterococcus frequency distributions during four summers at a single beach defined statistically valid correlations (Appendix T3-C). More sophisticated statistical studies were applied, and Staff did find a statistically valid contrast between enterococcus frequency distributions from beaches adjacent to septic and sewered beaches and a statistically valid correlation between septic beaches and rainfall. These results are not included here, but included in the response to peer review.

Enterococcus on Malibu Civic Center Beaches

The enterococcus measures recorded on beaches adjacent to the Malibu Civic Center area over the summers 2005 to 2008 were sorted by interval frequency, plotted against the concentrations of enterococcus (MPN/100mL) and shown in Figures 7-9. The method was chosen to minimize the impact of varying sample sizes, to large variations in the measures and is a commonly used technique to analyze data.

Figure 7: Surfrider Beach (site MC-2) Enterococcus Interval Frequency for May-October Summer Single Measures



The enterococcus interval frequencies calculated for the beaches for the four summers were compared using the Pearson's correlation coefficient. The number of measures were counted in each of 8 intervals: values less than or equal to ten; more than ten but less than or equal to 25; more than 25 but less than or equal to 50; more than 50 but less than or equal to 100; more than 100 but less than or equal to 250; more than 250 but less than or equal to 500; more than 500 but less than or equal to 1000; and more than 1000. The intervals approximate a logarithmic distribution, but include more intervals between 25 and 100 and between 250 and 1000, ranges in which the beaches contrasted most sharply. Pearson's correlation coefficient was applied following the method used in EPA's *Ambient Water Quality Criteria for Bacteria, 1986* as described in the following quote:

> "The examination of a number of potential indicators, including the ones most commonly used in the United States (total coliforms and fecal coliforms), was included in the study. Furthermore, the selection of the best indicator [enterococcus] was based on the strength of the relationship between the rate of gastroenteritis and the indicator density*, as measured with the Pearson's Correlation Coefficient. This coefficient varies between minus one and plus one. A value of one indicates a perfect relationship, that is, all of the paired points lie directly on the line which defines the relationship. A value of zero means that there is not linear relationship. A positive value indicates that the relationship is direct, one variable increases as the other increases. A negative value indicates the relationship is inverse, one variable decreases as the other increases.* The correlation coefficients for gastroenteritis rates are related to the various indicators of water quality from both marine and fresh bathing water as shown….
> (page 5)"

Correlation coefficients between annual enterococcus frequency distributions for Surfrider Beach (MC-2) ranged from 0.78 to 0.98 suggesting little change in frequency distribution from year-to-year. Calculations of correlation coefficients for the Civic Center beaches with the best correlation, Surfrider, and the beach with the poorest correlation, next to Malibu Pier, are shown by year in Appendix T3-B:

Since enterococcus frequency distributions each year correlate well, this suggests that the distribution of bacteria frequencies is generally consistent at a beach, and not a function of random events such as swimmer shedding, the inappropriate disposal of a diaper or beach use by a homeless person.

Figure 8: Malibu Colony (site MC-1) Enterococcus Interval Frequency for May-October Summer Single Measures

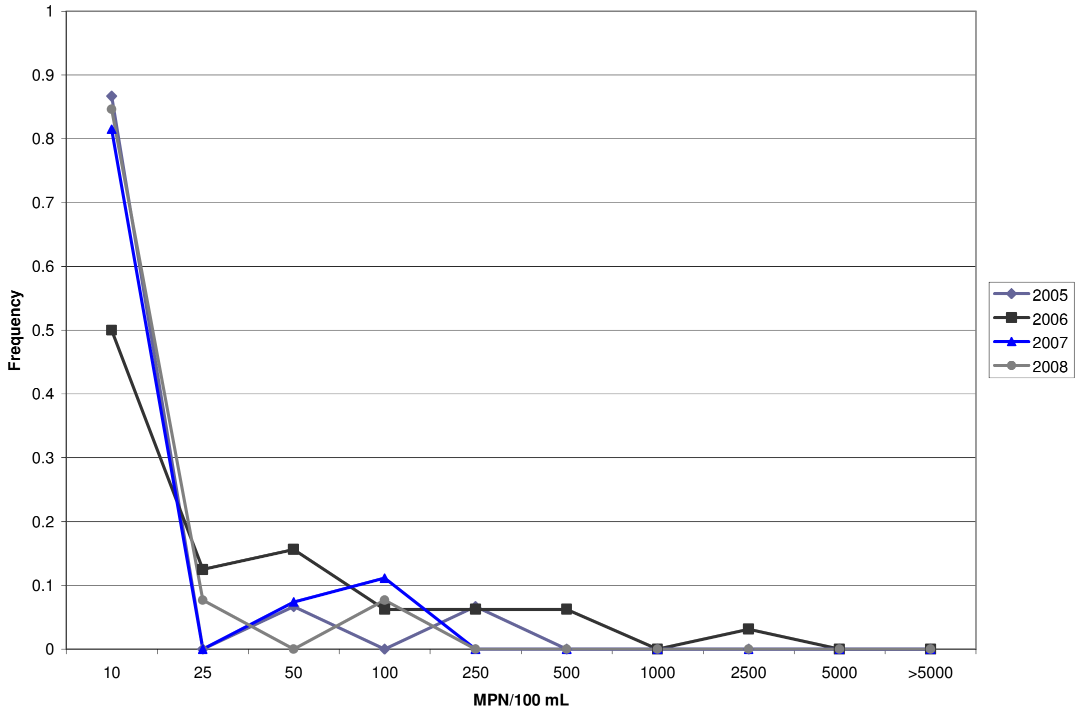
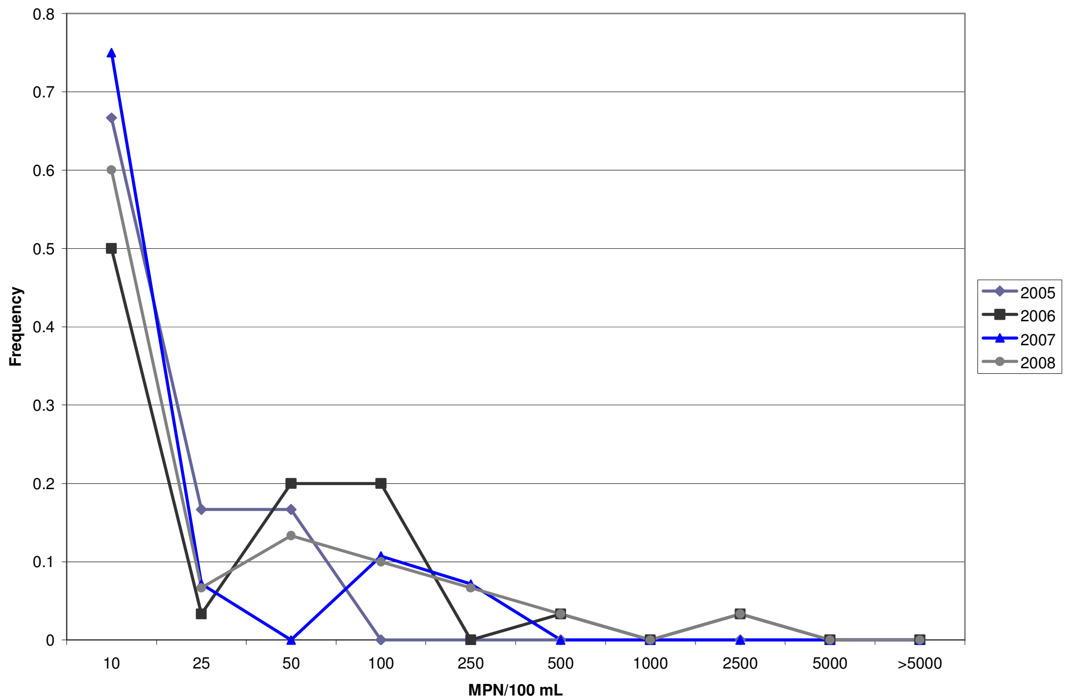


Figure 9: Adjacent to Malibu Pier (site MC-3) Enterococcus Interval Frequency for May-October Single Measures



4. Epidemiology Evidence of Human Health Impacts in the Malibu Civic Center.

Robert W. Haile and 13 co-authors (1996) completed an epidemiology study contrasting illness among immersed-head swimmers at Malibu's Surfrider Beach, Will Rogers Beach and Ashland Storm Drain. The results are summarized in Table 6. The first of its kind study on the health impacts of swimming at urban runoff contaminated ocean beaches was completed under the auspices of the USEPA's National Estuary Program's Santa Monica Bay Restoration Project (now a state commission). The study linked increased illness rates to fecal indicator bacteria densities at these beaches between June and September 1995.

Table 6: Epidemiology evidence of human impacts in Malibu

June 22 to September 17, 1995	Enterococcus Number > 104 MPN/100 mL	Percentage of days when exceeded 104 MPN/100 mL
Surfrider Beach	26	34.6
100 yards upcoast	4	5.1
100 yards downcoast	14	17.9

Will Rogers Beach	32	45.2
100 yards upcoast	5	6.8
100 yards downcoast	7	9.6
Ashland Beach	5	6.3
100 yards upcoast	0	0
100 yards downcoast	1	1.3

Illness rates are given below for each of the days when enterococcus was above 104 MPN/100 mL at any beach. As a point of comparison, the EPA bathing water criteria for enterococcus (geometric mean of 35 MPN/100 ml and 104 MPN/ 100 ml for single samples) was determined by EPA to lead to a Highly Credible Gastrointestinal Illness (HCGI) rate of an additional 19 people with HCGI out of 1,000. The HCGI illness identified by EPA included a fever and correlates with Haile's HCGI 2 category.

Significant respiratory Disease (runny nose, coughing and fever) (SRD)	One of: vomiting, diarrhea and fever or stomach pain and fever. (HCGI 2)
45 per 1,000 swimmers	39 per 1,000 swimmers

The Santa Monica Bay bacteria and Malibu Creek and Lagoon TMDL used the term 'urban runoff' to identify surface dry weather flows not otherwise quantified and did not preclude surface flow originating as groundwater. The 1999 Haile study attributed decreasing illness in swimmers with increasing distance from the stormwater outlet point to the dilution of bacteria delivered at the stormwater outlet via 'urban runoff." However, Haile also measured illnesses at Surfrider Beach even when no surface flow crossed the 'storm drain' sampling point. Because Stone (2004) found that under average conditions the majority of the water in the Lagoon and entering the ocean comes from groundwater, the bacteria Haile measured could be associated with groundwater flows moving through the beach face at Surfrider as well as surface flows crossing the beach.

The Malibu beaches had more exceedances of the Ocean standard than the other two study areas in 2005, 2007 and 2008, after a low-flow diversion was installed on Will Rogers Beach to limit overland flow during the summer.

<u>5. Discussion of Historic and Recent Studies</u>

Historic Studies relating Malibu Civic Center Septic Systems to Human Health Risk and Beach Pathogens

Existing technical studies (summarized in Table 7) link OWDS at the Malibu Civic Center area to beach bacteria and are discussed below:

On February 5, 1970, Los Angeles County Health provided a letter to the Regional Board stating that serious potential hazards to human health were expected to result from OWDS. LACH has repeatedly closed Surfrider Beach at the Malibu Civic Center due to high bacteria concentrations.

On July 8, 1987, Los Angles County Public Works held a public meeting to discuss a Draft Environmental Impact Report for a centralized waste water treatment plant and sewer for Malibu to address human health risk caused by OWDS system pathogens. The City of Malibu subsequently incorporated and a group of citizens brought a lawsuit to block the formation of assessment districts. The legal settlement required the new City of Malibu to provide sufficient oversight of on-site waste water treatment facilities such that they would meet Regional Board requirements.

The 1994 Ph.D. dissertation of Dr. Mark Gold "What are the health risks of swimming in the Santa Monica Bay?" identified human viruses in Malibu Lagoon and identified a potential source of the contamination as adjacent OWDS.

On January 24, 2002, the Regional Board adopted a Resolution amending the Santa Monica Beach Bacteria TMDL to the Basin Plan. The staff report found that bacteria loads from OWDS contribute to beach pathogens.

On August 30, 2004, the Stone report found that bacteria in the groundwater may enter receiving water where OWDS are found within 6-month groundwater travel time of the Ocean or Malibu Creek.

The September 17, 2004, Memorandum of Understanding between the City of Malibu and the Regional Board stated that "ordinances shall be drafted by staff, and recommended for adoption within the six-month-time-of-travel zone, as identified in the Risk Assessment Report (Stone), to provide advanced treatment and disinfection. The six-month time-of-travel zone shall include all areas contributing to Malibu Creek and Lagoon, and beaches between Sweetwater Canyon outfall and Winter Canyon outfall. OWTS located outside of the six-month-travel-time zone that cannot demonstrate compliance through inspection or that are identified as impacting groundwater by any other means shall provide adequate vertical separation and/or advanced treatment with disinfection." As of the date of this document, the City of Malibu has not provided documentation that systems within the six-month-time-of-travel zone have been upgraded to prevent bacteria discharge to the subsurface or include disinfection, nor has an ordinance to this effect been passed by the City of Malibu.

On Dec. 13, 2004, the Regional Board adopted a Resolution incorporating the Malibu Creek and Lagoon Bacteria TMDL into the Basin Plan. The staff report references a surface water model prepared by Tetra Tech which quantifies bacteria loads contributed by OWDS in the Malibu Civic Center.

Numerous studies have been completed to describe the ecosystem, hydrology, land use, possible mechanisms of waste water treatment, and costs to support policy decisions about bacteria and human health risk in the Malibu Civic Center (Ambrose et al. 2008; Bing Yen and Associates, 2001; Crawford Multari and Clark Associates, 1997, 2006, 2007; Ensitu Engineering, 2008; Gold, 1994; Jones and Stokes, 2008; Regional Board 1972, 1998, 1990, 2002, 2004b, 2008, 2008b; Lucero, 2008; Warshall, 1992; Questa, 2003; RMC, 2008; SMBRP, 1999, 2001; UCLA, 2000; URS Greiner, 1999; EPA, 2003; Stone, 2004a, 2004b, 2004c; Trim, 1994; Thorsen, 2008; and Van Beveren, 2008a, 2008b, 2008c).

Table 7: Historic Findings of Human Health Risk related to Malibu OWDS.

Date	Source	Summary
Feb 5, 1970	LA County Flood letter to Regional Board	Future OWDS will pollute groundwater in Malibu Creek with nutrients
Feb 5, 1970	LA County Health to Regional Board	Serious potential hazard to health from OWDS
Feb 11, 1970	CA DWR to Regional Board	Malibu Valley needs an area wide Water Quality plan
Apr. 8, 1970	Public Hearing SWRCB	Discontinue OWDSs, continue Regional Board surveillance
Jan. 21, 1971	CA DPH Status Ocean and streams in Malibu	Local ocean and freshwater bacteria exceed standards to protect shell fish collection in areas of development
Mar. 12, 1971	Regional Board EO to LA County Supervisors	Sewer for Malibu must be provided
May 31, 1972	Regional Board Resolution 72-4	Waste Discharge Requirements only allowed if a timetable is established to provide future connections to LA County sewer
Apr. 10, 1985	CA DPH to LA County Supervisors	Staff report and recommendation to authorize Sewer districts
July 8, 1987- Nov. 30 1988	LA Public Works Public Meeting and Malibu Citizens Committee public meetings	Draft Environmental Impact Report for Sewer, discussion of Malibu incorporating, discuss alternatives for centralized system with wetland treatment
Jan. 18, 1989	LA County Supervisors hearing	STEP WWTP system construction approved
1992	Warshall et al. report finalized	OWDS in Malibu described. Pathogen removal quantified. Author states that systems require extensive management and recommends centralized system in some areas like Civic center
1994	Mark Gold Dissertation	Three studies between 1990 and 1992 show high fecal-indicator-bacteria densities at ankle-depth wave wash and human viruses in runoff from three storm drains in Santa Monica Bay including Malibu Creek and Lagoon
May 7, 1996	Haile, et.al. 1996 epidemiology study	22,085 subjects in epidemiology study at Surfrider, Will Rogers and Santa Monica, with detailed study results for Malibu.
Dec. 14, 1998	Regional Board Resolution 98-023	Directs Report of Waste Discharge for all OWDSs and ACL to City of Malibu
Aug 12, 1999	Regional Board Resolution 99-13	El Rio septic staff report: Poorly maintained septic linked to nitrogen contamination in groundwater

January 22, 1999	Haile, et al, 1999 epidemiology study	In Epidemiology July 1999, vol. 10, n. 4 22,085 subjects in epidemiology study at Surfrider, Will Rogers and Santa Monica showing increased risk to immersed-head swimmers for illness where fecal indicator bacteria are present.
1999	Dames and Moore study	Salt tracer, no pathogens found in wells within 200 feet, but tidal reversal confounds results
1999	URS Greiner study	Salt Tracer found at 20 feet in wells, but indicator bacteria not seen in short period test.
Dec. 12, 2002	Regional Board Resolution	Santa Monica Bay Bacteria Total Maximum Daily Load: beach pathogens attributed to loads from septic systems
March 21, 2003	EPA Malibu Creek Nutrient TMDL	Total Maximum Daily Load sets loads and numeric targets for total Nitrogen
2003	Questa study	Groundwater discharge to receiving water, quantified including volume from septic system discharge.
Aug 30, 2004	Stone study	Bacteria may enter receiving water where septic systems are found within 6-month travel time
Jan. 24, 2004	Regional Board Resolution	Malibu Creek and Lagoon bacteria TMDL: Tetra Tech surface water model sets loads for bacteria from septic systems
March 2006	Richard Viergutz, M.S. Thesis	Discharge of sewage-polluted groundwater into Malibu Creek and Lagoon resulting from groundwater surface interactions

Enterococcus as a Study Focus

Enterococcus is a bacteria indicative of the possible presence of etiological agents of human illness and a study focus for this analysis. Enterococcus was emphasized over fecal, total or Escherichia coli bacteria for the following reasons: (1) it is part of the flora of the human gut; (2) it is prevalent in discharge from septic systems into the leachfields in the Malibu Civic Center; (3) Annette Pruss' 1998 survey of epidemiology studies linking beach pathogens to human illness identified enterococcus as one of two bacteria correlating most strongly with highly credible gastrointestinal illness among swimmers; (4) The 58 sites sampled during the summers in Santa Monica Bay include data from the wet year of 2005 and the dry year of 2007; (5) it was correlated with increased human illness at Surfrider Beach, adjacent to the Civic Center, in the 1999 epidemiology study by Robert Haile and others; (6) the protocol for the sampling, transportation, and analysis of the most probable number of enterococcus colonies in 100 milli-Liters of water is well established in the refereed literature; and (7), the 1983 EPA marine recreational standard and its interpretation in the 2005 California Ocean Plan relate enterococcus density to both an acceptable illness threshold of 19 per 1000 swimmers and both a single sample and a geometric mean sample water quality objective.

Alternative indicators of human pathogens have been proposed, but the supporting research for candidates such as bacteroides or genetically defined species of enterococcus is insufficiently developed to support a new EPA criteria. In fact the 2005 study by Southern California Coastal Water Research Project or SCCWRP found bacteriodes in Ballona Creek, but not in Malibu Creek and Lagoon. Additional work is underway to determine if the density of bacteriodes retained after transport is sufficient for the species to serve as an indicator of human risk.

Species of enterococcus have also been identified in the feces of domestic animals, wild animals, birds, and in some plants. The genetic typing of enterococcus species in water along with the identification of other human-characteristic chemicals such as optical brighteners has been used to distinguish human from non-human enterococcus with some success in areas outside Malibu. The 1999 Haile epidemiology study results do not support dilution of enterococcus bacteria so as to preclude its value as an indicator of human illness. Specifically, the study found that for the same enterococcus densities, Surfrider Beach had a highly credible gastrointestinal illness with fever rate of 39 per 1,000 swimmers, which is higher than the 19 per 1,000 illnesses rate reported by EPA. The enterococcus concentration on the Malibu Civic Center beaches can be considered a conservative measure of the contribution of human fecal matter.

OWDS and Transport of Pathogens

Many studies have been completed within the last twenty years to characterize the transportation mechanisms of pathogens through the groundwater from the leachfield of septic systems or other OWDSs: Schaub and Sorber (1977) reported that viruses move by rapid infiltration and concluded that removal can be limited by low absorption rate of virus particles to soil. The authors used a mixed compound consisting of the tracer virus f2 and indicator bacteria in the tested septic tank and monitored the mitigation of indicators in well samples. It was found that enteric bacteria were quickly filtered by soil and concentrated on the soil surface; but the tracer viruses was not observed on the upper soil layers but was found in the down-gradient groundwater layers. Vaughn et al. (1983) also observed a preferential entrainment of bacteria, as opposed to viruses from septic discharge, in a shallow, sandy soil aquifer. These results illustrate that even when indicator bacteria are not present, viruses may still be present.

Goyal et al. (1979) further investigated the adsorption rates for different types or strains of viruses/bacteria to various types of soils. No specific viruses or bacteria were found to represent the general adsorptive behaviors of all viruses to soils, and no specific soil type can serve as a general model for all the soil types. Similarly, Chu et al. (2003) investigated the transportation rates of viruses passing through saturated and unsaturated soil columns. Strong correlations were found between virus adsorption and various factors, i.e. existence of metal oxides, water content, organic matter, pH, etc.

Bloch et al. (1990) presented a case study of a human virus infection (hepatitis A virus, HAV) due to groundwater contamination from on-site discharge system. The leachfield of the septic system in the studied site (a trailer park) was approximately 30 to 60 meters away from the drinking water well, and the author confirmed the direct association between septic discharge and virus infection. Fecal coliform was not significantly higher during the outbreaks period of hepatitis A.

These studies indicate the significant differences between viral and bacterial contaminants: viruses have the potential to penetrate the soil layers to a greater extent than bacteria. This highlights a limitation of using bacterial water quality indicators to predict viral groundwater contamination. However, it can be also implied that when higher densities of indicator bacteria occur, there is a higher risk that the soil layer can be contaminated by viruses. For example, Cuyk et al. (2004) reported a high correlation between virus concentrations and bacteria indicators in well-operated soil columns and field septic systems.

Recent work also shows that the beach is a more complex hydrologic environment than the steady state condition previously modeled (Stone 2005 Malibu Risk Assessment). Episodic freshwater transport has recently been documented (Izbicki, 2009 in process). Bacteria densities have been tentatively linked to tidal and seasonal changes (Boehm et al., 2004; De Sieyes et al. , 2008, Izbicki, 2009 in press). Other researchers used sand column studies to show bacteria and virus retention and remobilization was related to the movement of organic material and bacteria and viruses have recently been shown to adhere and remain viable in beach material until remobilized (Yamahara et al., 2007; Azadpour-Keeley et al., 2003; Noble et al., 1996; Schaub et al., 1997, Schijven et al., 2002; Stramer et al., 1984).

In 2007, Nathalie Tifenkni provided a survey of particulate transport in the groundwater and noted that the existing models are deficient in successfully predicting the movement of organic particles. The survey specifically notes that work predicting the subsurface slowing of bacteria movement has not been paralleled by equally vigorous exploration of the subsurface enhancement of bacteria movement.

> ”A substantial research effort has been aimed at elucidating the role of various physical, chemical and biological factors on microbial transport and removal in natural subsurface environments. The major motivation of such studies is an enhanced mechanistic understanding of the these processes for development of improved mathematical models of microbial transport and fate. In this review, traditional modeling approaches are systematically evaluated. A number of these methods have inherent weaknesses or inconsistencies (page 1455)….For instance, calculations based on Tufenkji and Elimelech (TE) equation indicate that particles in the size range of [about] 2μm (e.g. many bacteria) are nearly twice as mobile in porous media than previously believed (page 1461)….The release (detachment) of microorganisms from sediment grain surfaces can be of considerable importance in natural subsurface environments and engineered water treatment systems…an improved understanding of.. factors controlling microbial release are required before practical incorporation of this process into mathematic transport models (page 1646)… Future areas for fundamental research in this area have been identified and include (i) inactivation kinetics of microorganisms in soils, (ii) role of protozoan grazing in removal of bacteria, (iii) mechanisms of microbial detachment from sediment grain surfaces,)iv) interactions between cell/cyst surface biomolecules and mineral surfaces, and (v) the influence of physical and geochemical aquifer heterogeneity on microbial transport (page 1468).”

Other possible mechanisms that may result in the preservation of enterococcus include elevated nitrogen and/or oxygen levels (Azadpour-Keeley et al., 2003; Yates, 1985, 1986) in the subsurface or on the beach face. In addition, septic plumes are now known to stay intact during subsurface movement (Groundwater Monitoring and Assessment Program: Baxter, Minnesota, 1999) limiting the impact of subsurface dilution of discharged enterococcus densities.

Studies relating OWDS to Beach Pathogens[6]

Research completed over the last ten years has expanded the understanding of beach bacteria sources . For example, it has been demonstrated that the fecal-indicator-bacteria enterococcus are present at many California beaches. In 2003(b), Borchardt et al. reported that the density of septic systems correlated with increased rates of infectious diarrhea in children in central Wisconsin. The authors found that viral diarrhea increased by 8% for every additional holding tank in 640 acres and bacterial diarrhea increase by 22% for every additional holding tank in 40 acres. While household wells were sampled for bacterial, risks were attributed to surface contact with pathogens near septic systems.

In 2004, Boehm et al. reported that groundwater discharge of microbial pollution moved from a shallow beach aquifer on to the beach face at Huntington Beach. While fecal indicator bacteria were found in only one groundwater sample, column studies show that the transport of enterococcus is not inhibited by sand collected in the field. In addition, radium isotopes characteristic of groundwater linked 38% of the enterococcus variation to groundwater discharge.

In 2007, Yamahara et al. reported in Environmental Science and Technology, Vol. 41, No. 12, that 91% of sampled California coastal beaches had enterococcus present in sand. The presence of a putative pollution source such as a river, wave shelter and surrounding anthropogenic land use correlated with higher enterococcus concentrations in the sands.

In 2008, De Sieyes et al. reported that fresh nutrient-rich groundwater discharges in fortnightly pulses into the ocean across a beach from adjacent septic systems and leachfields. While fecal indicator bacteria and human enterococcus genes were found in monitoring wells and attributed to pollution from adjacent septic systems, the concentrations of these pathogens did not increase with nutrients in the surf zone.

In 2009, the American Association for the Advancement of Science summarized studies identifying Methicillin Resistant Staphylococcus Aureus Bacteria (MSRA) in ocean water and on beaches in Florida.. Citizens have claimed an MSRA infection was contracted at Malibu beaches. The infections, which are resistant to antibiotics and are more commonly found in hospitals, are now known to be transmitted to beach water through contact with infected individuals and, according to one report, through municipal effluent. The ability of the bacteria to travel via sewage has not been quantified.

Enterococcus has been grown in the laboratory setting in unseeded beach sand (Yamahara et al., 2009) and found in a freshwater environment free from human impact (Tiefenthaler et al., 2008 Enterococcus has also been shown to persist in the beach sand and occur in higher concentrations in organic beach

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[6] Early Technical Reviewers recommended enhancements of staff's summary of studies on beach pathogens completed since 2004. While it is beyond the scope of this document to present a complete literature study on the topic, the summary emphasizes the scope of ongoing technical investigations in the field. The authors of the papers cited, some of whom were Early Technical Reviewers, wished staff to emphasize that additional study is necessary to characterize the physical, chemical and biological processes which allow bacteria and viruses to move through the groundwater for surface discharge. The authors should be contacted for the most up-to-date information on their research and the interpretation of the work already completed.

debris where it may later be transported to near shore waters (Pednekar et.al, 2007; Yamahara et al., 2007).

These studies and others show that the beach is a more complex microbiological environment than was previously understood.

Potential Scenarios for Sources and Transport Mechanisms for Bacteria in the Malibu Civic Center.

Figure 10 shows the Malibu Civic Center with planned development (Questa, 2003), and the line of the cross section shown in Figure 11. The cross section shows possible paths of transport for the bacteria discharged into OWDS leachfields/seepage pits to Malibu Creek, Malibu Lagoon and the ocean. Note in the cross section that bacteria leaving OWDS in Malibu Colony or adjacent to Legacy Park have the shortest travel times and fewest opportunities for subsurface physical detention, chemical attack or biological predation.

The movement of septic system bacteria from the Civic Center area north of Pacific Coast Highway via subsurface transport to Surfrider Beach under summer conditions would require movement through the beach barrier into marine water (see Figure 11 [cross section]). Enterococcus from septics must survive physical, chemical and biological destruction in the subsurface before ocean discharge. Enterococcus from higher elevations within the watershed must travel further on the surface and both light and distance are known to cause de-activation of both viruses and bacteria (Azadpour-Keeley, 2003;Yates, 1985, 1986).

Figure 10. Planned development in the Malibu Civic Center from Questa 2003 and cross section line

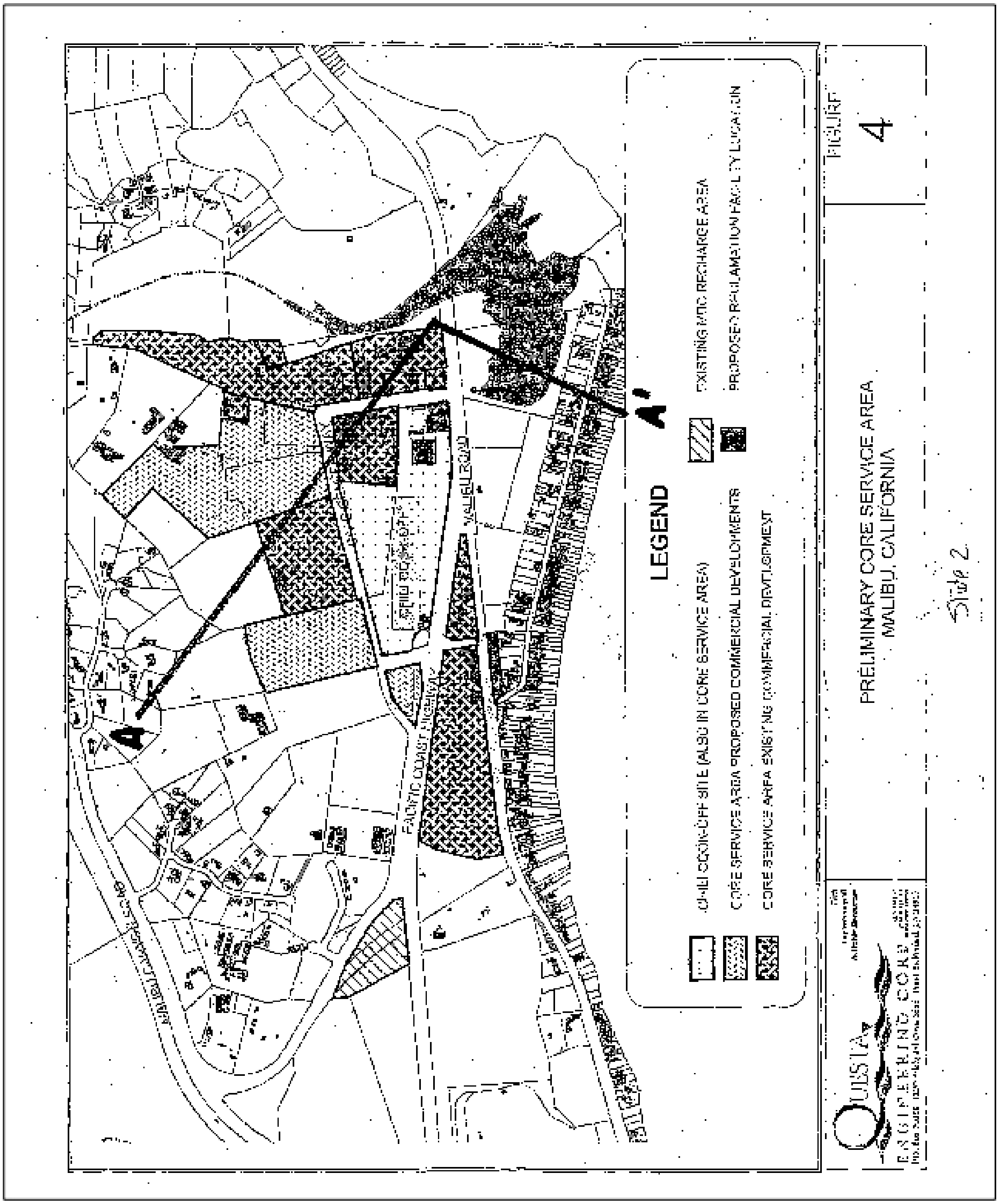
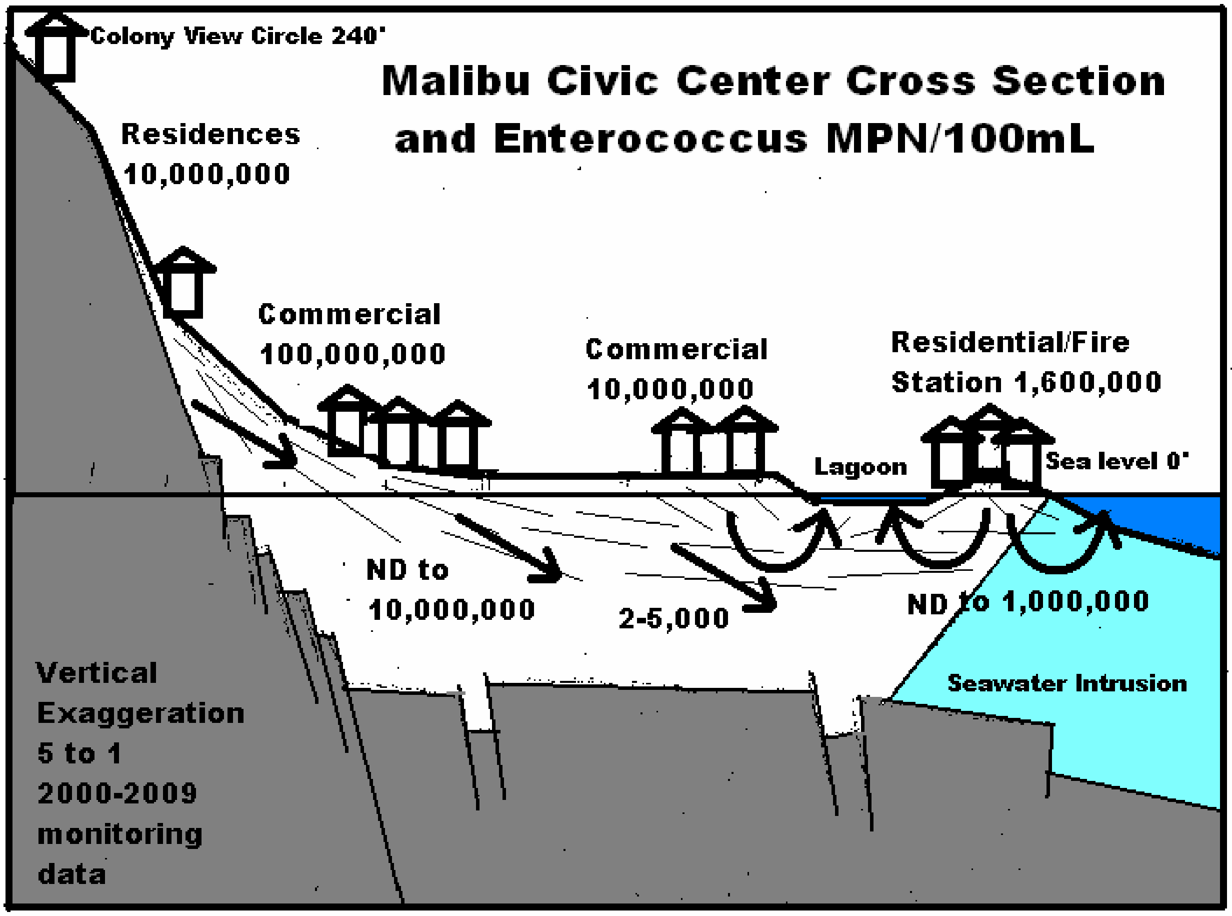


Figure 11. Cross Section A to A' showing facility and groundwater bacteria and flow paths



6. Conclusion

Malibu Creek, Lagoon, and nearby beaches are popular within the local community and as a destination for well over 1 million visitors per year. In the Basin Plan, the Regional Board has designated these waters for both water contact recreation (e.g. swimming) and non-contact water recreation (e.g. sunbathing, aesthetic enjoyment), and set standards, using the best available science, at levels that will protect human health.

As determined by the Regional Board and US Environmental Protection Agency, surface waters in the Malibu Creek Civic Center area are impaired for water contact recreation, and consistently have failed to meet State health and water quality standards set to protect swimmers and surfers in contact with the water. Repeated failures to meet standards set to protect public health have resulted in a poor water quality reputation for Surfrider Beach.

To examine the hydraulic connection of discharges from Onsite Wastewater Disposal Systems (OWDSs) through groundwater to nearby surface waters, staff evaluated more than 8,000 samples of wastewater effluent, underlying or nearby groundwater, and surface waters. Staff determined that pathogens from wastewaters are likely migrate to surface waters and that, consistent with data supporting the designations of impairments, threaten human health. This conclusion is based on our analysis of the indicator bacteria enterococcus. The levels of this bacteria do not meet standards protective of human health. Staff also determined that risks of infectious disease from water contact recreation were elevated at beaches in the Malibu Civic Center based on work by Haile et. al. 1999.

Staff also reviewed numerous previous studies, and found conclusions from these other studies to be consistent with staff's determination of impairment to the beneficial use of water contact recreation.

ATTACHMENT 3-A: Monitored Santa Monica Bay Beaches[7]

No	CSMP	Location	Linked Watershed	Treat-ment Type	Strom drain/ Freshwater	Total Acres
1	SMB 1-01	Arroyo Sequit Creek, Leo Carrillo State Beach	Arroyo Sequit	Septic	Y	7,549
2	SMB 1-02	El Pescador State Beach	Los Alisos	Septic	N	2,396
3	SMB 1-03	El Matador State Beach	Encinal	Septic	N	1,794
4	SMB 1-04	Trancas Creek	Trancas	Septic	Y	6,514
5	SMB 1-05	Zuma Break at Zuma Beach	Zuma	Septic	Y	6,339
6	SMB 1-06	Walnut Creek	Ramirez	Septic	Y	3,334
7	SMB 1-07	Ramirez Canyon at Paradise Cove Pier	Ramirez	Septic	Y	3,334
8	SMB 1-08	Escondido Creek	Escondido	Septic	Y	2,295
9	SMB 1-09	Latigo Canyon	Latigo	Septic	Y	813
10	SMB 1-10	Solstice Creek at Dan Blocker County Beach	Solstice	Septic	Y	2,841
11	SMB 1-11		Corral	Septic	Y	4,280
12	SMB 1-12	Marie Canyon Strom Drain on Puerco Beach	Corral	Septic	Y	4,280
13	SMB 1-13[8]	Sweetwater Canyon on Carbon Beach	Carbon	Septic	Y	2,320
14	SMB 1-14	Las Flores Creek on Las Flores State Beach	Las Flores	Septic	Y	2,897

[7] Data as reported in Santa Monica Bay beaches Bacteria TMDLs and SMB beaches Bacteria TMDL Coordinated Shoreline Monitoring Plan

15	SMB 1-15	Big Rock Beach	Piedra Gorda	Septic	Y	664
16	SMB 1-16	Pena Creek on Las Tunas County Beach	Pena	Septic	Y	608
17	SMB 1-17	Tuna Canyon	Tuna	Septic	N	1,013
18	SMB 1-18	Topanga Canyon on Topanga State Beach	Topanga	Septic	Y	12,575
19	SMB 2-01	Castlerock storm drain aka Parker Mesa Storm Drain	Castlerock	Sewer	Y	4,976
20	SMB 2-02	Santa Ynez Storm Drain	Santa Ynez	Sewer	Y	1,203
21	SMB 2-03	Will Rodgers State Beach 1/4 mile east of Gladstones	Santa Ynez	Sewer	N	1,203
23	SMB 2-04	Pulga Storm Drain on Will Rodgers State Beach	Santa Ynez	Sewer	N	1,203
24	SMB 2-05	Bay Club Storm Drain on Will Rodgers State Beach	Santa Ynez	Sewer	N	1,203
25	SMB 2-07	Santa Monica Canyon	Santa Monica Canyon	Sewer	Y	10,088
26	SMB 2-08	Venice Beach Pier	Venice Beach	Sewer	N	5,241
27	SMB 2-09	Topsail Street, Venice Beach	Venice Beach	Sewer	N	5,241
28	SMB 2-10	Culver Storm Drain	Dockweiler	Sewer	Y	6,573
29	SMB 2-11	North Westchester Storm Drain	Dockweiler	Sewer	Y	6,573
30	SMB 2-12	Dockweiler Beach	Dockweiler	Sewer	N	6,573
31	SMB 2-13	Imperial Highway Storm Drain	Dockweiler	Sewer	Y	6,573
32	SMB 2-14	Hyperion Plant, Dockweiler Beach	Dockweiler	Sewer	N	6,573
33	SMB 2-15	Grand Ave, Dockweiler Beach	Dockweiler	Sewer	Y	6,573
34	SMB 3-01	Montana Ave, Santa Monica Storm Drain, Santa Monica State Beach	Santa Monica	Sewer	Y	8,850

35	SMB 3-02	Wilshire Storm Drain, Santa Monica State Beach	Santa Monica	Sewer	Y	8,850
36	SMB 3-03	Santa Monica Pier Storm Drain, Santa Monica State Beach	Santa Monica	Sewer	Y	8,850
37	SMB 3-04	Pico-Kenter Storm Drain	Santa Monica	Sewer	Y	8,850
38	SMB 3-05	Ashland Storm Drain	Santa Monica	Sewer	Y	8,850
39	SMB 3-06	Rose Ave Storm Drain, Venice Beach	Santa Monica	Sewer	Y	8,850
40	SMB 3-07	Brooks Ave Storm Drain, Venice Beach	Santa Monica	Sewer	Y	8,850
41	SMB 3-08	Venice Pavillion	Santa Monica	Sewer	Y	8,850
42	SMB 3-09	Strand Street, Santa Monica State Beach	Santa Monica	Sewer	N	8,850
43	SMB 4-01	San Nicholas Canyon	Nicholas	Septic	Y	1,235
44	SMB 5-01	40th Street, Manhattan Beach	Hermosa	Sewer	N	2,624
45	SMB 5-02	28th Street Drain, Manhattan Beach	Hermosa	Sewer	Y	2,624
46	SMB 5-03	Manhattan Beach Pier	Hermosa	Sewer	Y	2,624
47	SMB 5-04	26th Street, Hermosa Beach	Hermosa	Sewer	N	2,624
48	SMB 5-05	Hermosa Beach Pier	Hermosa	Sewer	N	2,624
49	SMB 6-01	Herondo Storm Drain	Redondo	Sewer	Y	3,544
50	SMB 6-02	Redondo Beach Pier	Redondo	Sewer	Y	3,544
51	SMB 6-03	Sapphire Street	Redondo	Sewer	N	3,544
52	SMB 6-04	Topaz Groin	Redondo	Sewer	N	3,544
53	SMB 6-05	Avenue I	Redondo	Sewer	Y	3,544
54	SMB 6-06	Malaga Cove	Redondo	Sewer	N	3,544
55	SMB BC-01	Ballona Creek	Ballona Creek	Sewer	Y	81,980

56	SMB MC-01	Malibu Point on Malibu State beach	Malibu Creek	Septic	Y	70,410
57	SMB MC-02	Breach Point of Malibu Lagoon on Malibu State Beach	Malibu Creek	Septic	Y	70,410
58	SMB MC-03	Malibu Pier on Carbon Beach near Malibu Creek	Malibu Creek	Septic	Y	70,410
59	SMB 7-01	300 Paseo Del Mar, Palos Verdes Estates	Palos Verdes Peninsula	Sewer		10,023
60	SMB 7-02	Bluff Cove, Palos Verdes Estates	Palos Verdes Peninsula	Sewer		10,023
61	SMB 7-03	Long Point, 7200 Palos Verdes Drive South, Rancho Palos Verdes	Palos Verdes Peninsula	Sewer		10,023
62	SMB 7-04	6000 Palos Verdes Drive South, Rancho Palos Verdes	Palos Verdes Peninsula	Sewer		10,023
63	SMB 7-05	Portuguese Bend Club, Rancho Palos Verdes	Palos Verdes Peninsula	Sewer		10,023
64	SMB 7-06	White's Point/Royal Palms County Beach, San Pedro	Palos Verdes Peninsula	Sewer		10,023
65	SMB 7-07	Midway between White Point County Beach and Wilder Annex	Palos Verdes Peninsula	Sewer		10,023
66	SMB 7-08	Point Fermin/Wilder Annex, San Pedro	Palos Verdes Peninsula	Sewer		10,023
67	SMB 7-09	Cabrillo Beach, San Pedro	Palos Verdes Peninsula	Sewer		10,023

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Appendix T3-C[9]										
Enterococcus Frequency distributions for Civic Center Beaches and Selected Correlation Coefficients										
Malibu Pier						**Surfrider Beach**				
MPN/100mL	2005	2006	2007	2008		MPN/100mL	2005	2006	2007	2008
<10	0.417	0.067	0.464	0.233		<10	0.21	0.262	0.58	0.435
10	0.25	0.433	0.286	0.367		10	0.11	0.123	0.221	0.183
25	0.167	0.033	0.071	0.067		25	0.14	0.131	0.015	0.099
50	0.167	0.2	0	0.133		50	0.19	0.154	0.076	0.076
100	0	0.2	0.107	0.1		100	0.2	0.138	0.076	0.115
250	0	0	0.071	0.067		250	0.06	0.123	0.015	0.053
500	0	0.033	0	0.033		500	0.01	0.031	0.015	0.015
1000	0	0	0	0		1000	0.07	0.031	0	0
2500	0	0.033	0	0.033		2500	0	0.008	0	0.023
5000	0	0	0	0		5000	0	0	0	0
>5000	0	0	0	0		>5000	0	0	0	0
sum of frequencies	1	1	1	1.033			1	1	1	1
Correlation Coefficients			**2005-2006**	**2006-2008**		**Correlation Coefficients**			**2005-2006**	**2006-2008**
2007-2008	**2006-2007**		0.437	0.847		**2007-2008**	**2006-2007**		0.904	0.871
0.8075	0.427					0.98	0.78			

[7] Shaded boxes indicate corrections of clerical errors since 9/09/2009 Draft

State of California
California Regional Water Quality Control Board, Los Angeles Region

Peer Review – Staff Memorandum

Technical Memorandum #3:
Pathogens in Wastewaters that are in Hydraulic Connection with Beaches Represent a Source of Impairment for Water Contact Recreation

By

Elizabeth Erickson, Professional Geologist
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November 5, 2009

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To: Wendy Phillips, C.E.G., C.H.G.,
Chief of Groundwater Permitting and Landfills Section
Rebecca Chou, Ph.D. P.E., Chief of Groundwater Permitting Unit

From Elizabeth Erickson, P.G. Groundwater Permitting Unit

Date: October 21, 2009

Subject: Peer Review Response to Comments - Technical Memo #3: Pathogens in Wastewaters that are in Hydraulic Connection with Beaches Represent a Source of Impairment for Water Contact Recreation

Attachments:

1. Comments dated October 5, 2009 from Dr. Robert Arnold, Arizona State University
2. Comments dated October 7, 2009 from Dr. Jörg Drewes, Colorado School of Mines
3. Comments dated September 10, 2009 from Dr. JoAnn Silverstein, University of Colorado at Boulder

To ensure that the proposed amendment to the *Basin Plan*[1] is based on sound science and engineering principles, the scientific elements of Technical Memorandum #3: "Pathogens in Wastewaters that are in Hydraulic Connection with Beaches Represent a Source of Impairment for Water Contact Recreation" dated September 9, 2009, was peer reviewed. This peer review was conducted in accordance with requirements and guidelines from the Cal/EPA Scientific Peer Review Program, Office of Research, Planning and Performance.

Summary

Dr. Robert Arnold of Arizona State University, Dr. Jörge Drewes of Colorado School of Mines, and Dr. JoAnn Silverstein of the University of Colorado at Boulder agreed that the approach and methods used in Tech Memo #3 incorporate sound scientific and engineering principles. Although some suggestions were made to improve staff's discussion, none of the comments materially altered the conclusion of Tech Memo #3. That is: OWDSs in the Malibu Civic Center area cumulatively release bacteria to Malibu Beaches, where the enterococcus densities exceed the water quality criteria for the protection of human health.

[1] Proposed amendment to the *Water Quality Control Plan for Coastal Watersheds of Los Angeles and Ventura Counties (Basin Plan)* to prohibit on-site subsurface disposal systems (OWDSs) in the Malibu Civic Center area.

New Material Added

Dr. Bob Arnold asked for additional material to be added. Statistical support for the findings were added on page T3-17 and summarized in Appendix 1.

Dr. Arnold: "The contention here is that the correlations among annual frequency distribution provides evidence of annual similarities at each beach for which data were provided and thus an indication that fluctuation in enterococcus numbers is probably the result of some regular pattern of events as opposed to random odd events like direct communication with bathers, etc. I am unable to provide a convincing statistical analysis as part of this review…" (page 3).

Response: The enterococcus interval frequencies calculated for the beaches for four summers were compared using the Pearson's correlation coefficient. The number of measures were counted in each of eight intervals: (1) values less than or equal to ten; (2) more than ten but less than or equal to 25; (3) more than 25 but less than or equal to 50; (4) more than 50 but less than or equal to 100; (5) more than 100 but less than or equal to 250; (6) more than 250 but less than or equal to 500; (7) more than 500 but less than or equal to 1,000; and (8) more than 1,000. The intervals approximate a logarithmic distribution, but include more intervals between 25 and 100 and between 250 and 1,000, ranges in which the beaches contrasted most sharply. Pearson's correlation coefficient was applied following EPA's "Ambient Water Quality Criteria for Bacteria, 1986" as described in the following quote:

> "The examination of a number of potential indicators, including the ones most commonly used in the United States (total coliforms and fecal coliforms), was included in the study. Furthermore, the selection of the best indicator [enterococcus] was based on the strength of the relationship between the rate of gastroenteritis and the indicator density, *as measured with the Pearson's Correlation Coefficient. This coefficient varies between minus one and plus one. A value of one indicates a perfect relationship, that is, all of the paired points lie directly on the line which defines the relationship. A value of zero means that there is not linear relationship. A positive value indicates that the relationship is direct, one variable increases as the other increases. A negative value indicates the relationship is inverse, one variable decreases as the other increases.* The correlation coefficients for gastroenteritis rates are related to the various indicators of water quality from both marine and fresh bathing water as shown in Table 2" (page 5).

Staff also conducted an additional study to determine if evidence for groundwater contributions to beach bacteria could be statistically linked to existing water quality and hydrology data. Early technical reviewers commented that the approach had not been used before and asked for additional time to evaluate the study. The analysis is provided in Attachment #1.

Requests for Clarification

Dr. Arnold, Dr. Jorge Drewes and Dr. JoAnn Silverstein asked for clarification on three topics. Dr. Arnold requested clarification on how the scientific process was used. Dr. Drewes' inquiry on non-human sources for enterococcus and Dr. Silverstein's query about bacteria transport in groundwater have been resolved with clarifying language in the memo.

Dr. Arnold: "I feel that this is a weak argument, primarily because the statement does not seem to rest on statistically valid hypothesis testing. That is, do the calculated correlation coefficients in fact justify the conclusion that the distribution of values observed is derived from the same population of actual values each year - that the distribution of MPNs does not change from year to year. Even if that distribution of concentrations is time invariant (as suggested) it seems that the population of enterococcus concentrations in the waters tested may take on a distribution of this sort for any number of reasons, including a somewhat randomly generated source of contamination due to bathing and so forth. It seems difficult to justify the elimination of such an explanation based on the data provided."

Response: Material has been added on pages T3-2 and T3-25 to clarify the hypothesis testing process which led to the results.

Dr. Drewes: "The author neglects to state that there are also non-human sources for enterococcus, which could potentially contribute to the concentrations observed in beach samples, although the likelihood for non-human contributions is small in the given settings (page 1)."

Response: Enterococcus has been attributed by some researchers to feces from warm-blooded animals such as raccoons, a source which may be present at the Malibu beaches. See the additional clarifying material included on page T3-23 and in Attachment 2.

Dr. Silverstein: "..the Haile et. al. epidemiology study was based on illness resulting from swimming at or near storm drain outfalls. The 1983 EPA document, Health Effects Criteria for Marine Recreational Waters, was based on studies of illness linked with treated wastewater outfalls. These are both point sources at beaches. The mechanism for transport of septic tanks and subsurface infiltration such as those in Malibu is thorough porous media, which may lessen the risk of these discharges. One source of difference resulting from subsurface discharge is the removal of particulate matter and attached bacteria. The 1983 EPA Health Effects document noted that removal of suspended solids during wastewater treatment reduced the density of Salmonella."

Response: Both the Haile and EPA epidemiology studies measured illnesses associated with enterococcus from point and non-point sources. Additional clarifying discussion was added at T3-24 and in Attachment 3.

Recommendations Not Incorporated

Staff appreciated comments from Dr. Drewes and Dr. Silverstein and provides further explanation, but did not incorporate two recommendations. Dr. Drewes requested that more surface water information should be provided in the memo. Staff chose to rely on existing surface water documents. Dr. Silverstein commented that the end-of-pipe enterococcus measures were not consistent with average raw sewage densities. Staff agrees, but inserted additional discussion describing why a change was not made.

Dr. Drewes: "Data presented in this Technical Memorandum provide support that beach water quality in the vicinity of the Malibu Creek watershed repeatedly fails to meet water quality objectives. The data presented would not support that the water quality "persistently" fails to meet the water quality objectives since only a limited data set is presented. For some tables, information is missing regarding the size of the data set considered. For example, regarding Table 2, what is the total number of samples collected? Exceedances reported for the Surfrider Beach (2006 and 2007) in Table 2 seems to be based on data collected during six weeks in 2006 only, whereas the 2007 data set represents data collected over a four-month period. Are results presented in Tables 3-5 all data that is available for these sampling locations? At a minimum, a clarification should be provided in the Memorandum" (page 3).

Response: Sufficient evidence of a persistent problem has already been made available to the public in EPA's 2002 303(d) list, Santa Monica Bay Bacteria, Malibu Creek and Lagoon bacteria and Malibu Creek and Lagoon nutrient TMDLs and the 2008 NOV on stormwater exceedances in Malibu, but additional discussion was provided on page T3-7.

Dr. Silverstein: "Some of the data in Table 1 (page T3-3) seem questionable. For the Malibu Colony Plaza, the numbers of total and fecal coliform are identical, and typically fecal coliform are a log unit less than total. Also the number of Enterococci is higher than either total or fecal coliform, which is atypical in general, and not consistent with the other samples. For Fire Station 8, the data are more puzzling. In all samples, the MPN for enterococcus is equal to or greater than either total or fecal MPNs. …..these data should be questioned by anyone familiar with typical trends for these three indicators reported in the literature and therefore some explanation of the differences should be offered."

Response: The end-of-pipe data were provided to document that enterococcus can be discharged from OWDSs into groundwater. The bacteria densities and proportions are not consistent with sewage or non-sewage related waters. Inconsistencies within these samples is attributed to the wide range of data reported for OWDS effluent where disinfection has failed and different detection methods are used on serial grab samples of samples of partially treated sewage. See discussion added on page T3-4.

Dr. Silverstein: "The scientific basis for Figure 11 is weak…"

Response: The end-of-pipe values included in this figure show the wide variation in enterococcus densities entering the groundwater at the location indicated and discussed above. Staff questions if 'average' range of enterococcus in raw sewage concentrations from homogenized municipal waste is an appropriate criteria for well testing or septic tank outlet to a seepage pit. Numerous reported enterococcus values in the Malibu Civic Center wells and at end-of-pipe range up to 1×10^8 MPN/100 mL, suggesting that any one high value is not a computational, sampling or reporting error.

Comments in Support

Dr. Arnold: "Considering the entire argument presented and supporting information provided, the staff has made an adequate case for improving the microbial quality (indicators of fecal contamination) in Malibu ground water in order to improve the water quality in the near shore marine area off the Malibu coastline in order to reduce associated threats to human health (page 4)."

Dr. Arnold: "There are somewhat speculative, but increasingly accepted, mechanisms for the transport of bacteria and viruses from proximate ground waters, through the near-surface beach sand and into the surf zone. Observations regarding transport through the beach front were derived from studies outside the Malibu area, but in southern California, from multiple lines of experimentation. These have been described in peer-reviewed archival journals, adding to their credibility (page 4)."

Dr. Drewes: "The reviewer concurs with the interpretation of the key literature considering in this Technical Memorandum indentifying factors that increase the levels of pathogen indicators and risk to human health. The reviewer also concurs with the selection of enterococcus bacteria, since it is more persistent in water and sediments as compared to coliforms, as a recreational water quality indicator illustrating the presence of human waste at the sites studied "(page 1).

Dr. Drewes: "The reviewer agrees with staff's determination of impairment through pathogenic organisms and the conclusion that groundwater in this area is a source of impairment to lagoon and beaches (page 3)."

Dr. Drewes: "Plotting enterococcus occurrence data as frequency graphs is appropriate to illustrate distribution changes over several years for May-October summer time periods. (page 3)"

Dr. Drewes: "Correlation coefficients between annual enterococcus frequency distributions are reported for the Surfrider Beach (MC-2) data set only and they demonstrate that the variability of the distribution is small from year to year (page 3)."

Dr. Silverstein: "Overall, the movement of groundwater from the area served by OWDSs is well documented in other reports (Tech Memo 4). Literature cited confirms that pathogens, especially viruses, are transported in the subsurface from OWDSs, and would therefore reach the ocean water, especially in a sandy aquifer with short travel time. The presence of enterococcus in septic tank effluent, nearby groundwater, and the beaches is credible support for the contribution of OWDSs to contamination of the Malibu beaches by bacteria."

Dr. Silverstein: "a particular source of pathogen risk is associated with the fact that OWDSs serve a small number of people. This was discussed in the EPA Health Effects Criteria for Marin Recreational Waters (1983, page 49). That document notes that when the number of individuals who are sources of fecal waste becomes smaller, the ratio of pathogen-to-indicator density will vary highly from numbers based on aggregate wastes from a large population. If one or a small number of individuals in these small systems have an infectious disease, the ratio could approach 1, making the risk a significantly higher than that addressed by the water quality standard. The EPA document advises in that case, which may include OWDSs : " The solution is administrative action prohibiting such discharges into recreational waters."

Dr. Silverstein: "Taken as a whole, the conclusions of Technical Memos #3 and #4 are based on sound scientific principles and reasoning. Epidemiologic studies cited provide a strong basis for increased health risks to swimmers and the presence of indicator bacteria measured at the beaches, especially enterococcus, at concentrations higher than marine recreational water quality standards. There are some relatively minor concerns about interpretations of literature and some of the reported data as discussed above and in previous comments on Tech Memo #4. Addressing these will acknowledge real uncertainties that always exist with environmental studies, but will not weaken the conclusions."

Other Revisions

Dr. Arnold: "I feel that the case is well made for construction of sewerage in the Malibu area, but I was convinced in part by information from the supporting documents that might be included directly in the technical memorandum. The epidemiological case in particular requires supporting information. In my opinion, further studies are not required to justify Board action, so that recommendations specific to such studies are unnecessary. The complexity of the hydrology conditions, microbiological transport mechanisms and so forth are sufficiently plain (page 4)."

Response: The supporting documents have been included as part of the administrative record and posted on the website for the use of the public in considering Technical Memo #3. Specifically, we included Haile et. al, "An epidemiological study of possible adverse health effects of swimming in Santa Monica Bay", 1996; Haile et. al. "The health effects of swimming in ocean water contaminated by storm drain runoff", 1999; Gold, M.A. "What are the health risks of swimming in Santa Monica bay", 1994; and EPA "Health Effects Criteria for Marine recreational waters", 1983.

Dr. Silverstein: "Caution should be used in associated the bacteria indicator with human waste."

Response: Corrections in the text are made as per your recommendations emphasizing that enterococcus can also be associated with non-human waste.

Editorial and grammatical suggestions have been followed as appropriate, but are not specifically listed here. Staff wishes to express appreciation for the contributions of the peer reviewers.

Attachment #1

Comparison of Santa Monica Bay Beaches Adjacent to OWDS and to Sewers with Winter Rainfall using Gehan Statistical Test.

Dr. Arnold asked for additional statistical support for staff's findings.

Data

Beach data were collected as part of the "Santa Monica Bay Beaches Bacteria Total Maximum Daily Load Coordinated Site Monitoring Plan, April 7, 2004" (CSMP) and can be found at http://ladpw.org/wmd/npdes/beachplan.cfm.

Sampling procedures are standardized, including morning sampling in ankle-deep water at fixed points with testing in State certified laboratories. The study focused on records for June through August in 2005, May through October in 2006, April through October in 2007, and May through October in 2008, on a total of 58 beaches, 36 of which receive freshwater drainage (with MS-4 stormwater permits) and 22 of which do not. The beaches stretch from El Pescador Beach in the northwest to Redondo Beach in the southeast.

The sample sites were sorted according to characteristics, such as watershed size, land-use, fecal-indicator-bacteria concentrations, septic system presence, wave strength and beach visitor population. A full array of site characteristics were found to be represented: sewage or septic system waste treatments, adjacent groundwater levels of enterococcus levels above 1 MPN/100mL, watershed sizes ranging from 813 acres to 81,980 acres, urban acres ranging from 128 acres to 68,700 acres, and wave action identified from surf web-sites ranging from none to persistent. Some beaches had adjacent lagoons, tidally influenced pools, stormwater containments and low flow diversions.

Results

Enterococcus on Malibu Civic Center Beaches and all Santa Monica Bay Beaches

The enterococcus measures recorded on CSMP beaches over the summers 2005 to 2008 were sorted by interval frequency and plotted against the concentrations of Enterococcus (MPN/100mL). The method was chosen to minimize the impact of varying sample sizes and simplify large variations in the measures.

The beaches were found to have the most measures at 10 MPN/100 mL and some additional measures above 1,000 MPN/100 mL Figures A to D and Tables A to D of all Santa Monica Bay beaches for 2005 through 2008 show that these general characteristics are present for all the studied beaches.

Figure A. 40 Santa Monica Bay Beaches 2005 (All MS-4 beaches) Enterococcus Interval Frequency for June-August Single Measures[2]

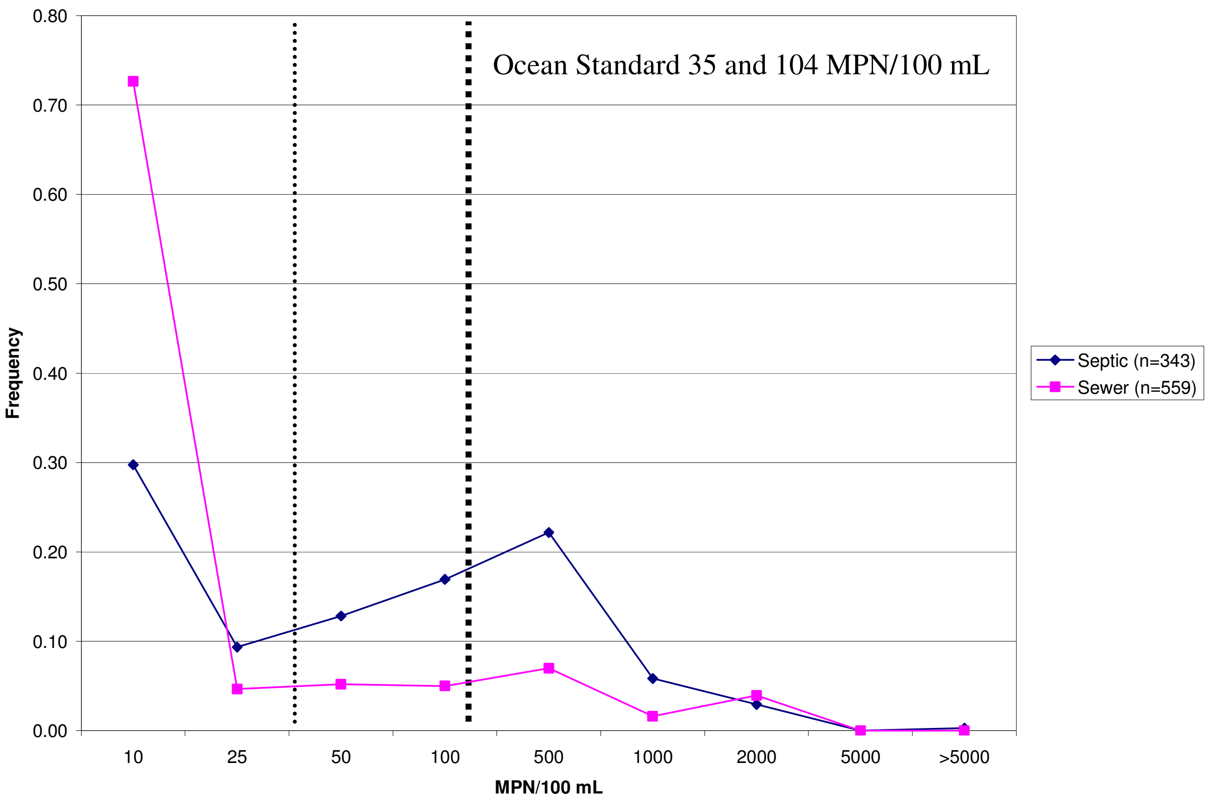


Table A: Relative Number of Exceedances for 57 Septic and Sewered Beaches in 2005.

In MPN/100mL	all beaches in 2005			
Enterococcus	Septic (n=466)	% total days reported at septic sites	Sewer (n=859)	% total days reported at sewer sites
Days above 35	206	44%	207	24%
Days above 104	108	23%	126	15%

[2] For the purposes of this study, the following site definitions were made: MS-4 Septic (19) 1-01, 1-03, 1-04, 1-05, 1-06, 1-07, 1-08, 1-09, 1-10, 1-11, 1-12, 1-13, 1-14,1-16,1-18, 4-01, MC-01, MC-02, MC-03; MS-4 Sewer (21) 2-01, 2-02, 2-06, 2-07, 2-10, 2-11, 2-13, 2-15, 3-01, 3-02, 3-03,3-04, 3-05, 3-06, 3-07, 3-08, 5-02, 5-03,6-01,6-05, BC-01; Non MS-4 Septic (3)1-02,1-15,1-17;
Non MS-4 Sewer (15) 2-03,2-04,2-05,2-08,2-09,2-12,2-14,3-09,5-01,5-04,5-05,6-02,6-03,6-04,6-06

Figure B. 40 Santa Monica Bay Beaches 2006 (All MS-4 beaches) 1nterococcus Interval Frequency for May-October Single Measures

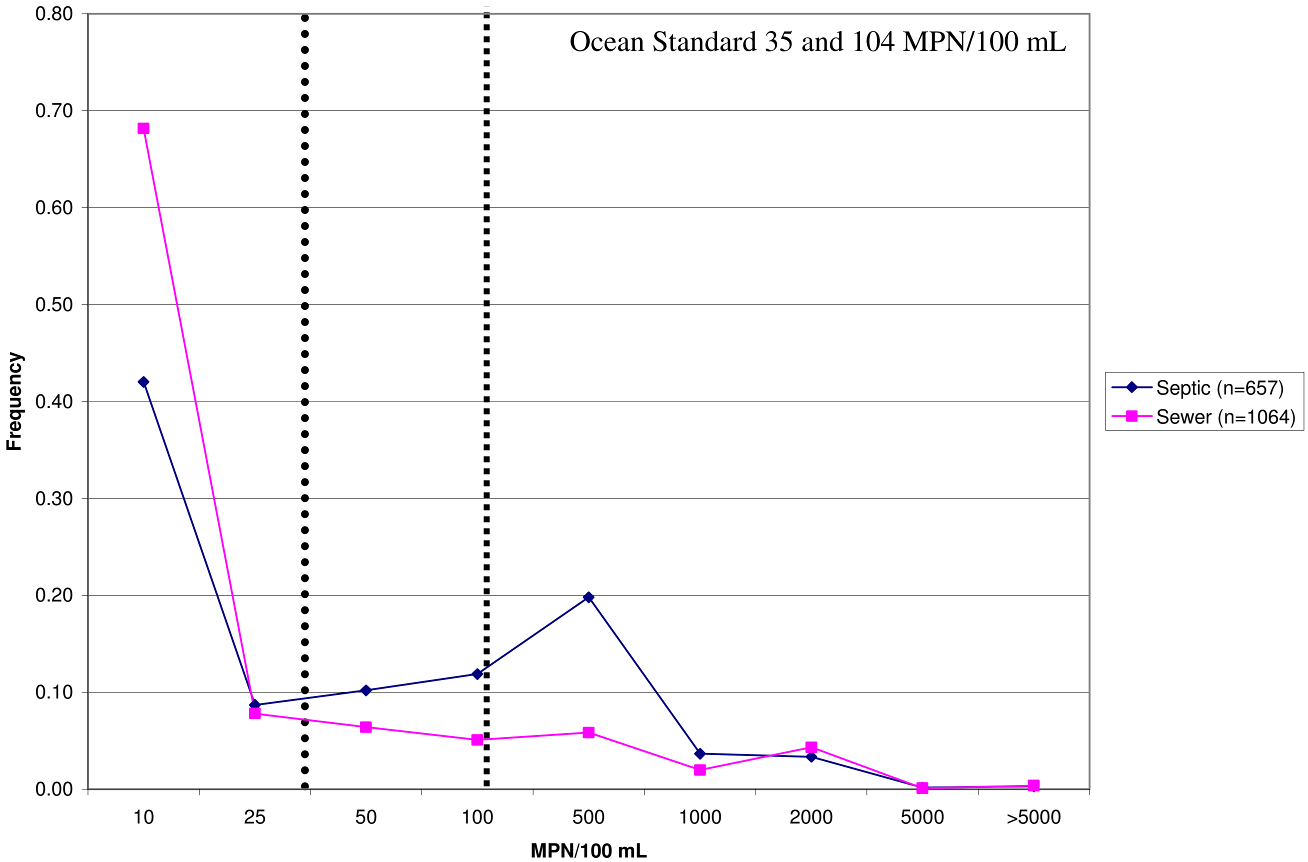


Table B: Relative Number of Exceedances for 57 Septic and Sewered Beaches in 2006. Sewered beaches were tested about one and a half times as often, in this year, as septic beaches, yet more days were recorded when enterococcus densities on septic beaches were higher than the Ocean single sample and geometric mean objectives.

In MPN/100mL	all beaches in 2006			
Enterococcus	Septic (n=903)	% total days reported at septic sites	Sewer (n=1669)	% total days reported at sewer sites
Days above 35	326	36%	295	18%
Days above 104	183	20%	156	9%

Figure C. 40 Santa Monica Bay Beaches 2007 (All MS-4 beaches) Enterococcus Interval Frequency for May-October Single Measures

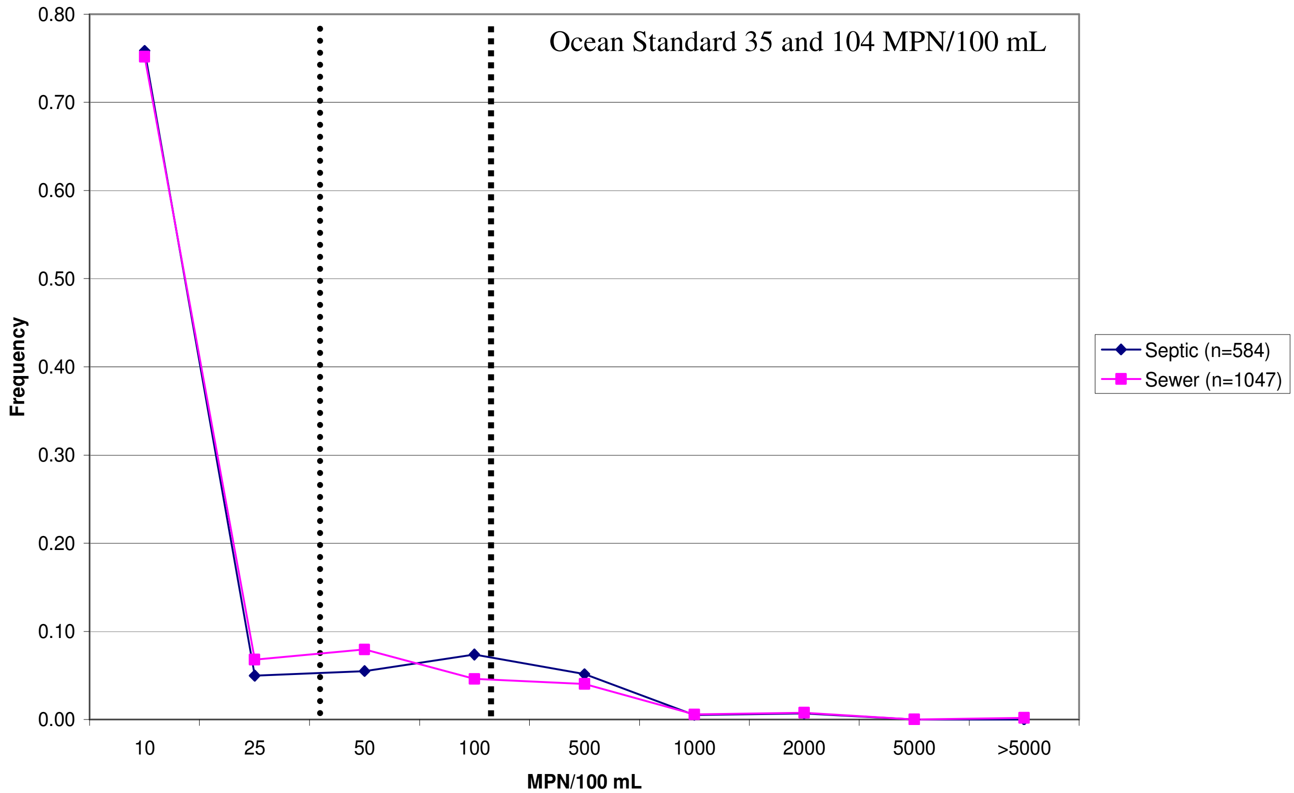


Table C: Relative Number of Exceedances for 57 Septic and Sewered Beaches in 2007. Sewered beaches were tested about twice as often, in this year, as septic beaches, and both had the same frequency of exceedances.

In MPN/100mL	all beaches in 2007			
Enterococcus	Septic (n=816)	% total days reported at septic sites	Sewer (n=1705)	% total days reported at sewer sites
Days above 35	106	13%	215	13%
Days above 104	38	5%	79	5%

Figure D. 40 Santa Monica Bay Beaches 2008 (All MS-4 beaches) Enterococcus Interval Frequency for May-October Single Measures

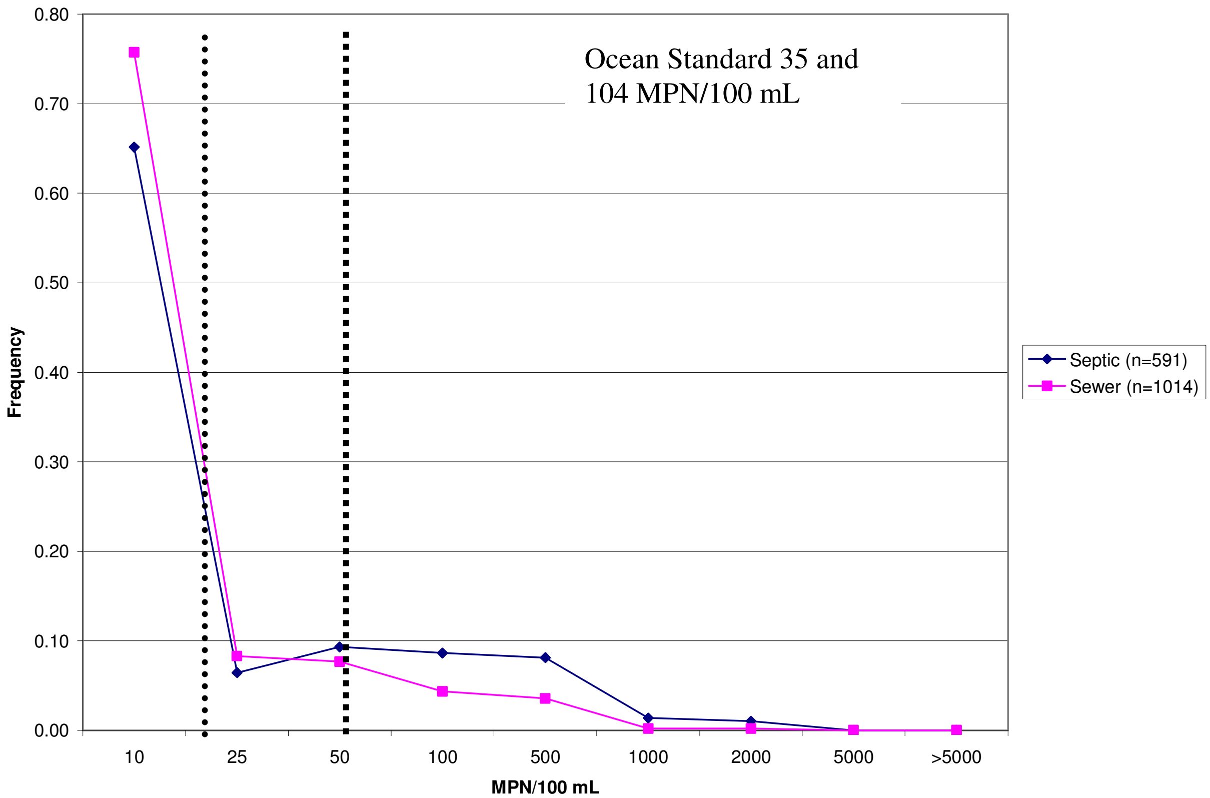


Table D: Relative Number of Exceedances for 57 Septic and Sewered Beaches in 2008.

In MPN/100mL	all beaches in 2008			
Enterococcus	Septic (n=813)	% total days reported at septic sites	Sewer (n=1644)	% total days reported at sewer sites
Days above 35	145	18%	176	11%
Days above 104	59	7%	54	3%

This annual comparison of all Santa Monica Bay beaches is consistent with the hypothesis that the mechanism(s) supplying enterococcus bacteria to beaches during the summer months does not operate uniformly every year. Further, the mechanism which supplies enterococcus bacteria to the beaches at levels of 10 MPN/100 mL, and to a lesser extent at levels above 1,000 MPN, must operate on all beaches regardless of the year or the method of waste treatment in the adjacent area.

The difference between the septic and sewered data sets for 2005, 2006 and 2008 is statistically significant.

Statistic analysis was performed for the same data sets of 2005-2008 using a t-test, and a Chi-square test. The use of these tools to measure the significance of enterococcus distributions was found to produce variable results depending on the size of the population and any truncation of the population. This observation is attributed to the non-normal and non-Chi-square shape of the distributions with a predominance of very low values and wide variations in the number and size of the largest values.

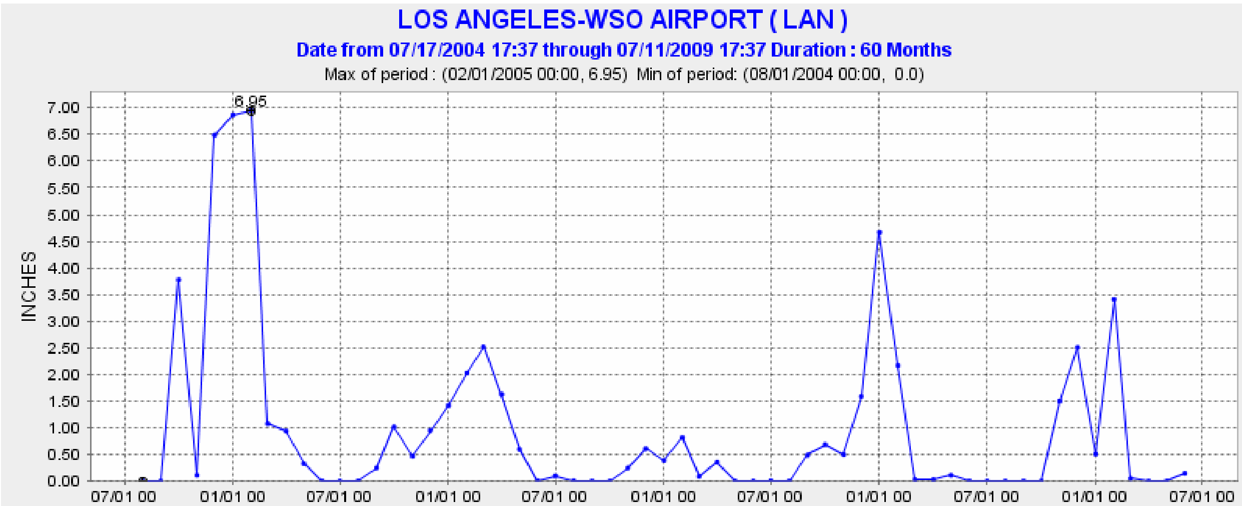
Consistent statistical results were obtained for the entire population of over 8,000 measures using the Gehan Test (a non-parametric Statistical Program) from USEPA ProUCL Statistical Program in conjunction with the Wilcoxsin and Quartile tests. All results confirmed hypothesis that enterococcus concentrations at septic beaches are greater than sewered beaches with 95% confidence level except for 2007 data. Gehan Test results and a discussion of the discarded methods are provided below.

This examination of all Santa Monica Bay beaches over four years provides evidence that bacteria may be transported by groundwater to the beach face as other mechanisms such as stormwater flow, overland urban flow, storm surge are minimal in the summer and the only other major source present only at septic beaches in groundwater discharge. Because bacteria must be transported by the groundwater between the septic systems and surface receiving waters and groundwater gradients increase after rain, a correlation between the number of enterococcus measures per site and the rainfall is expected at beaches where groundwater movement of the bacteria takes place.

Rainfall and Enterococcus

The highest monthly volume of rain fell in 2005 (wet year), among the years evaluated here, when 6.95 inches were recorded. The lowest was reported in 2007 (dry year) when less than one inch was recorded. However, the average annual rain fall in this area is 12 inches per year, significantly larger than the rain received in this study's "wet" year of 2005. Rain gauge reports from Los Angeles International Airport reported by the Department of Water Resources confirm annual variations in precipitation by year and are shown in Figure E.

Figure E. Rain gauge information for Los Angeles International Airport



1/1/05 1/1/06 1/1/07 1/1/08

Septic beaches are more distinct from sewered beaches in summers preceeded by rainy winters. The relative frequency of bacteria densities above 35 MPN/100mL on the beaches during the summer are seen to decrease between 2005 and 2007 in Tables A through D. The rainfall also decreases during this period as shown in Figure E.

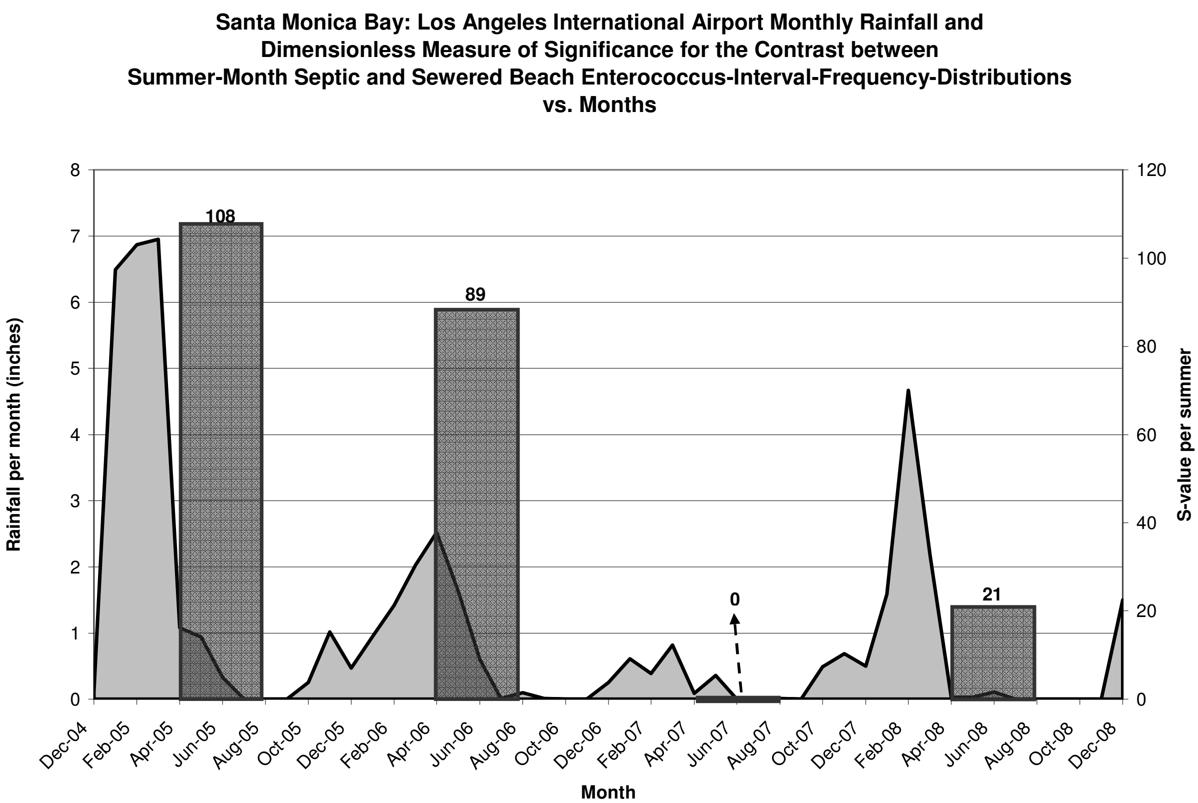
Non parametric statistical tools were applied to the enterococcus beach data sets using Gehan Test from EPA's ProUCL statistical program. Using Form 1 Test, the Null Hypothesis is "Septic Beach Mean/Median Less Than or Equal to Sewer Beach Mean/Median;" and the Alternative Hypothesis is "Septic Beach Mean/Median Greater Than Sewer Beach Mean/Median". The result of the Gehan Test for 2005, 2006 and 2008 shows that the Null Hypothesis is rejected by a low P-value with an alpha value of 0.05 (a confidence level of 95%) , which rejects the Null Hypothesis and supports the Alternative Hypothesis "Septic Beach Mean/Median Greater Than Sewer Beach Mean/Median".

The statistical assessments of the 2007 enterococcus data are not consistent with the statistical results for 2005, 2006, and 2008. The same results were also obtained with an alpha value of 0.01 (a confidence level of 99%); enterococcus concentrations at septic beaches are higher than concentrations at sewered beaches statistically. Form 2 Test is also performed using the Gehan Test to verify the above conclusions.

The "Substantial Difference" (S) is used to estimate the difference in enterococcus concentration between septic and sewered beaches and is shown in Figure F. The rainfall was low in 2007, as is the S value. The S increases as the winter rains increase in 2008.

Because septic or sewered beach have little stormwater discharge for June to September, these observations document a supply and transport mechansim. Ground water discharge with elevated enterococcocus densities after wet winters is affecting septic beaches to a greater extent than is occuring on sewered beaches. In the summer of 2008, the frequency of enterococcus densities above 35 MPN/100mL does not increase to the 2006 summer levels, despite increasing rainfall in the winter of 2007-2008, nor does the S value increase to 2006 levels. This observation is attributed to short term rain events in February 2008 when discharge was via stormwater and not groundwater recharge.

Figure F.



Septic Density

Septic Density did not show a strong correlation with enterococcus measures or interval frequencies.

The number of septic systems at a beach within 1000 feet of the CSMP monitoring location was estimated by counting roofs on air photos dating after 2004 and available for coastal areas on Google for the area northwest of Castlerock Mesa, where no sewer hook up is available. The counts are as follows:

Table E.

Beach with Lower Septic System Density	Sampling Point	Number of roofs within 1000 feet
Zuma Beach	1-05	3
Malibu Pier	MC-3	4
Leo Carrilo	1-01	5
San Nicholas Canyon	4-01	10
Solstice Creek an Dan Blocker Beach	1-10	10

Table F.

Beach with Higher Septic System Density	Sampling Point	Number of roofs within 1000 feet
Latigo Canyon	1-09	20
Surfrider Beach	MC-2	21
Trancas Creek	1-04	22
Walnut Creek	1-06	29
Sweetwater Canyon on Carbon Beach	1-13	32
Corral Canyon	1-11	34
Escondido Creek	1-08	34
Pena Creek on Las Tunas County Beach	1-16	36
Topanga Beach	1-18	41
Marie Canyon	1-12	43
Malibu Colony	MC-1	45
Las Flores Creek	1-14	58
Tuna Canyon	1-17	93
Ramirez Creek	1-07	120

Six beaches with no sewer connections and less than 20 roofs within 1000 feet of the CSMP monitoring point were compared with 14 beaches with no sewer connections and more than 20 roofs, as shown in Tables E and F and Figures G, H, J, and K. The plots below demonstrate that significant differences, as measured by the less reliable student t-test, were found on beaches in 2005 and 2006, when some rain fell. The following two years, a significant difference was not found. A weather related summer month difference, when direct discharge across the beaches is limited, is most likely attributed to groundwater flows.

Figure G.

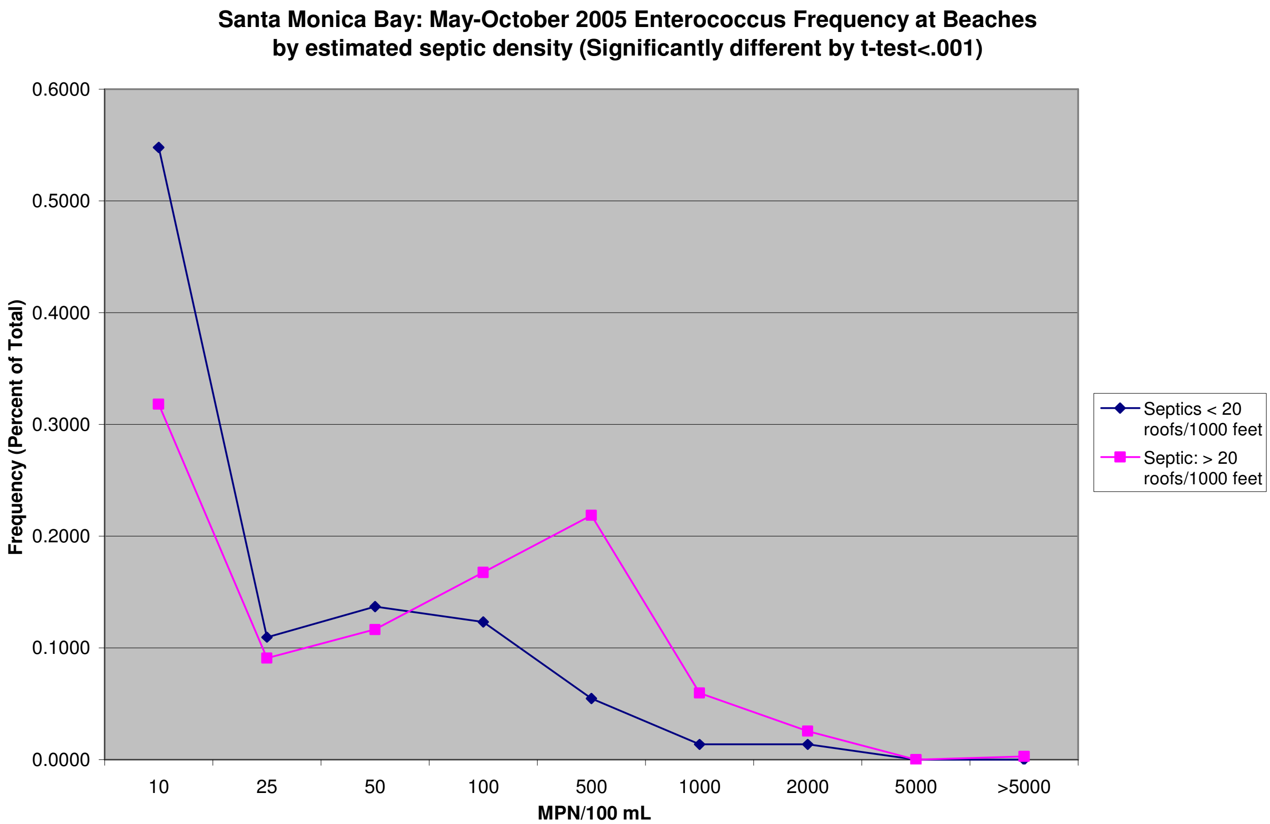

Santa Monica Bay: May-October 2005 Enterococcus Frequency at Beaches
by estimated septic density (Significantly different by t-test<.001)
Frequency (Percent of Total)
0.6000
0.5000
0.4000
0.3000
0.2000
0.1000
0.0000
10
25
50
100
500
1000
2000
5000
>5000
MPN/100 mL
Septics < 20 roofs/1000 feet
Septic: > 20 roofs/1000 feet

Figure H.

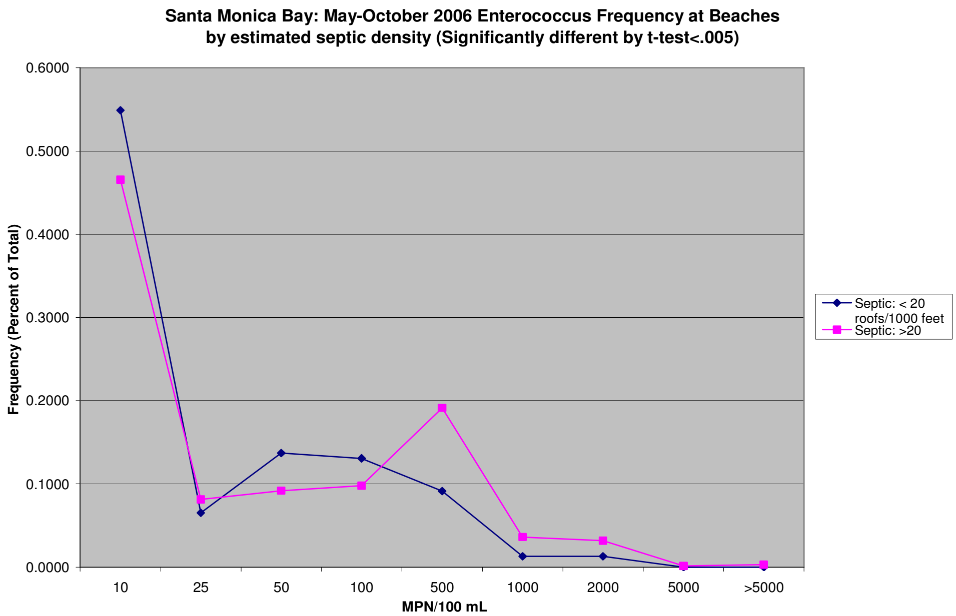


Figure J.

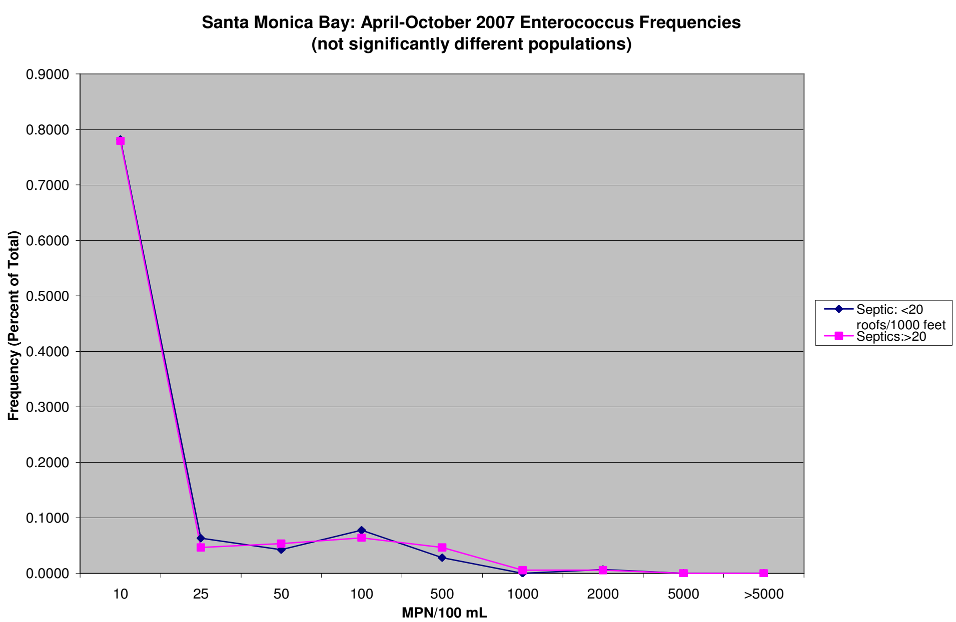
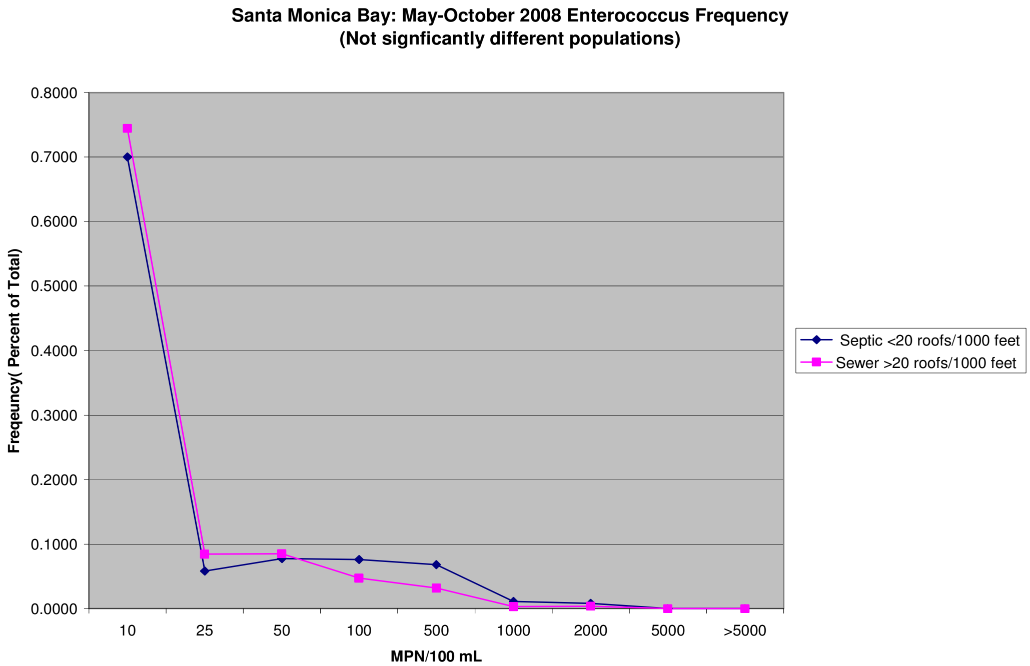


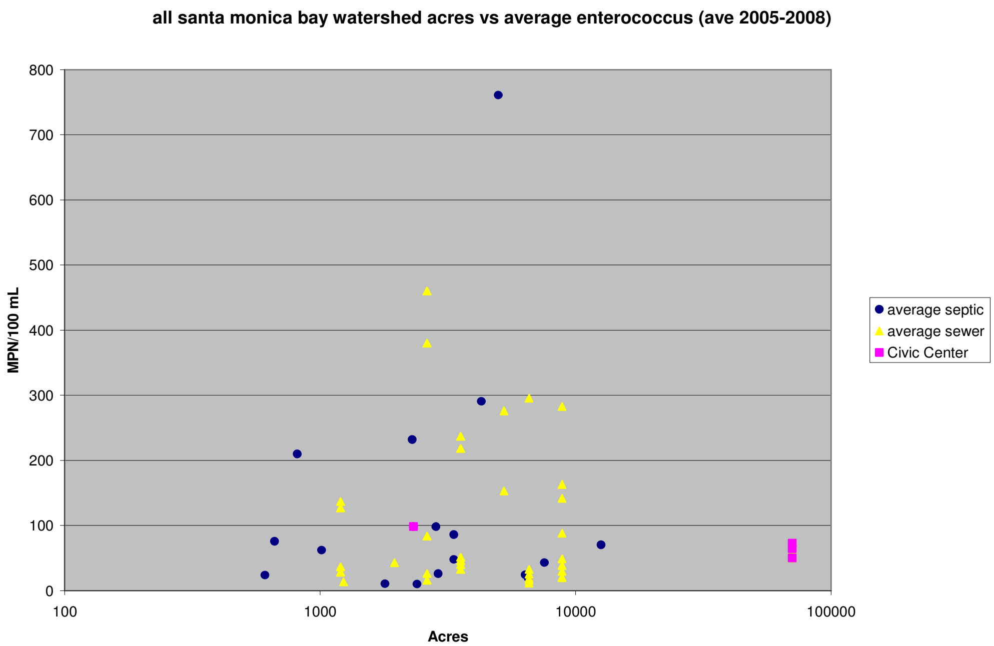
Figure K.



Watershed Area, Urban development and Beach populations

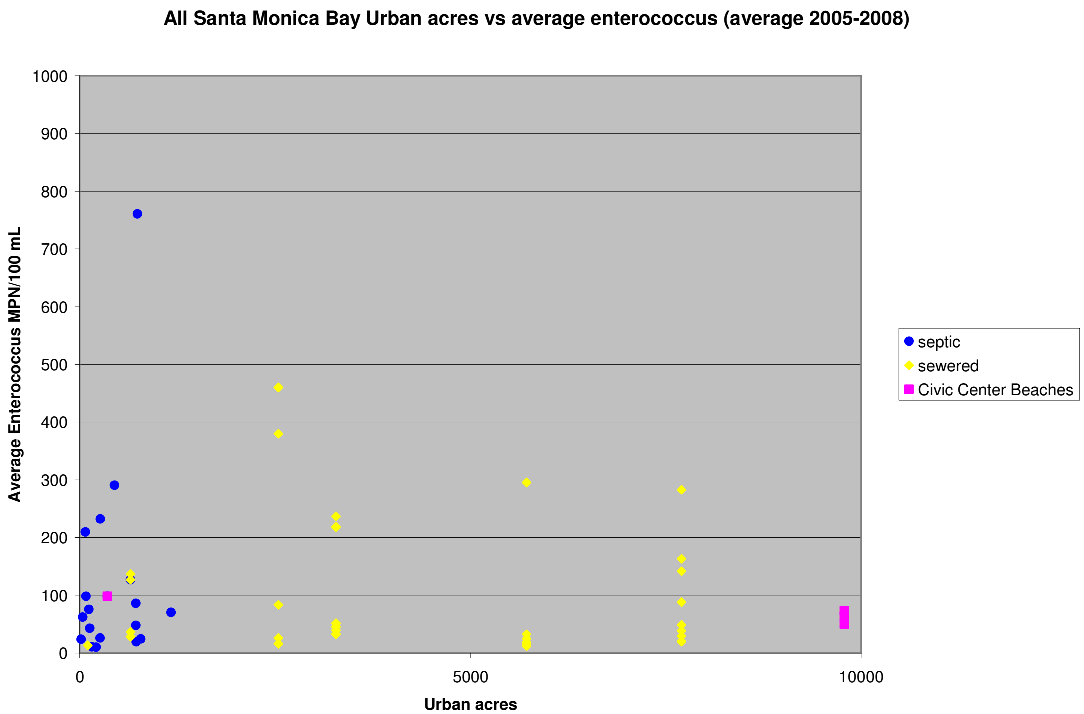
Watershed area, urban acreage and beach populations were not found to correlate with variations in enterococcus density distributions in Figure K. The following charts were prepared to show that the average enterococcus density on beaches with or without adjacent sewers is not seen to vary with these potentially confounding factors.

Figure L.



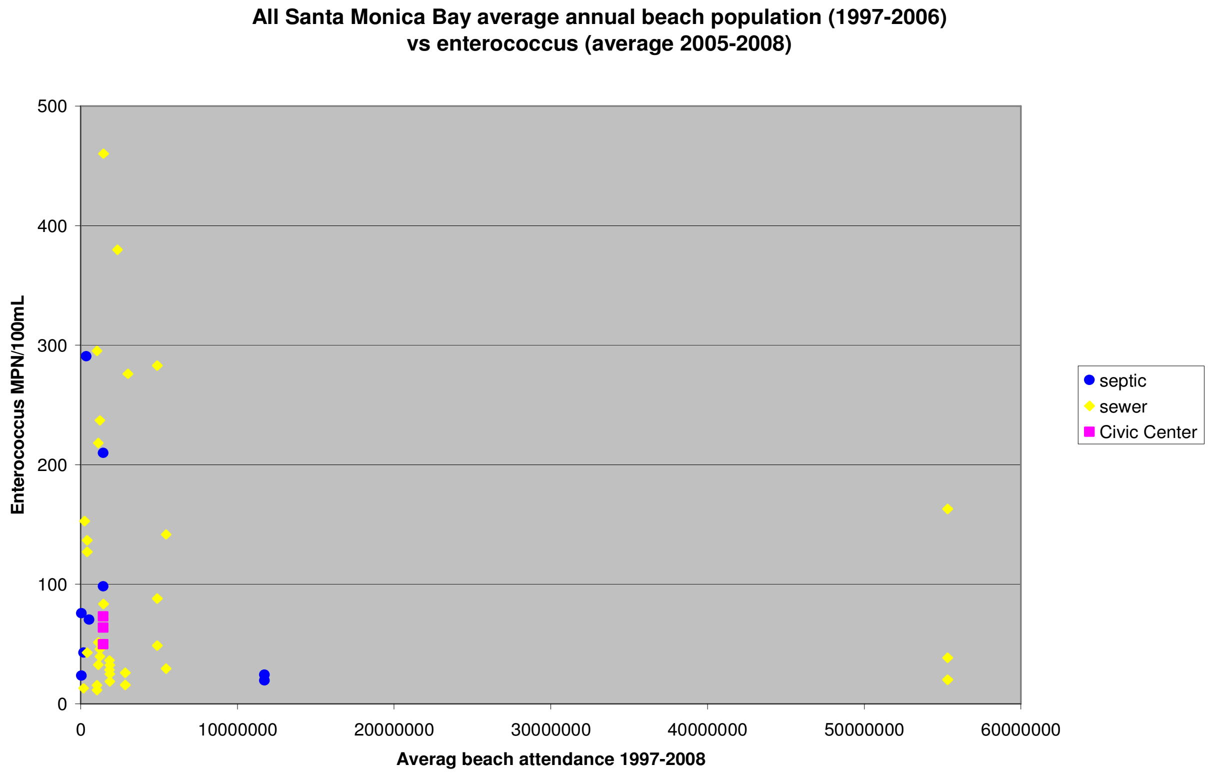
The Surfrider, Malibu Colony and Malibu Pier septic beaches appear on the right side of Figure L (greater than 10,000 acres) and a nearby beach, Sweetwater Canyon at Carbon beach, appears in the center (less than 5,000 acres). The acreage values come from the Santa Monica Bay bacteria Total Maximum Daily Load documents, and staff notes that three Civic Center beaches share the same high value for acreage. This may incorrectly suggest that the watershed size for is much greater than other beaches. Further evidence that watershed size does not correlate with enterococcus average comes from the two largest watersheds: Santa Monica Canyon with an average of 117.42 MPN/100 mL and acreage of 10,088; and, Ballona Creek with an average of 47.42b MPN/100 mL and acreage of 81,980.

Figure M.



No strong correlation is seen in Figure M above between urban acreage and average enterococcus densities for beaches with or without sewers. The Surfrider, Malibu Colony and Malibu Pier septic beaches appear on the right side of the chart (at 10,000 acres) and Sweetwater Canyon at Carbon beach appears on the left (at less than 1,000 acres). The acreage values come from the Santa Monica Bay bacteria Total Maximum Daily Load documents.

Figure N.



No strong correlation is seen in Figure N between acreage beach attendance and average enterococcus densities for beaches with or without sewers. The Surfrider, Malibu Colony, and Malibu Pier beaches appear on the left (at less than 1,000,000 people).

Statistical Significance

The application of statistical tools to the beach bacteria data sets revealed that standard tests have a high potential to produce misleading results. Additional statistical tests were used to confirm a significant difference between enterococcus interval frequency distributions for septic and sewered beaches in 2005, 2006 and 2007 for non-MS-4 beaches not including beaches with direct discharge to beach wave wash. The examination of enterococcus on beaches requires the manipulation of very large data sets. As an example, 7,081 measures were collected from beaches receiving MS-4 discharge in the summers of 2005 through 2008. The measures were not all normally distributed and were dominated by densities at or below 10 Most Probable Number (MPN)/100 mL (considered to be non-detect), with the presence of occasional measures above 24,000 MPN/100mL. The majority of the bacteria measures in the beach data sets had low and high enterococcus densities which together constitute a log normal distribution, but with interval frequencies between 50 and 1,000 MPN/100 mL which were not consistent with a log normal distribution.

Statistics which rely on normal distributions may produce false positive measures of significance for the beach bacteria populations. Many single beach samples assembled through weekly sampling over 4 summers did not have sufficiently large populations to allow statistical assessment with such tests. For example, an attempt to compare Surfrider and Manhattan (40th Street) beaches during the summer of 2007 was not successful because of the distribution of the measures for Manhattan Beach (9 measures below 10 MPN/100 mL, one of 24,000 MPN/100mL and 5 of 10 MPN/100mL). The resulting sample distribution was not normally distributed nor was the natural log of the sample distribution normally distributed. A comparison of the data with the larger sample at Surfrider Beach varied with the interval to which the statistical test was applied.

Where data sets are large, normal distributions can be created through repeated sampling. However, the largest data sets also had a few very large measurements and many small measurements, suggesting that population distribution is not improved with sampling. As an example, annual populations for all sewered and septic beaches had high correlation coefficients for large and small intervals, but not for the interval between 50 and 1,000 MPN/100 mL.

If normality was assumed and Student's t-tests and Correlation Coefficient were applied to the entire population, the results were repeatedly inconsistent. T-tests and t-tests of normal log values would show sewer and septic populations were distinct in a given year, but fail to provide this result if the data were truncated to remove high values or low values. The statistic package Minitab was used to apply the Chi-square test. When the chi square correlation was made on truncated populations of all beaches with some values below 10 MPN/100 ML removed, the results ($p<.05$) indicated that septic and sewered beaches did not belong to the same population. However, the removal of about half of the population was of concern.

Non parametric statistical tools were applied to the same data sets. When all septic and sewered beaches for the year 2005 - 2008 were contrasted using the non-parametric Quartile Hypothesis Test, the Wilcoxon-Mann-Whitney (WMW) Test and Gehan Test from EPA's ProUCL statistical program, the Quartile Test results recommend using the WMW Test. However, the WMW Test is only applicable for data set with less than 40% non-detect level of 10 MPN/100mL. Therefore, the Gehan Test is the most appropriate Test for this study. The Gehan test looks at all intervals and emphasizes the mean/median interval. The results are summarized in Tables 1 through 4.

The Null Hypothesis is termed "Septic Beach Mean/Median Less Than or Equal to Sewer Beach Mean/Median;" and the Alternative Hypothesis is "Septic Beach Mean/Median Greater Than Sewer Beach Mean/Median" using Gehan Form 1 Test.

The result of the Gehan Test for 2005, 2006 and 2008 shows that the Null Hypothesis is rejected by a low P-value with an alpha value of 0.05 (a confidence level of 95%) , which rejects the Null Hypothesis and supports the Alternative Hypothesis "Septic Beach Mean/Median Greater Than Sewer Beach Mean/Median". The 2007 data are not consistent with the results of 2005, 2006, and 2008 due to low groundwater discharge to beaches after dry winter. The same results were also obtained with an alpha value of 0.01 (a confidence level of 99%) that enterococcus concentration at septic beaches is higher than concentration at sewered beaches statistically.

Table 1 - 2005 Gehan Site vs Background Comparison Hypothesis Test for Data Sets with Non-Detects

User Selected Options		
From File	WorkSheet.wst	
Full Precision	OFF	
Confidence Coefficient	95%	
Substantial Difference	0	
Selected Null Hypothesis	Site or AOC Mean/Median Less Than or Equal to Background Mean/Median (Form 1)	
Alternative Hypothesis	Site or AOC Mean/Median Greater Than Background Mean/Median	
Area of Concern Data: septic		
Background Data: sewered		
Raw Statistics		
	Site	Background
Number of Valid Data	358	754
Number of Non-Detect Data	113	482
Number of Detect Data	245	272
Minimum Non-Detect	10	10
Maximum Non-Detect	10	10
Percent Non detects	31.56%	63.93%
Minimum Detected	20	20
Maximum Detected	9208	4200
Mean of Detected Data	261.7	368.9
Median of Detected Data	87	99
SD of Detected Data	661.3	591.3
Site vs Background Gehan Test		
H0: Mean/Median of Site or AOC <= Mean/Median of background		
Gehan z Test		
Value	9.461	
Critical z (0.95)	1.645	
P-Value	1.52E-21	
Conclusion with Alpha = 0.05		
Reject H0, Conclude Site > Background		
P-Value < alpha (0.05)		

Table 2 - 2006 Gehan Site vs Background Comparison Hypothesis Test for Data Sets with Non-Detects

User Selected Options		
From File	WorkSheet.wst	
Full Precision	OFF	
Confidence Coefficient	95%	
Substantial Difference	0	
Selected Null Hypothesis	Site or AOC Mean/Median Less Than or Equal to Background Mean/Median (Form 1)	
Alternative Hypothesis	Site or AOC Mean/Median Greater Than Background Mean/Median	

Area of Concern Data: septic
Background Data: sewered

Raw Statistics

	Site	Background
Number of Valid Data	685	1377
Number of Non-Detect Data	293	921
Number of Detect Data	392	456
Minimum Non-Detect	10	10
Maximum Non-Detect	10	10
Percent Non detects	42.77%	66.88%
Minimum Detected	20	20
Maximum Detected	24192	48010
Mean of Detected Data	324.9	532.3
Median of Detected Data	86.5	42
SD of Detected Data	1320	2701

Site vs Background Gehan Test

H0: Mean/Median of Site or AOC <= Mean/Median of background

Gehan z Test

Value	11.74
Critical z (0.95)	1.645
P-Value	4.17E-32

Conclusion with Alpha = 0.05
Reject H0, Conclude Site > Background
P-Value < alpha (0.05)

Table 3 - 2007 Gehan Site vs Background Comparison Hypothesis Test for Data Sets with Non-Detects

User Selected Options	
From File	WorkSheet.wst
Full Precision	OFF
Confidence Coefficient	95%
Substantial Difference	0
Selected Null Hypothesis	Site or AOC Mean/Median Less Than or Equal to Background Mean/Median (Form 1)
Alternative Hypothesis	Site or AOC Mean/Median Greater Than Background Mean/Median

Area of Concern Data: septic

Background Data: sewered

Raw Statistics

	Site	Background
Number of Valid Data	731	1364
Number of Non-Detect Data	574	1023
Number of Detect Data	157	341
Minimum Non-Detect	10	10
Maximum Non-Detect	10	10
Percent Non detects	78.52%	75.00%
Minimum Detected	10	20
Maximum Detected	2000	24192
Mean of Detected Data	127.5	260
Median of Detected Data	52	41
SD of Detected Data	281	1713

Site vs Background Gehan Test

H0: Mean/Median of Site or AOC <= Mean/Median of background

Gehan z Test	
Value	-1.226
Critical z (0.95)	1.645
P-Value	0.89

Conclusion with Alpha = 0.05

Do Not Reject H0, Conclude Site <= Background

P-Value >= alpha (0.05)

Table 4 - 2008 Gehan Site vs Background Comparison Hypothesis Test for Data Sets with Non-Detects

User Selected Options	
From File	WorkSheet.wst
Full Precision	OFF
Confidence Coefficient	95%
Substantial Difference	0
Selected Null Hypothesis	Site or AOC Mean/Median Less Than or Equal to Background Mean/Median (Form 1)
Alternative Hypothesis	Site or AOC Mean/Median Greater Than Background Mean/Median

Area of Concern Data: septic
Background Data: sewered

Raw Statistics

	Site	Background
Number of Valid Data	734	1315
Number of Non-Detect Data	514	979
Number of Detect Data	220	336
Minimum Non-Detect	10	10
Maximum Non-Detect	10	10
Percent Non detects	70.03%	74.45%
Minimum Detected	20	20
Maximum Detected	2000	2000
Mean of Detected Data	146.8	90.55
Median of Detected Data	53	31
SD of Detected Data	290.3	226.3

Site vs Background Gehan Test

H0: Mean/Median of Site or AOC <= Mean/Median of background

Gehan z Test	
Value	3.45
Critical z (0.95)	1.645
P-Value	2.81E-04

Conclusion with Alpha = 0.05
Reject H0, Conclude Site > Background
P-Value < alpha (0.05)

An additional measurement of significance using the Gehan test can be achieved by adding an investigation value (i.e. enterococcus concentration) to the mean/median before assessing the Null hypothesis to demonstrate the magnitude of difference using Gehan Form 2 Test. The larger this value, called substantial difference, S, the greater the difference between the populations, i.e., the greater an S, the greater an enterococcus concentration for septic beaches versus sewered beaches. Definitions from EPA's ProUCl program are detailed follow.

> Δ (delta): The true difference between the mean concentration of X in one sample and the mean of X in a second sample. Delta is an unknown parameter which describes the true state of nature. Hypotheses about its value are evaluated using statistical hypothesis tests. In principle, we can select any specific value for Δ and then test if the observed difference is as large as Δ or not with a given confidence and power.
>
> S (substantial difference): A difference in mean concentrations that is sufficiently large to warrant additional interest based on health or ecological information. S is the investigation level. If Δ exceeds S, the difference in concentrations is judged to be sufficiently large to be of concern, for the purpose of the analysis. A hypothesis test uses measurements from the site and from background to determine if Δ exceeds S.

In the study cases, the S value was calculated to determine the significance of the contrast between sewered and septic beaches for the summers of 2005, 2006, 2007 and 2008. The resulting S values show that septic beaches were most distinct from sewered beaches in 2005 after wet winter and not distinct in 2007 after dry winter. A substantial difference exists between septic and sewered beaches for every year except 2007.

Year	2005	2006	2007	2008
S value MPN/100 mL	108	89	0	21

The Gehan calculation with S factor calculation for the 2005 - 2008 are shown in Tables 5 - 9.

Table 5 – 2005 Gehan Site vs Background Comparison Hypothesis Test for Data Sets with Non-Detects

User Selected Options	
From File	WorkSheet.wst
Full Precision	OFF
Confidence Coefficient	95%
Substantial Difference	108
Selected Null Hypothesis	Site or AOC Mean/Median Greater Than or Equal to Background Mean/Median plus a Substantial Difference, S (Form 2)
Alternative Hypothesis	Site or AOC Mean/Median Less Than Background Mean/Median plus a Substantial Difference, S

Area of Concern Data: septic beaches
Background Data: sewered beaches

Raw Statistics

	Site	Background
Number of Valid Data	358	754
Number of Non-Detect Data	113	482
Number of Detect Data	245	272
Minimum Non-Detect	10	10
Maximum Non-Detect	10	10
Percent Non detects	31.56%	63.93%
Minimum Detected	20	20
Maximum Detected	9208	4200
Mean of Detected Data	261.7	368.9
Median of Detected Data	87	99
SD of Detected Data	661.3	591.3

Site vs Background Gehan Test

H0: Mu of Site or AOC >= Mu of background 108

Gehan z Test Value	-1.631
Critical z (0.95)	-1.645
P-Value	0.0514

Conclusion with Alpha = 0.05
Do Not Reject H0, Conclude Site >= Background + 108.00
P-Value >= alpha (0.05)

Table 6 – 2006 Gehan Site vs Background Comparison Hypothesis Test for Data Sets with Non-Detects

User Selected Options	
From File	WorkSheet.wst
Full Precision	OFF
Confidence Coefficient	95%
Substantial Difference	89
Selected Null Hypothesis	Site or AOC Mean/Median Greater Than or Equal to Background Mean/Median plus a Substantial Difference, S (Form 2)
Alternative Hypothesis	Site or AOC Mean/Median Less Than Background Mean/Median plus a Substantial Difference, S

Area of Concern Data: septic beaches
Background Data: sewered beaches

Raw Statistics

	Site	Background
Number of Valid Data	685	1377
Number of Non-Detect Data	293	921
Number of Detect Data	392	456
Minimum Non-Detect	10	10
Maximum Non-Detect	10	10
Percent Non detects	42.77%	66.88%
Minimum Detected	20	20
Maximum Detected	24192	48010
Mean of Detected Data	324.9	532.3
Median of Detected Data	86.5	42
SD of Detected Data	1320	2701

Site vs Background Gehan Test

H0: Mu of Site or AOC >= Mu of background 89

Gehan z Test Value	-1.353
Critical z (0.95)	-1.645
P-Value	0.088

Conclusion with Alpha = 0.05
Do Not Reject H0, Conclude Site >= Background + 89.00
P-Value >= alpha (0.05)

Table 7 – 2007 Gehan Site vs Background Comparison Hypothesis Test for Data Sets with Non-Detects

User Selected Options	
From File	WorkSheet.wst
Full Precision	OFF
Confidence Coefficient	95%
Substantial Difference	0
Selected Null Hypothesis	Site or AOC Mean/Median Greater Than or Equal to Background Mean/Median plus a Substantial Difference, S (Form 2)
Alternative Hypothesis	Site or AOC Mean/Median Less Than Background Mean/Median plus a Substantial Difference, S

Area of Concern Data: septic beaches
Background Data: sewered beaches

Raw Statistics

	Site	Background
Number of Valid Data	731	1364
Number of Non-Detect Data	574	1023
Number of Detect Data	157	341
Minimum Non-Detect	10	10
Maximum Non-Detect	10	10
Percent Non detects	78.52%	75.00%
Minimum Detected	10	20
Maximum Detected	2000	24192
Mean of Detected Data	127.5	260
Median of Detected Data	52	41
SD of Detected Data	281	1713

Site vs Background Gehan Test

H0: Mu of Site or AOC >= Mu of background 0

Gehan z Test Value	-1.226
Critical z (0.95)	-1.645
P-Value	0.11

Conclusion with Alpha = 0.05
Do Not Reject H0, Conclude Site >= Background + 0.00
P-Value >= alpha (0.05)

Table 8 – 2008 Gehan Site vs Background Comparison Hypothesis Test for Data Sets with Non-Detects

User Selected Options	
From File	WorkSheet.wst
Full Precision	OFF
Confidence Coefficient	95%
Substantial Difference	21
Selected Null Hypothesis	Site or AOC Mean/Median Greater Than or Equal to Background Mean/Median plus a Substantial Difference, S (Form 2)
Alternative Hypothesis	Site or AOC Mean/Median Less Than Background Mean/Median plus a Substantial Difference, S

Area of Concern Data: septic beaches
Background Data: sewered beaches

Raw Statistics

	Site	Background
Number of Valid Data	734	1315
Number of Non-Detect Data	514	979
Number of Detect Data	220	336
Minimum Non-Detect	10	10
Maximum Non-Detect	10	10
Percent Non detects	70.03%	74.45%
Minimum Detected	20	20
Maximum Detected	2000	2000
Mean of Detected Data	146.8	90.55
Median of Detected Data	53	31
SD of Detected Data	290.3	226.3

Site vs Background Gehan Test

H0: Mu of Site or AOC >= Mu of background 21

Gehan z Test Value	-0.305
Critical z (0.95)	-1.645
P-Value	0.38

Conclusion with Alpha = 0.05
Do Not Reject H0, Conclude Site >= Background + 21.00
P-Value >= alpha (0.05)

Attachment #2

Non-Human Sources for Enterococcus

Dr. Drewes asked Staff to include additional discussion on non-human sources for enterococcus

Staff finds that enterococcus densities exceeding the water quality objective are a sufficiently reliable indicator of human health risk despite research documenting non-human sources for the bacteria.

Enterococcus, a genus of bacterium, has been found in feces from humans and warm-blooded animals including marine birds. State and federal standards establish a water quality objective of 35 MPN/1000 mL enterococcus for any marine human-contact recreation, yet genetic typing of the enterococcus has been used to preferentially close beaches when human enterococcus was identified. The Vermont case, described below, resulted in fewer beach closures using this more sophisticated method when combined with a reduction of the human-sourced bacteria identified, a process which has not proved successful in Malibu.

> "The Vermont staff deployed Microbial Source Tracking (MST) to classify isolates of enterococcus as being from humans, birds, dogs, or wildlife sources, and flurometery (detection of optical brighteners in detergents from sewers and septic drain fields) was added as a chemical method to differentiate between human and non-human sources of pollution. Based on 2004 results that human sources of pollution were present at several beaches, investigations by officials from Hampton, Newport News and Hampton Road Sanitation Districts identified probable sources of the pollution and took steps to eliminate the problems. Sampling in 2005 and 2006 confirmed the success of these efforts (reduction in the level of pollution from human sources) and demonstrated improved water quality conditions at beaches….Hilton, King-Lincoln and Anderson Beaches all had advisories in 2004 and 2005, but none in 2006. This demonstrated the success of using MST to identify sources of fecal pollution in 2004, performing remediation to remove the origins of the pollution in 2005, and then follow-up with MST in 2006 to prove that the sources found in 2004 and 2005 were no longer present in 2006. This is the first report where MST results indicated pollution from a particular source was present (human-origin sewage), the origin of the pollution was then located, steps taken to eliminate the pollution, and subsequent MST results indicated the success of those remediation efforts. (Hagedorn, C., 2006, *Final Project Report: Microbial Source Tracking and Virginia Beach Monitoring Program.* Virginia Polytechnic Institutes and State University and Virginia Department of Health)"

Anti-biotic resistant enterococcus has been identified in bird waste and the proportion of antibiotic resistant species used to conclude that non-human sources generated entercoccus in densities exceeding water quality standards. In the Huntington Beach studies, garbage and an offshore sewage outfall were also identified the sources for anti-biotic resistant enterococcus to enter the food chain. The United States Fish and Wildlife provided the alternative explanation that the bird population, alone, was insufficient to explain the bacteria densities.

> "The Huntington Beach studies showed that the levels of bacteria generated within the marsh contributed to the bacteria population, but were not sufficient, in and of themselves, to account for the problem itself. Specifically, the studies showed that bacteria generated by birds in the Talbert Marsh could cause bacteria concentrations in the surf line near the marsh to briefly exceed criteria on outgoing nighttime or early morning tides. The study further concluded that fecal material deposited by western gulls is a significant source of indicator bacteria in the water flowing out of Talbert Marsh and that indicator bacteria growing on vegetation in the marsh and in marsh sediment may also contribute to the near shore loading of these microorganisms. The study additionally concluded that the levels of bacteria recorded along the beach were higher than could possibly have been generated by Talbert Marsh alone and that there has to be another source (page 47)…….data show that beaches near tidal wetlands do not have chronic beach postings. Postings on beaches near tidal wetlands had an average of about 2 postings for 12 days in 1999 while beaches not near wetlands had an average of about 3 posting for 32 days(page 49)." (US Fish and Wildlife Service, 2001 Staff Report and Recommendation on Consistency Determination: Bolsa Chica Lowlands, Orange County, California Coastal Commission Determination CD-061-01.)

Further, literature on non-human enterococcus sources does not include an epidemiology study linking decreased illness rates among swimmers exposed only to enterococcus species generated outside the human body. In fact, the 1983 Cabelli epidemiology study, upon which the 1983 EPA enterococcus criteria is based, states that the beaches studied did not all have an identifiable point source of human sewage. In addition, the 1999 Haile study looked at fecal, total, e. coli, and enterococcus and related human illness to the densities of each of these bacteria on the beach, even though both fecal and total bacteria are known to include bacteria species not related to human feces.

The literature on non-human sources of enterococcus reviewed by staff also fails to interpret a change to the enterococcus water quality objective, except to say in the most general way that the criteria may 'require revision.' Instead, Pruse's review in 1998 found that enterococcus was among the most reliable indicators of illness.

> "The indicator organism which correlate best with health outcome were enterococcus/fecal streptococci for both marine and freshwater (pg 3)." (Pruse, A, 1998, *Review of Epidemiological Studies on Health Effects from Exposure to Recreational Water*. International Epidemiological Association vol. 17, pages 1-9)

Future research is desirable to resolve these apparent contradictions in the application of the enterococcus standard. Staff offers the possible explanation that bacteria densities correlate with human illness because bacteria and virus densities are highest in microbiological and hydrological environments where bacteria are successfully transported and protected. The proximity and volume of a human fecal source would be the secondary variable controlling the infectious natural of the enterococcus observed. The 1998 Pruse summary confirms a correlation between illness and indicator bacteria in 19 of 22 studies.

Staff's explanation allows agreement with research showing enterococcus can exceed the water quality objective where no human fecal sources are present, without negating its use in protecting beaches where a proximal human fecal source is present. In the Malibu Civic Center, the three sources of human feces are stormwater, urban runoff and groundwater containing septic discharge. Further, concerns about an over-stringent application of the enterococcus standard are settled by the site specific epidemiology study linking illness rates at the Civic Center beach called Surfrider to bacteria density at approximately the published criteria rate for gastrointestinal symptoms which include a fever (HCGI 2). Staff notes that the enterococcus water quality standard is implemented nation-wide, has not been revised since 1983, and is the criteria upon which the Board must evaluate the exceedances shown.

Attachment #3

Bacteria Transport in Groundwater

Dr Silverstein comments that a reduction in pathogen density is expected between the OWDSs and the ocean. In fact, the rate and manner of bacteria and virus transport is not fully understood. The hydraulic and microbiological setting of the Civic Center beaches contains characteristics which may prevent bacteria and viruses destruction in the subsurface and enhance transport through the beach sand to the ocean on occasion in some locations.

In 2007, Nathalie Tufenkji provided a survey of particulate transport in the groundwater and noted that the existing models are deficient in successfully predicting the movement of organic particles. The survey specifically notes that work predicting the subsurface slowing of bacteria movement has not been paralleled by equally vigorous exploration of the subsurface enhancement of bacteria movement.

> ”A substantial research effort has been aimed at elucidating the role of various physical, chemical and biological factors on microbial transport and removal in natural subsurface environments. The major motivation of such studies is an enhanced mechanistic understanding of the processes for development of improved mathematical models of microbial transport and fate. In this review, traditional modeling approaches are systematically evaluated. A number of these methods have inherent weaknesses or inconsistencies (pg 1455)….For instance, calculations based on Tufenkji and Elimelech (TE) equation indicate that particles in the size range of [about] 2 um (e.g. many bacteria) are nearly twice as mobile in porous media than previously believed (pg 1461)….The release (detachment) of microorganisms from sediment grain surfaces can be of considerable importance in natural subsurface environments and engineered water treatment systems…an improved understanding of….factors controlling microbial release is required before practical incorporation of this process into mathematical transport models (pg 1646)… Future areas for fundamental research in this area have been identified and include (i) inactivation kinetics of microorganisms in soils, (ii) role of protozoan grazing in removal of bacteria, (iii) mechanisms of microbial detachment from sediment grain surfaces, (iv) interactions between cell/cyst surface biomolecules and mineral surfaces, and (v) the influence of physical and geochemical aquifer heterogeneity on microbial transport (page 1468) (Tufenkji, N. 2007, *Modeling Microbial Transport in Porous Media: Traditional Approaches and Recent Developments.* Advances in Water Resources vol. 30, pages 1455-1469)

Referred literature shows that colloids travel at elevated rates in discrete macro-pores instead of through uniform concentration fronts like dissolved species. Further, changes in colloidal movement have been attributed to chemistry, such as the difference between freshwater and saltwater, with more rapid colloid movement freshwater. As another example, a 2001 study showed that bacteria move more rapidly in ‘dirty’ packed sand than in clean sand.

> “We characterize the filtration and deposition profiles of a recombinant analog of Norwalk virus, an important waterborne pathogen, in packed beds of saturated quartz sand under both ‘clean-bed’ and ‘dirty-bed’ conditions. Under clean-bed conditions with

> NaCl as the electrolyte, the retained Norwalk virus particles decline like a power-law with depth. The power-law decay in retained particle concentration is consistent with the predictions of a recently proposed filtration model which assumes that microscale heterogeneity leads to particle filtration length scales of all sizes, i.e. the filtration is fractual in nature. However, under dirty-bed conditions with either groundwater or wastewater as the pore fluid, the deposited Norwalk virus particles profiles are considerably more complex. Analysis of these data using both the traditional filtration model and the fractal filtration model suggest that, under dirty-bed conditions, macroscale heterogeneity dominates virus removal rates. (Redman, J. A., Estes, M.K., and Grant, S.B, 2001, *Resolving macroscale and microscale heterogeneity in virus filtration*, Colloids and Surfaces A: Physicochemical and Engineering Aspects. Vol. 191, Issues 1-2, pg 57- 70)

Staff found literature both supporting and refuting the conclusion that the method and rate of groundwater well pumping may affect the reliability of bacteria samples collected. Higher pressure extraction rates are discussed as a possible mechanism for the destruction of bacteria. Staff proposes that well testing may not successfully sample the zones of preferential transport described above. Heterogeneity in aquifer properties and bacteria transport may not be represented by the homogeneous conditions assumed in traditional groundwater modeling.

Future research is desirable to resolve these challenges to existing groundwater modeling methods and introduce a measure of caution in predicting microbiological transport based solely on water movement. The prediction that variations in subsurface flow conditions can affect bacteria transport is consistent with Izbicki's recent studies at Santa Barbara, his ongoing hydrology at Surfrider Beach, as well as De Sieyes work which links episodic nutrients pulses correlated with tides, to septic systems, and Boehms work which links groundwater to bacteria.

Staff offers the comment that rapid change in the subsurface hydrology, such as with breaching of the lagoon, may create variations in the proportion of septic bacteria which are present at the beaches. Just as swimming next to a flowing storm drain is currently discouraged, additional study may identify an elevated risk with summer swimming during periods of increased septic discharge, such as during neap tides or during low ebb of a spring tide.

State of California
California Regional Water Quality Control Board, Los Angeles Region

Peer Review

Technical Memorandum #3:
Pathogens in Wastewaters that are in Hydraulic Connection with Beaches Represent a Source of Impairment for Water Contact Recreation

By

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TM3-77

November 5, 2009

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Memorandum

5 October 2009

To: Ms. Wendy Phillips; Chief, Groundwater Cleanup and Permitting Section, CA Regional Water Quality Control Board

From: Bob Arnold

Subject: Review of Regional Board Staff Technical Memorandum #3: ***Pathogens in wastewaters that are in hydraulic connection with beaches represent a source of impairment for water contact recreation.***

I will first cover the technical issues delineated for review in an attachment to your email dated 10 September.

1. The interpretation of four technical documents selected to support Technical Memorandum #3—emphasis on the Haile documents (1996, 1999) and the 1983 EPA criteria for recreational risk in marine water.

- **An Epidemiological Study of Possible Adverse Health Effects of Swimming in Santa Monica Bay**—Haile et al., 1996. This is a detailed and convincing piece of research that illustrates the type of health effects and relative risk associated with bathing on Santa Monica beach sites that are proximate to discharge points for overland runoff. Although the document does not bear directly on situations in which the presumed source of contamination is the proximate groundwater, the study shows very clearly that runoff containing contaminants of fecal origin produces both elevated concentrations of fecal indicators and higher incidence of waterborne disease among those bathing in impacted waters. The study also establishes the relevance of enterococcus concentration as a useful indicator and the usefulness of the disease parameters (symptoms such as gastrointestinal and respiratory problems, rash and so forth) eventually selected for use in Technical Memorandum #3.
- **Haile, R.W., Witte, J.S., Gold, M. *et al.* 1999. The health effects of swimming in ocean water contaminated by storm drain runoff. *Epidemiology 10*: 355-363.** This is apparently the peer reviewed form of the same study in Santa Monica Bay. The fact that the work withstood peer review for archival publication is noteworthy and adds to the credibility of the study and interpretation of findings. The authors note that their findings may have widespread relevance since the indicators of fecal contamination are similar to those at a great number of other

beaches. They also indicate that incremental risk upon exposure to waters containing those levels of the indicator organisms is probably significant based on the results of their work (incremental risk on the order of >1 per 100 exposed). Finally, they make the point that the standards for fecal indicators in marine recreational areas appear to be relevant since exposure at lower levels had no statistically significant health outcome. The article did not stress use of enterococcus results in predicting incidence of disease, but relied on coliform measurements and direct measurement of virus.

- **Gold, M. 1994. What are the health risks of swimming in Santa Monica Bay: an examination of the issues surrounding the public health debate. Ph.D. dissertation, UCLA.** The dissertation largely set the stage for the subsequent epidemiological study (above). The major finding related to high concentrations of fecal indicators including enteric viruses across the bay. There was comment about higher than acceptable levels of indicator organisms in Malibu Bay, but that was not the primary focus of the work. The importance of the work was that it was done competently and that it provoked the subsequent study.
- **Cabelli, V.J. 1983. Health effects criteria for marine recreational waters. EPA-600/1-80-031.** This is an exceptional piece of work, as evidenced in part by the fact that we are still reading it. The document uses data from a variety of studies in the United States and Egypt to establish the methodologies for epidemiological work of this kind, selection of disease indicators, and justification for use of specific indicator organisms. The fact that findings are appropriate to several locations attests to their utility. Interestingly, the response of Egyptians to enterococci-indicated exposure was reduced, but that of visitors was not, in the Alexandria study. The current standards for enterococci in seawater can be justified on the basis of the study results, since significant swimming-related disease incidence was provided by exposure to waters containing 10-100 enterococci per 100 mL. In fact, the swimming related incidence of HCGI illness was about double that of the endemic rate among non swimmers when waters contained ~50 enterococci per 100 mL. The author concluded that enterococci have a survival behavior more similar to the infectious agents that do other indicator organisms tested. The linear relationship suggested between swimming related incidence and log transformed enterococci data seems justified based on the studies reviewed.

2. Discussion of correlation coefficients among annual frequency distributions for enterococcus MPN data at Malibu beaches.

The contention here is that the correlations among annual frequency distributions provides evidence of annual similarities at each beach for which data are provided and thus an indication that fluctuation in enterococcus numbers is probably the result of some regular pattern of events as opposed to random odd events like direct contamination by bathers, etc.

I am unable to provide a convincing statistical analysis as part of this review. Nevertheless, I feel that this is a weak argument, primarily because the statement does not seem to rest on statistically valid hypothesis testing. That is, do the calculated correlation coefficients in fact justify the conclusion that the distribution of values observed is derived from the same population of actual values each year—that the distribution of enterococcus MPNs does not change from year to year. Even if that distribution of concentrations is time invariant (as suggested) it seems that the population of enterococcus concentrations in the waters tested may take on a distribution of this sort for any number of reasons, including a somewhat randomly generated source of contamination due to bathing and so forth. It seems difficult to justify the elimination of such an explanation based on the data provided.

As a minor point, the text on p. T3-15 indicates that correlation coefficients for MPN-dependent frequencies at the Surfrider Beach ranged from 0.82-0.98. The values provided in the Appendix T3-B table indicate that the correlation coefficient varies from 0.72-0.98. For those not statistically well informed (including me), the method of calculation of the correlation coefficient might be provided.

3. Validity of conclusion that water quality during dry weather at Surfrider Beach, Malibu Colony Beach, Malibu Pier Beach, Carbon Beach and Marie Canyon persistently fails to meet water quality objectives. This statement is well supported by the enterococcus data provided.

4. Conclusions regarding the groundwater origin of microbial contamination at Malibu Lagoon and beaches. Since this is the crux of the technical paper, it is well to consider the evidence presented in total. The staff report and references therein establish the validity of enterococcus measurements as an indicator of fecal contamination that provides a potential source of health risk. There is no reason to question the validity of the enterococcus standards for protection of public health. That is, consistent violations of the marine standard for recreational use will likely produce a significant disease increase among bathers. Consequently, the waters off Malibu, which do not meet standards, probably present a health-related problem. There are high concentrations of bacterial indicators of fecal contamination in the ground waters of heavily populated and commercial sections of the Malibu community. Furthermore, groundwater contaminants appear to add contamination to the enterococcus levels in the Malibu Lagoon at the MCW-1 sampling station, downstream from the Malibu Civic Center area. Finally, there are somewhat speculative, but increasingly accepted, mechanisms for the transport of bacteria and viruses from proximate ground waters, through near-surface beach sands and into the surf zone. Observations regarding transport through the beach front were derived from studies outside the Malibu area, but in southern California, from multiple lines of experimentation. These have been described in peer-reviewed archival journals, adding to their credibility.

No other credible sources of near-shore marine pollution are described in the technical report. If land surface runoff is a possibility, it seems unlikely that the effects would be so general or unmanageable during summer months, particularly since the period 2005-2008—the period of record for the measurements provided—was apparently an unusually dry period for the region. In any case, rainfall would likely increase the efflux of groundwater bacteria into the surf zone as well as increasing the rate of surface runoff.

Considering the entire argument presented and supporting information provided, the staff has made an adequate case for improving the microbial quality (indicators of fecal contamination) in Malibu ground water in order to improve the water quality in the nearshore marine area off the Malibu coastline in order to reduce associated threats to human health.

Additional comments. On page T3-2, it is indicated that several changes were made to the technical memorandum based on an Early Technical Review. These changes include generation of statistical support for conclusions, recommendations regarding additional supporting studies, emphasis on the hydrological and microbiological complexity of the subsurface intertidal region and verification of the relationship between human illness due to marine recreational activities and coastal OWDSs. In my opinion, statistically based inference remains largely missing from the document. The treatment of incremental risk at Surfrider Beach (Table 6) is apparently based on results reported in the 1983 EPA report and published information regarding bathing near stormwater discharge point in Santa Monica Bay. However, the connection here is not well developed and results of those studies that contribute to the staff position should be clearly laid out.

At this point, I feel that the case is well made for construction of sewerage in the Malibu area, but I was convinced in part by information from the supporting documents that might be included directly in the technical memorandum. The epidemiological case in particular requires supporting information. In my opinion, further studies are not required to justify Board action, so that recommendations specific to such studies are unnecessary. The complexity of the hydrological conditions, microbiological transport mechanism and so forth are sufficiently plain.

The technical memorandum (#3) is clearly written and easy to understand. The staff has done its work very well.

State of California
California Regional Water Quality Control Board, Los Angeles Region

Peer Review

Technical Memorandum #3:
Pathogens in Wastewaters that are in Hydraulic Connection with Beaches Represent a Source of Impairment for Water Contact Recreation

By

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November 5, 2009

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October 7, 2009

California Regional Water Quality Control Board
Attn.: Wendy Phillips
Chief, Groundwater Permitting and Landfills Section
320 W. 4th Street, Suite 200
Los Angeles, CA 90013

Re: Peer Review of Technical Memorandum #3 in support of an amendment to the Water Quality Control Plan for Coastal Watersheds of Los Angeles and Ventura Counties to Prohibit On-Site Subsurface Disposal Systems – Malibu Civic Center Area

Dear Mrs. Phillips,

Please find enclosed my review of the Technical Memorandum #3 *"Pathogens in Wastewaters that are in Hydraulic Connection with Beaches Represent a Source of Impairment for Water Contact Recreation"* prepared by Elizabeth Erickson.

The review is providing responses to questions formulated in Attachment 2.

Please feel free to contact me if you have any further questions.

Thank you very much.

Sincerely,

Professor Jörg Drewes

Scientific Review Report of Technical Memorandum #3

Pathogens in Wastewaters that are in Hydraulic Connection with Beaches Represent a Source of Impairment for Water Contact Recreation

by Elizabeth Erickson

a. The interpretation of key literature identifying factors that increase the levels of pathogen indicators and risks to human health at the beach

General:

The reviewer concurs with the interpretation of key literature considering in this Technical Memorandum identifying factors that increase the levels of pathogen indicators and risk to human health. The reviewer also concurs with the selection of entercoccus bacteria, since it is more persistent in water and sediments as compared to coliforms, as a recreational water quality indicator illustrating the presence of human waste at the sites studied. However, the author neglects to state that there are also non-human sources for enterococcus, which could potentially contribute to the concentrations observed in beach samples, although the likelihood for non-human contributions is small in the given settings.

Specifics:

- Table 1: Please clarify what the numbers reported for each site represent? – Are these replicates or discrete measurements at different days? What is the time period of data collection?

b. In particular, the interpretation of Haile et al. (1996 and 1999) epidemiology study and the 1983 EPA marine health criteria for health risk

Haile et al. (1996 and 1999) are representing the same experimental dataset published as a final research report (1996) and a subsequent peer-reviewed journal article (1999). Both Haile et al. studies (1996 and 1999) are reporting findings of epidemiological studies conducted in areas that are highly representative and directly linked to surface water and beaches targeted in this Technical Memorandum, - the Santa Monica Bay, Will Rogers Beach, and the Surfrider Beach. It is noteworthy that Haile et al. (1999) represents a journal article that was subject to a peer review process. The reviewer agrees with the key findings of this study that exposure to water impacted by storm run-off exhibits a higher risk of a broad range of human health symptoms, including both upper respiratory and gastrointestinal effects. The strength of the Haile et al. (1996, 1999) study is the size of the study population, the diversity of the population studied, and the assessment of adverse health outcomes through exposure to coliforms, enterococci, and viruses.

Staff's interpretation of the 1983 EPA marine health criteria for health risk agrees with the general published literature in this field (see review article by Pruess, 1998).

Pruess, A. (1998). Review of epidemiological studies on health effects from exposure to recreational water.

International Journal of Epidemiology 27: 1-9

c. The application of correlation coefficients in Figures 7, 8, and 9

Plotting enterococcus occurrence data as frequency graphs is appropriate to illustrate distribution changes over several years for May-October Summer time periods. These graphs illustrate that exceedance of the ocean standard of enterococcus is occurring consistently across the three study sites (MC-2, MC-1, and MC-3). The data also illustrate the gradient of severity in impact and as a consequence health effect outcomes. The classification scheme of either "safe" or "unsafe" based on meeting or failing ocean water standards does not seem to reflect this dynamic.

Correlation coefficients between annual enterococcus frequency distributions are reported for the Surfrider Beach (MC-2) data set only and they demonstrate that the variability of the distribution is small from year-to-year.

d. The conclusion, on pages T3-7 through T3-9, that water quality persistently fails to meet water quality objectives during dry weather at Surfrider Beach, Malibu Colony Beach, Malibu Pier Beach, Carbon Beach, and Marie Canyon

Data presented in this Technical Memorandum provide support that beach water quality in the vicinity of the Malibu Creek watershed repeatedly fails to meet water quality objectives. The data presented would not support that the water quality "persistently" fails to meet the water quality objectives since only a limited data set is presented. For some tables, information is missing regarding the size of the data set considered. For example regarding Table 2, what is the total number of samples collected? Exceedance reported for the Surfrider Beach (2006 and 2007) in Table 2 seems to be based on data collected during six weeks in 2006 only, whereas the 2007 data set represents data collected over a four-month period. Are results presented in Tables 3-5 all data that is available for these sampling locations? At a minimum, a clarification should be provided in the Memorandum.

e. The conclusion that groundwater, contaminated with indicators of pathogens, is a source of impairment to lagoon and beaches

The reviewer agrees with staff's determination of impairment through pathogenic organisms and the conclusion that groundwater in this area is a source of impairment to lagoon and beaches.

Overarching questions:

(a) In reading Tech Memos #3 and #4, are there any additional scientific issues, not described above, that are part of the scientific basis of the proposed rule? If so, please comment with respect to the statute language given above.

Regarding Tech Memo #3, there are not additional scientific issues that need to be addressed.

(b) Taking each of Tech Memo #3 and #4 as a whole, is the conclusion of each tech memo based on sound scientific knowledge, methods, and practices?

Regarding Tech Memo #3, with the exception of comments provided above, the conclusions presented in this Tech Memo are based on sound scientific knowledge, methods, and practices.

State of California
California Regional Water Quality Control Board, Los Angeles Region

Peer Review

Technical Memorandum #3:
Pathogens in Wastewaters that are in Hydraulic Connection with Beaches Represent a Source of Impairment for Water Contact Recreation

By

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November 5, 2009

Peer Review of Technical Memorandum #3:

Pathogens in Wastewaters that are in Hydraulic Connection with Beaches Represent a Source of Impairment for Water Contact Recreation

Revised Draft dated September 10, 2009

a. Interpretation of key literature, identifying factors that increase the levels of pathogen indicators and risks to human health at the beach.

Caution should be used in association of indicator bacteria with human waste, as is suggested on page T3-3, in two places. In the first sentence, referring to Table 1: "**Highlighted measures on the chart are fecal-indicator-bacteria values in human waste** which [sic, grammar incorrect] the water quality objectives for protection of body contract [sic, typo, should be "contact"] recreation." [emphasis added] The data in Table 1 are not per se values in human waste. The table caption is more accurate: "End-of-pipe Effluent Bacteria Densities," and should be used in the text. Also on page T3-3, paragraph 2, the last sentence mischaracterizes the link between Enterococcus and human waste: "Importantly, the occurrence of Enterococcus in groundwater at these wells **illustrates that human waste is present** in the groundwater at the study site." [emphasis added] The EPA document provided: Health Effects Criteria for Marine Recreational Waters, reported the results of a study at Lake Ponchartrain which stated that although Enterococcus may have been the most reliable indicator of recreational water quality, it was "not specific for human wastes." Other studies, including the epidemiologic studies of Haile et al (1999; 1996) found Enterococcus in storm water. In the glossary of Haile et al (1996), Enterococcus is described as: "A bacteria that is part of the normal flora found in human **and animal** waste." [emphasis added] Therefore, the sentences in the report overstate the association of Enterococcus with human waste compared with scientific literature.

Although not directly related to literature, some of the data in Table 1 (page T3-3) seem questionable. For the Malibu Colony Plaza, the numbers of total and fecal coliform are identical, and typically fecal coliform are a log unit less than total. Also the number for Enterococci is higher than either total or fecal coliform, which is atypical in general, and not consistent with other samples. For Fire Station 88, the data are more puzzling. In all samples, the MPN for Enterococcus is equal to or greater than either total or fecal coliform MPNs. Other sources (Metcalf and Eddy, 2003, citing Crook, 1998) suggest Enterococci density is two to three logs less than fecal coliform and three to four logs less than total coliform bacteria density in raw sewage. In one sample from the Fire Station the Enterococcus MPN is one log higher than the total coliform. MPN in one sample; total and fecal coliform and Enterococcus are identical in another sample. These data would be questioned by anyone familiar with the typical trends for these three indicators reported in the literature and therefore some explanation of the differences should be offered.

There is a small inconsistency in the 1996 study by Haile et al and Technical Memo #3 in the use of the high cutoff for Enterococcus. Haile et al report the exceedences of a high cutoff of 106 MPN/100 ml (Tables 12 and 13); while the Memo uses 104 MPN/100 ml, the actual standard.

b. Interpretation of the Haile et al epidemiology study and the 1983 EPA marine health criteria for health risk

The Haile et al epidemiology study was based on illness resulting from swimming at or near storm drain outfalls. The 1983 EPA document, Health Effects Criteria for Marine Recreational Waters was based on studies of illness linked with treated wastewater outfalls. These are both point sources at beaches. The mechanism for transport of septic tank and subsurface infiltration systems such as those in Malibu is through porous media, which may alter the risk of these discharges. One source of difference resulting from subsurface discharge is the removal of particulate matter and attached bacteria. The 1983 EPA Health Effects document noted that removal of suspended solids during wastewater treatment reduced the density of Salmonella.

c. Application of correlation coefficients (Figures 7, 8, and 9) referring to attached table sent 9/10/09

Use of correlation coefficients to show consistency of Enterococcus density frequency distributions from 2005-2008 at the three beach sites is acceptable, if unusual. Typically, bacteria counts, in this case for any year at any location, can be fitted to a Poisson Distribution by regression, and then comparing the mean, μ (which also equals the variance for the Poisson Distribution). Also, showing the frequency distributions as histograms rather than line graphs is more typical.

d. The conclusion, on pages T3-7 through T3-9, that water quality persistently fails to meet water quality objectives during dry weather at Surfrider Beach, Malibu Colony Beach, Malibu Pier Beach, Carbon Beach, and Marie Canyon

The conclusion that water quality is impaired at the five beaches as measured by Enterococcus counts exceeding the single count maximum (104 MPN/100 ml) is justified, although the degree of bacterial impairment varies among the five sites. It is interesting that there were no exceedences of the 104 MPN/100 ml standard at three of the beaches (Surfrider, Malibu Pier, and Carbon) in 2008. Haile et al. (1999) reported large increases in relative risk of a number of adverse health effects (skin rash, highly credible gastrointestinal illness, diarrhea with blood) when swimmers were exposed to these levels of Enterococcus.

e. The conclusion that groundwater, contaminated with indicators of pathogens, is a source of impairment to lagoon and beaches.

This conclusion is addressed on pages T3-20 – T3-23. There are two issues in this section. First is that septic tank discharge causes bacterial (and other pathogen) contamination of groundwater, and the second, implied, is that the discharge of groundwater contaminated with pathogens is a source of ocean/beach water quality impairment, presumably a significant source if removal of OWDS's from the Malibu Civic Center area is to result in improvement of beach water quality. The section *OWDS Systems and Transportation* [sic, "Transport" is probably the more appropriate term*] of Pathogens,* needs some editing for grammatical errors, e.g., "filtrated" instead of filtered in paragraph 1, line 6 on page T3-20 and "septic bacteria" in the same paragraph, line 9 which probably should be indicator bacteria. Paragraph 3, which cites the results of Stramer and Cliver which concern septage, not septic tank effluent, is irrelevant and should be deleted unless its relevance is explained. Most of the literature cited on pathogen indicator transport from OWDS's concerns viruses, and the last paragraph of this section, in paragraph 1 on page T3-21, provides a good explanation of the limitation of using bacterial indicators, which have different transport characteristics than viruses, to predict viral pathogens. In addition, as the paragraph points out, bacterial indicators are conservative, and also have been correlated with viruses from OWDS's.

The next section cites literature related to beach pathogens. The first paragraph summarizing the papers of Yamahara et al and DeSieyes et al does not provide strong support for the importance of septic systems with beach Enterococcus, especially as compared with other sources and transport mechanisms. A later citation of Yamahara et al (paragraph 5, page T3-21) is similarly weak support for the importance of OWDS's as a source of Enterococcus. The work of Borchardt et al was done in central Wisconsin and is not relevant to beaches. Paragraph 1 on page T3-22, citing DeSieyes, is almost impossible to understand. The AAAS review of MRSB has no mention of OWDS's and should be deleted unless a better connection besides ocean water and beaches is made.

The scientific basis for Figure 11 is weak, both as support for transport and Enterococcus density. The MPN values for Enterococcus shown in Figure 11 are very difficult to justify compared with other reports (see comments above). Metcalf and Eddy report a range of $10^4 - 10^5$ MPN/100 ml for Enterococcus in raw sewage. Figure 11 has residential septic tank effluent Enterococcus at 10^7/100 ml, and one commercial system as high as 10^8/100 ml. Also the ranges of non-detect (ND) to 10^7/100 ml and ND to 10^6/100 ml are so large as to be meaningless. The one very high MPN value in Table 1 which provides only minimal evidence is suspect (as discussed above).

Overall, the movement of groundwater from the area served by OWDS's is well documented in other reports (Tech Memo 4). Literature cited confirms that pathogens, especially viruses, are transported in the subsurface from OWDS's, and would therefore reach the ocean water, especially in a sandy aquifer with short travel time. The presence of Enterococcus in septic tank effluent, nearby groundwater, and the beaches is credible support for the contribution of OWDS's to contamination of the Malibu beaches by bacteria.

Overarching questions:

a. Are there additional scientific issues, not described above, that are part of the scientific basis of the proposed rule? If so, please comment with respect to the statute language given above.

A particular source of pathogen risk is associated with the fact that OWDS's serve a small number of people. This was discussed in the EPA Health Effects Criteria for Marine Recreational Waters (1983, page 49). That document notes that when the number of individuals who are sources of fecal waste becomes smaller, the ratio of pathogen-to-indicator density will vary highly from numbers based on aggregate wastes from a large population. If one or a small number of individuals in these small systems have an infectious disease, the ratio could approach 1, making the risk significantly higher than that addressed by the water quality standard. The EPA document advises in that case, which may include OWDS's: "The solution is administrative action prohibiting such discharges into recreational waters."

b. Taking each of Tech Memo #3 and #4 as a whole, is the conclusion of each tech memo based on sound scientific knowledge, methods, and practices.

Taken as a whole, the conclusions of Technical Memos #3 and #4 are based on sound scientific principles and reasoning. Epidemiologic studies cited provide a strong basis for increased health risks to swimmers and the presence of indicator bacteria measured at the beaches, especially Enterococcus, at concentrations higher than marine recreational water quality standards. There are some relatively minor concerns about interpretations of literature and some of the reported data as discussed above and in the previous comments on Tech. Memo #4. Addressing these will acknowledge real uncertainties that always exist with environmental studies, but will not weaken the conclusions.