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FINAL REPORT

Risk Assessment of Decentralized Wastewater Treatment Systems in High Priority Areas in the City of Malibu, California

Stone Project Number 011269-W

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EXECUTIVE SUMMARY

The City of Malibu (Malibu) has placed a priority on appropriate use of onsite wastewater systems for treatment and reuse of valuable water resources, and conducted this risk assessment to evaluate the environmental impacts of current and potential future levels of onsite wastewater management. On April 19, 2001, Malibu was informed that the Santa Monica Bay Restoration Commission (SMBRC) approved the study entitled, "Risk Assessment of Decentralized Wastewater Treatment Systems in High Priority Areas in the City of Malibu, California." As a developed coastal community with highly sensitive environmental resources, Malibu will use the outcomes of this risk assessment study to refine its citywide wastewater management program.

Malibu is located on the north shore of Santa Monica Bay, northwest of Los Angeles, California. The study area was defined by areas that appear to recharge groundwater in the alluvial aquifers around Malibu Lagoon, Winter Canyon and the beach area in the vicinity of Malibu Pier. Surface water resources include the lower portion of Malibu Creek and Lagoon and the coastal surfzone. There are approximately 395 residences, multi-family units, and commercial units in the study area.

The groundwater is the focus of this study since it receives the treated effluent from onsite wastewater treatment systems (OWTS) and transmits the mixture of treated effluent and groundwater to the local surface water bodies. The water table aquifer is the focus of this study since it is the aquifer that directly receives treated effluent from OWTS and flows directly to the surface waters. In the immediate vicinity of the Lagoon, the groundwater elevation has been shown to fluctuate with the tide.

The area of the Malibu Creek watershed is 109 square miles (Ambrose and Orme, 2000). The study area is roughly within the last two square miles of watershed, where the creek empties into Malibu Lagoon and ultimately into Santa Monica Bay. Lower Malibu Creek was included on the 303(d) list of impaired waters for both bacteria and nutrients. The lower creek area and upper Lagoon area includes undeveloped to low-density single family residential dwellings and commercial development. A significant hydrologic feature of the Malibu Lagoon is the intermittent nature of the opening and closing of the Lagoon outlet across the barrier beach. Typically, the Lagoon is open to the ocean during all or a portion of the wet weather season (winter) and the barrier beach is closed during all or a portion of the dry weather season (summer).

Regulations provide the legal framework for wastewater management. In 2000, the State of California Legislature passed Assembly Bill 885 that requires the development of regulations for onsite systems. The regional application of the Porter-Cologne Act is through the Water Quality Control Plan – Los Angeles Region – Basin Plan for the Coastal Watersheds of Los Angeles and Ventura Counties (LARWQCB, 1994) (Basin Plan). According to the Basin Plan (amended 2001), the water quality objectives for marine water for water contact recreation (REC-1) have been issued. The LARWQCB issued Order No. 01-031 in March 2001. This Waste Discharge Requirement

(WDR) sets standards for OWTS serving commercial and multifamily occupancies that require groundwater monitoring for all of these systems.

The City of Malibu has a program for management of wastewater under its jurisdiction. The City's Wastewater Management Plan, adopted in 2001 compiles all of the pertinent history and plans for future wastewater management. The current components of which are implemented through City of Malibu's Ordinance that includes local amendments to the Plumbing Code.

There are many different stakeholders that have an interest in the application of a risk assessment approach to evaluate OWTS and water quality issues in the Civic Center Area of Malibu. These stakeholders may be divided into two general groups. Stakeholders internal to Malibu include City Government, City Council, and City Departments including Environmental and Community Planning, Engineering, Geology, and Public Works. Other internal stakeholders include the Wastewater Advisory Committee, city and study area residents, the Chamber of Commerce, business owners, and the Malibu Board of Realtors. The following organizations were considered external stakeholders: Santa Monica Bay Restoration Commission; Malibu Creek Advisory Committee; SWRCB; LARWQCB; California Coastal Commission; California State Parks Department; Los Angeles County Environmental Health Division; State of California (Department of Health Services); Santa Monica Bay Keepers; Natural Resources Defense Council; Heal the Bay; and Surfrider International.

Nitrogen and phosphorus are nutrients that originate from anthropogenic sources, including OWTS, and can have an impact on groundwater and surface water quality. Nitrogen is typically more mobile in soils and groundwater, than phosphorus and therefore typically has a greater potential to impact surface waters. For these reasons, nitrogen is the focus of the nutrient assessment for this study.

Available existing records regarding OWTS, hydrogeology and geology of the study area were retrieved and reviewed. Available data regarding monitoring well construction; depth to groundwater and groundwater quality data was collected and entered into an MS Access database. This included data from WDR compliance files, and previous investigations. Data was entered from:

- 84 monitoring wells
- 143 total sampling events (not per well)
- 1,109 individual analyses

Available locations and stratigraphic logs from soil borings were retrieved from geotechnical and geological reports in the study area. Data for 383 boring locations 628 test pits were entered into Access. Boring locations were also digitized in GIS.

In order to make the data accessible to all of the various project team members, the City of Malibu staff, and others as approved by the City, Stone developed a web-based information wastewater management system (IWIMS). Data that had been initially imported into the MS Access database was transferred to the IWIMS including:

- Parcel, structure, and parcel owner information
- OWTS permits and component data
- Final approval drawings
- Monitoring well, sample, and analytical result data

A conceptual hydrogeological model was developed to provide information for the three-dimensional numerical modeling tool used to evaluate the impacts of onsite wastewater treatment systems on groundwater quality and to delineate directions of groundwater flow from major wastewater dispersal areas. A review of existing reports, studies, and other data was used to develop a conceptual understanding of sources and sinks of groundwater, nutrients, and bacteria in the hydrogeologic system. At this stage of model development, the sources of water to the system included recharge from upland runoff, recharge from approximately 430 onsite and offsite OWTS, infiltration of precipitation, and infiltration from Malibu Creek. The sinks for groundwater included discharge to the Pacific Ocean and Malibu Lagoon.

Manual observations of surface water elevations were made in Malibu Lagoon at the Pacific Coast Highway bridge, and in Malibu Creek at Arizona Crossing, at surveyed reference points. Automated observations of surface water elevations were also intermittently collected by Las Virgenes Municipal Water District (LVMWD) staff at the Malibu Lagoon monitoring point described above.

The study team initially had access to collect water level measurements and water quality samples from 23 existing monitoring wells. Verbal approval was also granted to collect water level measurements from eight privately owned monitoring wells. The sampling program included six existing monitoring wells and 14 new monitoring wells. Hydraulic conductivity tests were performed and estimates for the wells ranged from 0.0797 feet/day to 123 feet/day, with a geometric mean of 2.61 feet/day.

Manual groundwater level measurements were taken in conjunction with each of the twelve events in the groundwater sampling program. Water level measurements used to construct the water table maps for the hydrogeologic model were collected in two additional events from a network of monitoring wells within a relatively short time frame. During these measurement events, observations of surface water stage were also made on Malibu Creek. Automated observations of groundwater levels were collected in three monitoring wells.

Twenty monitoring wells were be sampled on a monthly basis between April 2003 and March 2004. Sampling constituents were developed to match prior and on-going studies, and included bacteriological (total coliform, fecal coliform and Enterococcus) and nitrogen (ammonia-N, nitrate-N, nitrite-N, and total Kjeldahl nitrogen or TKN) constituents, along with chloride. Laboratory results were entered into IWIMS for further analysis and reporting.

A groundwater model was developed as a specific tool for assessing the current level risk based on as much available data that could be readily retrieved and collected within the scope of this project. The extent of the model was designed to simulate groundwater flow in the alluvial deposits that underlie the Malibu Civic Center area along Malibu Creek and Lagoon. The groundwater model used for this investigation is MODFLOW, which was developed by the U.S. Geological Survey (McDonald and Harbaugh, 1988). The model was calibrated using two steady-state simulations based upon water levels and streamflow data collected on September 25, 2003 for a flooded Lagoon condition, and on March 9, 2004 for a breached Lagoon condition. Model hydraulic conductivity values were adjusted to improve the match between observed water levels and those calculated.

Results from the flow modeling were used as a basis to evaluate directions of groundwater flow, groundwater travel times in the flow system, and the capture zones for the Lagoon and ocean. The purpose of the solute transport modeling analyses was to estimate loading of nutrients to the ocean and to Malibu Creek and Lagoon. Transport modeling was done to simulate changes in concentrations of miscible contaminants in groundwater, with various types of boundary conditions and external sources or sinks. Source concentrations of nitrate from OWTS were assumed to be 20 mg/l from domestic wastewater disposal systems and 50 mg/l from commercial systems.

The level of risk of onsite systems having an unacceptable impact on water quality was evaluated for two constituents of wastewater: bacteria and nitrogen. The first step in risk assessment is to define what levels of risk are appropriate to protect human health, or to meet water quality objects established in the Basin Plan. Ideally, one would define what risks are acceptable and which are not acceptable. However, the variability inherent in natural systems and in OWTS loading means that the risks are not black and white. Therefore, a prioritization of risk levels will be used.

The level of risk for bacterial impacts on water quality depends on subsurface conditions for the attenuation of bacteria in the subsurface, specifically: the vertical separation between the infiltrative surface of the dispersal system and the water table; and the time of travel in the groundwater prior to reaching a water resource. The level of risk for nitrogen impacts is dependant on the mass loading of nitrogen and the degree of degradation that is likely to occur between the source and the receiving water. The nitrogen loading to surface waters will be calculated using a range of attenuation factors (half-lives) and no attenuation, to try to match measured values.

The risk posed by OWTS to groundwater quality was assessed relative to bacteria and nitrogen outcomes. Now that the contributing areas have been characterized, the City of Malibu and the LARWQCB can utilize the data to implement the action items involving consideration of new infrastructure, OWTS management, and water resource management from a common fact-based and outcome-driven perspective.

Individual OWTS are capable of providing bacteria reduction to marine water contact recreation quality standards using either adequate separation to groundwater or disinfection. Although many systems are providing adequate bacteria reduction, some systems do not appear to be currently meeting these standards. Although adequate bacteria attenuation from all OWTS is important, OWTS that are within a 6-month time of travel from surface water should be considered a high priority. Other sources of indicator bacteria in the study area should be characterized to develop appropriate TMDL implementation strategies for Malibu Lagoon and Surfrider Beach.

The area contributing groundwater to the Lagoon is much smaller than had previously been assumed based on surface topography. The overall nitrogen loading estimated in this study is generally consistent with previous studies. Any nitrogen reduction strategy will have a substantial lag time in producing significant water quality changes due to the slow travel time in the groundwater flow system. However, it is important to note that the nitrogen loading is diffuse and that some nitrogen reduction appears to be occurring naturally in the groundwater. A concurrent study of nutrient cycling in Malibu Lagoon sediments may be useful in characterizing the flux of nitrogen from the groundwater through the sediments and into the Lagoon.

Draft action items were developed and included in the draft report. The final action items include corrective actions such as upgrading or installing wastewater treatment infrastructure, OWTS management strategies, and water resource management strategies. The action items are based on the risk assessment, the analysis of mitigation alternatives, and water quality objectives.

Corrective Actions Involving Infrastructure

Onsite wastewater infrastructure initiatives should be developed as close to the source of the wastewater as possible. Individual property owners can carry out onsite infrastructure solutions. Cluster and community systems require additional engineering studies addressing site-specific evaluations of need and feasibility of various wastewater collection, treatment or reclamation, and dispersal or reuse options.

- Onsite Disinfection And Denitrification For Large Commercial And Multi-Family Occupancies In Malibu Lagoon Contributing Area
- Onsite Denitrification For All Systems In Malibu Lagoon Contributing Area
- Onsite Or Cluster Advanced Treatment And Disinfection For Systems With Inadequate Separation To Groundwater Within 6 Month Time Of Travel
- Community Wastewater Reclamation System With Onsite Dispersal
- Community Reclamation And Dispersal Outside Of Contributing Area
- Combination Of Above

OWTS Management Strategies

Both the LARWQCB and the City of Malibu are conducting intensive regulatory programs to manage OWTS. The following strategies are intended to focus those efforts on fact-based outcome-driven approaches to OWTS management.

- Site Specific Groundwater Monitoring for Large Commercial and Multifamily Systems (ongoing)
- Operating Permits for Commercial and Multifamily Occupancies (ongoing)
- Point of Sale Inspections with Operating Permits for all systems
- Mandatory Inspections for OWTS in Malibu Lagoon Contributing Area with operating permits for all systems
- OWTS with Regional Groundwater Quality Monitoring in Malibu Lagoon Contributing Area Sampling for Nitrogen constituents and Microbial Source Tracking for Bacteria identification
- Combination of above

Water Resource Management Strategies

Effective water resource management involves monitoring and use of monitoring data to provide feedback on the effectiveness of water quality infrastructure changes or management strategies in achieving water quality outcomes. The following is a list of strategies that have been developed in the preparation of this report, or can be pursued to improve TMDL compliance. These strategies can be continued to develop and continuously improve the sustainability of the City's and LARWQCB's water quality management programs.

City of Malibu

- Continue to work with other local agencies to develop implementation plan for Santa Monica Bay bacteria TMDL incorporating findings of this report as appropriate
- Continue regional groundwater quality sampling program in the Civic Center area on sites where permission to access existing monitoring wells can be extended
- Maintain and collect data continuous groundwater level from data loggers on sites where permission to access existing monitoring wells can be extended
- Conduct synoptic water level measurements twice a year (in flooded and breached Lagoon conditions)
- Require all hydrogeologic data associated with OWTS be submitted to the City as a condition of operating permits and enter that data into IWIMS
- Evaluate Civic Center area groundwater quality data and Malibu Creek, Malibu Lagoon and surfzone surface water quality data on an annual basis to develop understanding of the relationships between the groundwater and surface water systems
- Update the three dimensional computer model with new data once a year and run model to refine estimates of contributing area extent, time of travel, existing nitrogen loading, and effect of nitrogen reduction actions

City of Malibu and LARWQCB

- Enter into MOU regarding delegation of responsibility of single family residential and small commercial OWTS management to the City of Malibu
- Reassess nitrogen TMDL for the Malibu Creek subwatershed in light of new data and analysis.
- Reassess beneficial use designation of groundwater in Malibu Valley or at least clarify applicability of marine water contact recreation standard for groundwater
- Coordinate results of ongoing sediment study with this report.

The action items developed from this study will be brought to the City Council with a recommendation for adoption as amendments to the City of Malibu's Wastewater Management Plan.

1. INTRODUCTION AND PURPOSE OF THIS STUDY

The City of Malibu (Malibu) has placed a priority on appropriate use of onsite wastewater systems for treatment and reuse of valuable water resources, and conducted this risk assessment to evaluate the environmental impacts of current and potential future levels of onsite wastewater management. On April 19, 2001, Malibu was informed that the Santa Monica Bay Restoration Commission (SMBRC) approved the study entitled, "Risk Assessment of Decentralized Wastewater Treatment Systems in High Priority Areas in the City of Malibu, California". The study uses a three-dimensional numerical modeling tool to evaluate the impacts of onsite wastewater treatment systems (OWTS) on groundwater quality and to delineate directions of groundwater flow from major wastewater dispersal areas. The project's long-term goal is to protect public health, achieve water quality goals, and enable the environmentally sound long-term use of Malibu's decentralized wastewater treatment systems in the target area. As a developed coastal community with highly sensitive environmental resources, Malibu will use the outcomes of this risk assessment approach to refine its citywide wastewater management program.

Malibu is located in Los Angeles County on the north shore of Santa Monica Bay, northwest of the City of Los Angeles, California. The study area includes the densely developed areas of the lower Malibu Creek and Malibu Lagoon watersheds (Map 1). The approximate boundaries of the study area are as follows: the beach side of the Pacific Coast Highway from Malibu Canyon Road on the westerly boundary to Sweetwater Mesa Road on the east; inland to Potter Road off Malibu Canyon Road; and including Serra Retreat in the northeast corner of the study area. There are 395 residences, multi-family units, and commercial units in this area. Surface waters include the lower portion of Malibu Creek, Malibu Lagoon, and Malibu Beach to Malibu Pier State Park.

The main steps of this study include the following:

- Collect and review existing information from a variety of electronic and paper files on OWTS in the study area, soils, geology, groundwater and surface water levels and quality
- Develop an Information Management Plan and Quality Assurance Project Plan for data and sample management
- Customize and populate an internet-based Integrated Wastewater Information Management System (IWIMS)
- Conduct stakeholder meetings to assist in data collection and to obtain the use of existing groundwater monitoring wells for water level and quality measurements
- Develop a conceptual hydrogeological model to help understand known information, and identify gaps in data where new monitoring wells would be of benefit
- Install sixteen new groundwater monitoring wells
- Sample 20 wells total on a monthly basis, for water depth, bacteria and nitrogen
- Install and download continuous water level data from three monitoring wells

- Conduct two synoptic water level measurement exercises during two Lagoon conditions (breached to the ocean and flooded)
- Complete a hydrogeological model analyses of current conditions
- Complete a risk assessment based on the above results
- Complete a risk management process using the stakeholder process to prioritize potential action items
- Project dissemination to the City, region, state and nationally

This report is presented in five sections. The following sections are Background, Methods and Procedures, Results, and Conclusions and Recommendations. Also included to support the text are maps, tables, figures, and five appendices. The appendices include information on the monitoring wells, the complete hydrogeological model report, and key materials from stakeholder presentations.

2. BACKGROUND

The study area, locally called the Civic Center area, is located at the mouth of Malibu Creek, including Malibu Lagoon, and extending from Sweetwater Canyon to Winter Canyon along Santa Monica Bay (Map 1). There are 395 parcels served by OWTS in the study area; of these, approximately 47 parcels have commercial or multifamily occupancies, and 348 are residential or duplex occupancies (Table 1). The study area was defined to: (1) provide an area large enough to encounter apparent hydrologic boundaries for the purpose of groundwater modeling; and (2) include areas of concern regarding the potential risk of impacts of onsite wastewater treatment systems (OWTS) on groundwater and surface water quality.

The term onsite wastewater treatment system refers to the fact that the objective of this infrastructure is to provide treatment for the protection of public health and environmental quality and the safe dispersal of treated wastewater into the environment. This treatment can be accomplished by traditional means of septic tank-leachfield systems that utilize unsaturated soil as the principal treatment media, or by advanced treatment units that typically utilize packed media filters or aerobic treatment processes to attenuate specific wastewater constituents prior to subsurface dispersal.

There have been county regulations addressing siting and design of OWTS since the 1950s, and city programs since the City of Malibu was established in 1991.Traditional OWTS generally consist of two major types of components: septic tank(s) and dispersal unit(s) (Figure 1). The purpose of the septic tank is to provide a quiescent environment for settling and retention of solids, and floating and retention of fats, oils and grease. Septic tanks are typically comprised of two compartments, and sized for 2 to 3 days of residence time at design flows (Figure 2).

The purpose of the dispersal components is to release the clarified effluent into an unsaturated soil and geologic environment at a rate that will allow for absorption and treatment of the wastewater by natural physical, chemical, and biological processes. An important aspect is the development of a biomat that provides a treatment zone at the interface between the dispersal system and the unsaturated soil or geologic strata. Sufficient separation to groundwater is required to provide adequate conditions for filtering and assimilation of solids and colloidal organic matter, and pathogen attenuation. The dispersal components commonly used in the low-lying alluvial area are leachfields.

In areas with greater depths to groundwater, such as in the upper edges of the alluvial material, Winter Canyon and the bedrock upland areas, seepage pits are commonly used for dispersal. Both types of dispersal units are designed to provide sufficient infiltrative area for the soil/geologic material based on percolation characteristics. In addition to the vertical separation to groundwater, the horizontal separation to drinking water supply wells and surface waters are important criteria for the protection of public health and water quality. These horizontal setbacks provide residence time as the groundwater flows through soil or geologic strata for additional pathogen die-off, and chemical absorption of phosphorous. Nitrogen in the form of nitrate will reach the groundwater from properly operating onsite systems. If conditions are suitable, microbial denitrification can occur in unsaturated soil zones and the groundwater.

Properly sited and designed onsite systems do not ordinarily contribute bacteria or phosphorus to groundwater and surface water. Systems that have insufficient vertical separation to groundwater, excessive biomat accumulation, lack sufficient oxygen, or are either underdesigned or overloaded, may not provide adequate treatment prior to reaching groundwater.

2.1. Topography

The study area consists of a low-lying plain along Santa Monica Bay, and adjacent steep upland areas (Map 2). Ground surface elevations in the main terrace of the Civic Center range from sea level to approximately 100 feet above mean sea level (AMSL) in Winter Canyon (U.S. Geological Survey, 1995). The gently sloping valley bottom areas near Serra Retreat and Winter Canyon rise to elevations of 120 and 140 feet AMSL, respectively. The highlands in the study area rise quickly to elevations of 500 feet AMSL. More detailed topography (2 ft contour interval) was surveyed by J. M. Montgomery, Inc. (undated) but this information is not available in digital format. Since this study began, the study area was included an aerial survey; however, these data are available on a fee basis (Sanchez, 2003) and were not used in this study.

2.2. Water Resources

The water resources of concern in the study area include Malibu Creek, Malibu Lagoon, the surfzone, and the groundwater that flows toward these receiving waters. Table 1 lists the properties in the study area by surficial geological and groundwater designations, such as alluvial, bedrock, and beach deposits as described in this section.

2.2.1. Groundwater

The groundwater is the focus of this study, since it receives and provides an assimilation zone for the percolating water from OWTS and transmits to the local surface water bodies. The groundwater in the study area was described in detail in the Preliminary Conceptual Model Report (Stone Environmental, Inc., 2003) and this information was updated in Appendix 3 of this report; therefore, only a brief overview is provided here.

The study area was defined by areas that appear to recharge groundwater in the alluvial aquifers around Malibu Lagoon, Winter Canyon, and the beach area in the vicinity of Malibu Pier. Three general types of groundwater flow systems, or aquifers, have been identified in the study area: a water table aquifer, a semi-confined aquifer, and the bedrock aquifer. The term contributing area is used to refer to a portion of an aquifer that flows from a source of recharge to an area of discharge.

The water table aquifer in the study area is what would be encountered in the soils of the Civic Center area if a well was drilled to the first zone of saturated soil. In technical terms, water table aquifers include the unconfined groundwater in unconsolidated materials where the water pressure is in equilibrium with the atmosphere. The groundwater is unconfined in the sense that the top of the aquifer is exposed to atmospheric pressure through soil pores and the elevation of the top of the aquifer, or water table, fluctuates depending on the amount of water flowing into, through or out of the water table aquifer. The unconsolidated materials are typically water-transported sediments made up of rock fragments, gravel, sand, silt and clay. As discussed in Appendix 3, these sediments are stratified in alluvial, estuarine and fluvial deposits. Prior studies have shown the water table in the Civic Center area to be on the order of 2 to 30 feet below ground surface (Earth Consultants, Inc., 2000a; Bing Yen and Associates, 2001)

The semi-confined aquifer, known locally as the Civic Center Gravels, is a lens of coarser unconsolidated sediments, predominantly sands and gravels, that underlies a discrete area in the vicinity of Civic Center Way and the open space on the property where the Chili Cook-Off is held. This aquifer was encountered under the Ioki and Chili Cook-Off properties between 40 and 60 feet below ground surface. It is underlain by finer textured unconsolidated sediments.

The bedrock aquifers are in porous or fractured rock, or consolidated geologic materials. These aquifers border and underlie the water table aquifer and the Civic Center Gravels. Due to the location of the Civic Center area at the mouth of a canyon, it is apparent that the groundwater flow is predominantly from the bedrock aquifers into the unconsolidated sediments.

The water table aquifer is the focus of this study since it is the groundwater zone that receives percolating water from OWTS and discharges to the surface waters. In the immediate vicinity of the Lagoon, the groundwater elevation has been shown to fluctuate with the tide. Continuous groundwater elevations have been measured in previous studies (URS Greiner Woodward Clyde, 1999; URS Greiner Woodward Clyde, 2000; Earth Consultants International, Inc., 2000a; Earth Consultants International, Inc. 2000b).

2.2.2. Lower Malibu Creek

The Malibu Creek Watershed is 109 square miles (Ambrose and Orme, 2000). The study area is roughly within the last two square miles of watershed where the creek empties into Malibu Lagoon and ultimately into Santa Monica Bay. Lower Malibu Creek has been included on the 303(d) list of impaired waters for both bacteria and nutrients. The historical water quality data collected for Lower Malibu Creek were summarized by TetraTech in 2002. The Malibu Creek TMDL studies characterize the lower Malibu Creek watershed as having 2475 acres (TetraTech, 2002). For general purposes, it can be assumed that Malibu Creek extends downstream to the upstream limit of tidal influence, where the Lagoon begins. This boundary is generally below the Cross Creek Road Arizona crossing and varies with the condition of the Lagoon, whether it is breached or flooded. The study area includes the lowest few hundred feet of the Lower Malibu Creek Subwatershed and the entirety of the Malibu Lagoon Subwatershed (LARWQCB, 2004).

In the study area, the development along the lower creek area and upper Lagoon area consists of undeveloped to low density single family residential dwellings. Directly upstream of the study area, Lower Malibu Creek flows through the Santa Monica Mountains National Recreation Area. Further upstream and north of the Santa Monica Mountains is an area with urban, suburban and rural land use (TetraTech, 2002).

2.2.3. Malibu Lagoon

The Malibu Lagoon estuary is located at the mouth of the Malibu Creek watershed. While its size varies seasonally and from year to year, the Lagoon covers an area of roughly 13 acres according to Ambrose and Orme (2000), who have completed the most thorough evaluation of the Malibu Lagoon estuary to date. Their evaluation also covers the geologic and cultural history of the Malibu Lagoon estuary area. The historical water quality data collected in Malibu Lagoon has been summarized by TetraTech (2002).

A significant natural hydrologic feature of the Lagoon is the intermittent nature of the opening and closing of the Lagoon outlet across the barrier beach. Typically, the Lagoon is open (breached) to the ocean during all or a portion of the wet weather season (winter) and the barrier beach is closed (flooded) during all or a portion of the dry weather season (summer).

The Lagoon level fluctuates with the tide throughout the year. During dry weather when the barrier beach dams the outlet of the Lagoon this fluctuation is dampened by the barrier beach.

The Malibu Lagoon watershed has been calculated by TetraTech (2002) as having 681 acres or 1.06 square miles. This area is bounded by natural topography to the east, north and west. However the southern edge of the watershed is influenced by the Pacific Coast Highway road embankment that apparently diverts surface water runoff eastward towards Malibu Lagoon. The area contributing groundwater to Malibu Lagoon has not been previously mapped.

Most of the Malibu Lagoon and adjacent area is either state or county park lands. The Malibu Lagoon watershed has mixed land use with the following land uses: high density and low density urban residential; commercial; industrial; agricultural; open space; vacant; and undeveloped land (TetraTech, 2002).

2.2.4. Surfzone/Ocean

Santa Monica Bay defines the southern edge of the study area, extending from Sweetwater Canyon to Winter Canyon. Water quality has been and is currently measured by the County of Los Angeles and Heal the Bay on a regular basis (LARWQCB, 2002). Water quality in groundwater beneath the beach and off-shore sampling points were collected by URS Grenier (2000), and are discussed in Section 2.6 below.

This sandy beach has commercial and residential development on both sides of the Pacific Coast Highway from Sweetwater Canyon to Surfrider Beach, with the exception of Malibu Lagoon State Park. The Malibu Pier is located east of the Lagoon. Surfrider Beach extends from west of the Pier, across the barrier beach of Malibu Lagoon to Malibu Point. Malibu Colony is a private residential area that begins at Malibu Point with houses on both sides of Malibu Colony Road along the barrier beach and extends to Malibu Road. The remainder of the surfzone extends along Malibu Road to the beach below Winter Canyon.

2.3. Decentralized Wastewater Management

Decentralized wastewater management refers to the use of wastewater management solutions that are at or near the point of wastewater generation. This includes the use of individual onsite wastewater treatment systems (OWTS), shared onsite systems (for example, two or more buildings on the same property using a common system or systems), cluster systems (for example, buildings on multiple properties utilizing a common system); and community systems. Decentralized approaches do not preclude the use of wastewater collection systems (sewers) and force mains to off-site treatment and dispersal locations.

Management of decentralized wastewater infrastructure is necessary. Historically, centralized wastewater treatment systems have been managed, while decentralized and onsite systems have received little or no management. To provide for water quality and environmental health protection onsite wastewater treatment systems must be managed. The owners, users, maintenance providers, designers, installers and regulators must all play a part in an effective management program. There are a number of ongoing initiatives at the national, state, and local level that support managed onsite systems as an important and integral part of our wastewater infrastructure.

2.3.1. National Onsite Wastewater Management Initiatives

The United States Environmental Protection Agency (USEPA) estimates that approximately 23% of existing housing stock in the United States relies on 26 million OWTS for wastewater treatment (USEPA, 2002). There are approximately 1.2 million OWTS in California alone (COWA, 2003). The need to effectively manage these systems has evolved significantly over the past 30 years.

In 1972, the United States Congress passed the Clean Water Act, requiring the removal of discharges from surface waters. Significant federal funding accompanied that program which resulted in the installation of wastewater collection, treatment and dispersal systems across the country. At the same time, Congress funded the Small Scale Wastewater Management Project (SSWMP) at the University of Wisconsin. The SSWMP provided research into the science of onsite wastewater treatment and documented the effectiveness of soil-based onsite wastewater treatment systems, and is still going on today. A Design Manual for Onsite Treatment and Disposal Systems (USEPA, 1980) brought together the state of the art at that time.

On a national level, the funding available for centralized infrastructure has decreased steadily since the construction grants program was curtailed in the 1980s. Instead of construction grants, states were provided with funds to establish revolving loan programs to finance municipal wastewater infrastructure. In 1997, the USEPA issued a report to Congress that concluded that decentralized wastewater management can be an effective long term solution to wastewater management (USEPA, 1997). In 1998, Congress funded a Decentralized Wastewater Management Demonstration program, to provide examples of effective onsite wastewater management and technical solutions for communities across the country.

The 1980 USEPA Design Manual has been updated recently with the USEPA's Onsite Wastewater Treatment System Manual (2002). The 2002 USEPA Onsite Wastewater Treatment Systems Manual documents the methods of wastewater flow characterization, site evaluation, design, and installation based on current technology, science, and engineering. This manual includes an explanation of performance requirements, and management of OWTS, along with technical fact sheets which address proven approaches for wastewater treatment for small-scale systems.

This document was followed by voluntary guidelines for OWTS management (USEPA, 2003a) which provides program component descriptions and models for decentralized wastewater management, based on environmental risks and infrastructure complexities.

2.3.2. Risk-Based Management

The USEPA has developed an approach that enables the level of management of OWTS to be appropriate for the level of risk that systems will pose to public health or water quality. This risk-based approach is described in USEPA's Voluntary National Guidelines for Management of Onsite and Clustered (Decentralized) Wastewater Treatment Systems (2003a), Decentralized Community Wastewater Treatment prepared for The Massachusetts ad hoc Task Force on Decentralized Wastewater Management (Nelson, 1997), and Application of a Risk Based Approach to Community Wastewater Management (NDWRCDP, 2002).

The risk-based approach requires thorough assessment of the facts before developing a management program. The assessment should be an objective evaluation including scientific investigation of water quality problems and their causes. This enables a fact-driven decision making process to develop the most appropriate long-term wastewater management program. An effective community level process for assessing and managing risk requires stakeholder and public involvement to build understanding of the facts and relevant issues; and to build ownership and responsibility for implementing the resulting outcomes (Nelson, 1997; NDWRCDP, 2002).

2.4. Regulatory Framework

In California, all wastewater treatment and disposal systems, including individual OWTS, fall under the overall regulatory authority of the State Water Resources Control Board and the nine California Regional Water Quality Control Boards (Regional Boards). The Regional Boards are charged with the responsibility of protecting beneficial uses of State waters (ground and surface) from a variety of waste discharges including OWTS. The Regional Boards involvement in regulation of onsite systems most often involves the formation and implementation of basic water protection policies. These are reflected in the individual Regional Boards Basin Plan, generally in the form of guidelines, criteria and/or prohibitions related to the siting, design, construction and maintenance of onsite systems. The State Water Board's role has historically been one of providing overall policy direction, organizational and technical assistance, and communications link to the State legislature. However, with the passage of AB 885 in the fall of 2000, the State Water Board has been thrust into the important role of developing uniform statewide standards for onsite systems that are required to be incorporated into all Regional Board Basin Plans and become effective by July 2004. This deadline will not be met, and the standards are not likely to be in place until 2006 or 2007.

The Regional Boards may waive or delegate regulatory authority for onsite systems to counties, cities or special districts. This is not mandatory; however, it is normally done and has proven to be administratively efficient. In some cases this is accomplished through a Memorandum of Understanding (MOU), whereby the local agency commits to enforcing the Basin Plan requirements or other specified standards that may be more restrictive. The Regional Boards generally elect to retain permitting authority over large and/or commercial, multifamily, or industrial onsite systems, depending on the volume and character of the wastewater. A template MOU is under consideration by the LARWQCB with details to be negotiated with individual local agencies.

Cities or counties typically regulate OWTS via their environmental health and/or building or planning departments. Local OWTS ordinances often incorporate portions of the Uniform Plumbing Code's Appendix K and other specific requirements deemed appropriate for local circumstances (State of California, 1997). Most counties focus their local ordinances on new system installations and typically do not have specific repair standards or requirements for ongoing system maintenance. However, a growing number of local jurisdictions in California, including the City of Malibu, have become very involved in OWTS management, including implementation of programs related to on-going inspections, maintenance and monitoring of individual systems and/or the receiving environment.

2.4.1. Water Quality Control Plan

The City of Malibu falls within the jurisdiction of the Los Angeles Regional Water Quality Control Board (Regional Board). The regional application of the Porter-Cologne Act is through the Water Quality Control Plan – Los Angeles Region – Basin Plan for the Coastal Watersheds of Los Angeles and Ventura Counties (LARWQCB, 1994). The Regional Board has adopted policies and requirements pertaining to onsite systems that are contained within the Water Quality Control Plan – Los Angeles Region – Basin Plan for the Coastal Watersheds of Los Angeles and Ventura Counties, more commonly referred to as the "Basin Plan". The Basin Plan can be obtained from the Regional Board's website, at http://www.swrcb.ca.gov/rwqcb4/html/meetings/tmdl/Basin_plan/basin_plan.html.

The Basin Plan defines the local groundwater resource, excluding Winter Canyon and Serra Retreat areas, as the Malibu Valley. The Basin Plan designates this area as having a Potential Beneficial Use for Municipal and Industrial water withdrawal. A footnote in an amendment to the Basin Plan allows for use of marine water quality recreation standards for areas where groundwater is in connection with surface water (LARWQCB, 2001b). According to a recent Waste Discharge Requirements permit, the Ocean Plan Objectives are used for Waste Discharge Requirements in the vicinity of the Lagoon (LARWQCB, 2001a).

2.4.2. Water Quality Criteria - Total Maximum Daily Loads (TMDLs)

Section 303(d) of the Clean Water Act requires states to identify areas where surface waters do not meet water quality standards. The act further requires the development of Total Maximum Daily Loads (TMDLs) that would be compatible with achieving the required water quality standards. The Basin Plan includes water quality standards for all surface and groundwaters in Ventura and Los Angeles Counties, as well as incorporated cities within those counties. The Basin Plan has been amended numerous times since 1995 and the Total Maximum Daily Loads for the region are incorporated into the Basin Plan via amendments. The California State Water Resources Control Board is ultimately responsible for final amendments to the Basin Plan, via the review and adoption of TMDL resolutions passed by the LARWQCB.

Assembly Bill 411, which was implemented in July of 1999, mandated local jurisdictions throughout California to: (a) conduct, at a minimum, bacteriological testing of public beach waters; (b) establish, based on public health risks, monitoring parameters; (c) notify the public of health hazards; and (d) require microbiological testing, if needed, on a weekly basis from April 1st to October 31st. Currently, the County of Los Angeles Health Department routinely samples beaches in the City of Malibu.

A Basin Plan amendment (LARWQCB, 2001b) established the water quality objectives for marine water for water contact recreation (REC-1). Table 2 lists the bacteria load TMDL allocations for the Malibu Pier, Surfrider Beach, Malibu Point and Malibu Creek Watershed.

2.4.2.1. Water Quality Criteria for Surfrider Beach

Surfrider Beach has been included on the 303(d) list of impaired waters for high bacteria counts along a 0.66 miles length (LARWQCB, 1998). In 2002, the RWQCB adopted Total Maximum Daily Loads (TMDL) for bacteria during dry and wet weather conditions for Santa Monica Bay beaches (LARWQCB, 2002).

Both the dry weather and wet weather Santa Monica Bay TMDL documents emphasize storm water runoff as the principal source of contamination, and they provide no evidence of a specific connection between OWTS and surfzone water quality, nor do these TMDLs include a source characterization for OWTS. The Wet Weather Santa Monica Bay TMDL states: "With the exception of isolated sewage spills, storm water runoff conveyed by storm drains and creeks is the primary source of elevated bacterial indicator densities to Santa Monica Bay beaches during wet weather." (LARWQCB, 2002) "Malfunctioning septic tanks" are noted as potential non-point sources of bacteria in the dry weather TMDL Staff report (LARWQCB, 2002). There is no further characterization or quantification of the impact of OWTS on surfzone water quality in the Santa Monica Bay Beaches TMDLs.

2.4.2.2. Water Quality Criteria for Malibu Lagoon

As noted above, Malibu Lagoon is located at the mouth of the Malibu Creek watershed. The USEPA (2003b) has established TMDLs in the Malibu Creek watershed for both bacteria and nutrients.

Malibu Lagoon bacterial water quality targets are based on marine water recreational limits (Table 2). The LARWQCB (2004) has adopted a resolution to amend the Basin Plan for a Malibu Creek Watershed Bacteria TMDL. This resolution will be taken up by the SWRCB in the summer of 2004.

Malibu Lagoon nutrient water quality targets are based on achieving water quality objectives for biostimulatory substances in the creek and lagoon. The LARWQCB is expected to release a draft TMDL in autumn of 2004.

2.4.2.3. Water Quality Criteria for Malibu Lagoon: Bacteria

In the study area, Malibu Lagoon has been included on the 303(d) list of impaired waters due to high fecal coliform counts (13 acres). Furthermore, 9.5 miles of Malibu Creek, upstream of Malibu Lagoon is also included. A footnote in the USEPA Malibu Creek Watershed Bacteria TMDL documents the remainder of bacteria related 303(d) listings for Malibu Lagoon (USEPA, 2003b), as follows:

"Malibu Lagoon is also listed for swimming restrictions, enteric viruses, and shellfish harvesting advisories. EPA has concluded that implementation of the TMDLs for fecal coliform will be sufficient to address the listing for swimming restrictions. The fecal coliform TMDLs also are intended to address enteric viruses (see USEPA, 2003b). Shellfish harvesting is not a designated beneficial use of Malibu Lagoon, and the applicable water quality objectives are not designed to address this use. Therefore, these fecal coliform TMDLs are not designed to address the shellfish harvesting use."

In contrast to the Santa Monica Beaches TMDL, 20% the approximately 2,400 septic systems in the entire Malibu Creek watershed were identified as a potential source of bacterial contamination in the Malibu Creek Watershed TMDL.

The LARWQCB recently passed a resolution to amend the Basin Plan by adopting Total Maximum Daily Loads for Bacteria for Malibu Creek Watershed (LARWQCB, 2004). This will not become effective until it is reviewed and approved by the SWRCB, the State of California Office of Administrative Law, and the U.S. EPA. The number of allowable exceedance days for Malibu Lagoon are the same as Malibu Pier, Surfrider Beach, and Malibu Point.

The Malibu Creek Watershed Bacteria TMDL source allocation for Malibu Lagoon Subwatershed estimates to require a 94% reduction of bacteria from anthropogenic sources on a watershed wide basis, and a 99% bacteria reduction for the Malibu Lagoon Subwatershed (LARWQCB, 2004). This TMDL only requires compliance with Waste Load Allocations. These estimated reductions are included in the TMDL for informational purposes only. The measurement of success for this target will be via the number of exceedances of REC-1 standards (Table 2).

2.4.2.4. Water Quality Criteria for Malibu Lagoon: Nutrients

Nitrogen and phosphorus are nutrients that originate from anthropogenic sources, including OWTS, and can have an impact on groundwater and surface water quality. Nitrogen is typically more mobile in soils and groundwater, and typically has a greater potential to impact surface waters than phosphorus (Ambrose and Orme, 2000). For these reasons, nitrogen is the focus of the nutrient assessment for this study.

Malibu Lagoon (13 acres) is impaired for nutrients due to eutrophication. Similarly, 8.43 miles of Malibu Creek, upstream of Malibu Lagoon, was listed as impaired for nutrients due to algae scum/odors.

The Basin Plan sets water quality objective of 10 milligrams per liter (mg/l) nitrate plus nitrite, expressed as nitrogen, and 1 mg/l nitrite expressed as nitrogen for surface water in the Malibu Creek Watershed (LARWQCB, 1994). The Basin Plan also includes a narrative objective that "biostimulatory substances" such as nutrients shall not be present in concentrations sufficient to promote aquatic growth that results in either a nuisance condition, or an adverse impact on beneficial use.

The Malibu Creek Watershed Nutrient TMDL has been established by the USEPA (2003b). This TMDL sets a summer (April 15th to November 15th) target of 1 mg/L Nitrogen and a winter (November 16th to April 14th) target of 8 mg/L nitrogen. As pointed out in the EPA (2003b) bacteria TMDL: "For comparison, average Lagoon values during the summer were 1.39 mg/l for nitrogen and 0.49

mg/l [for phosphorus] (Ambrose and Orme, 2000). The average winter concentrations measured by Ambrose and Orme were 4.0 mg/l for nitrogen and 0.63 mg/l for phosphorus."

The next step is the adoption of the nutrient TMDL by the Regional Board as an amendment to the Basin Plan. Nitrogen and phosphorus are addressed in the TMDL; however, for reasons given previously, only nitrogen is addressed in this discussion.

According to estimates in the USEPA nutrient TMDL the total nitrogen load generated by OWTS in the entire Malibu Creek Watershed is 132,094 lb/year or 362 lb/day. Furthermore, the Malibu Lagoon subwatershed has a current 64.2 lb/day total annual mass nitrogen loading. Applying a 93% reduction would result in a target annual nitrogen loading of 4.5 lb/day for the Malibu Lagoon subwatershed.

According to the TetraTech (2002) report, the Malibu Creek Subwatershed has a 7200 lb/year summer or dry season nitrogen load based on model calibration. Using the 215-day dry season duration (April 15-November 15 (USEPA 2003b)), this translates to an estimated dry season daily load of 33.5 lb/day in this subwatershed. A 93% reduction of this dry season load would result in a 2.3 lb/day nitrogen load in the Malibu Lagoon Subwatershed. The USEPA (2003b) Malibu Creek watershed nutrient TMDL assumed a summer nitrogen load, attributed to OWTS, of 91 pounds per day (lb/day) for the entire watershed, which is 22% of the total estimated summer nitrogen loading. This TMDL targeted a 93% reduction of that load, resulting in a 6 lb/day summer nitrogen load allocation for OWTS in the entire watershed.

For winter conditions, the USEPA (2003b) estimated existing nitrogen loads from OWTS to be 47,285 pounds per five months (or 259 lb/day), or 9% of total nitrogen loading for the entire watershed. The winter target is proposed as a concentration rather than a mass loading due to the variability in winter creek flows. Therefore the winter water quality objective for the entire Malibu Creek watershed is 8 mg/l total nitrogen.

2.4.2.5. TMDL Assumptions for Bacteria and Nitrogen

The TMDL assumptions for OWTS in the Malibu Lagoon Subwatershed, with particular reference to bacteria and nitrogen loading are significant as a point of reference to how these issues are addressed in the analysis section of this report. The Nutrient and Coliform Modeling for the Malibu Creek TMDL Studies (TetraTech, 2002) report states that there are 34 "failed" OWTS out of the 170 onsite systems located “above the Lagoon”, 30 “short-circuited” OWTS adjacent to the Lagoon, and 20 “commercial” OWTS near the Lagoon.

The TMDL modeling report estimates that nitrogen loading from residential septic systems is 59.2 milligram/liter (mg/l) with a 274 gallons per day (gpd) average effluent flow rate. It also assumes that there are two billion coliform counts per person per day discharged into OWTS, and an average population of 3.4 persons per household. For “normal” OWTS, the TMDL report assumed 100% of the bacteria load is removed prior to reaching surface water bodies, and that 50% of the nitrogen loading reaches the surface water (TetraTech, 2002). For the purposes of the TMDL report, the number of failed OWTS was determined by a watershed-wide estimate of 20% by the Los Angeles County Department of Health. For the “failed” OWTS, it was assumed that 40% of the bacteria reach the Lagoon and 44% of the nitrogen reaches the Lagoon.

For short circuited systems, 87% of the nitrogen loads and 20% of the bacteria loads were assumed to enter the Lagoon. The systems that are assumed to be “short-circuiting” are located in Malibu Colony alongside the western arm of the Lagoon (LARWQCB, 2000).

Based on the above assumptions, TetraTech (2002) estimated current total annual bacteria load which OWTS contribute to surface water in the Malibu Lagoon subwatershed to be 1,176,760 x 10^9 counts per year (3,224 x 10^9 counts per day) for fecal coliform.

Similarly, the estimated current total annual nitrogen load that OWTS contribute to surface water in the Malibu Lagoon subwatershed was calculated to be 23,434 pounds per year, or 64.2 lb/day (TetraTech, 2002). Calibrated total annual nitrogen loads were estimated to be 16,500 lb/year or 45 lb/day.

2.4.3. Regional Board Requirements for OWTS

The LARWQCB issued general Waste Discharge Requirements (WDR) in March 2001 that sets standards for OWTS serving commercial and multifamily occupancies. Among other things, this WDR requires groundwater monitoring for all of these systems. Under Order No. 01-031, adopted February 22, 2001, general WDRs can be issued for systems with less than 20,000 gallons per day (gpd) flows and that have greater than 10 feet of vertical separation between the point of discharge and the water table. Order No. 01-131 allows less than 10 feet separation to groundwater with disinfection, but no separation less than 5 feet. For systems with greater than 20,000 gallons per day or less than 10 feet vertical separation to groundwater, advanced treatment to meet secondary standards is required to ensure compliance with Basin Plan water quality objectives under individual WDRs.

Per the requirements of Senate Bill 390, the Regional Board is required to review the OWTS management programs of all local agencies and, if found satisfactory, renew waivers for single family residential systems. The Regional Board has proposed a combination of a Memorandum of Understanding, between the Board and each local agency, and a General Waste Discharge Requirement for single family and small (<2,000 gallons per day) commercial OWTS.

2.4.4. City of Malibu Onsite Wastewater Management Program

The City of Malibu has a program for management of wastewater under its jurisdiction. The City's Wastewater Management Plan, adopted in 2001, contains all of the pertinent history and plans for future wastewater management (City of Malibu, 2001). The current components of which are implemented through the City of Malibu's Ordinance that includes local amendments to the Plumbing Code. The City of Malibu's onsite wastewater management program is guided by the City's General Plan (1995), the recommendations of the Warshall Report (Peter Warshall and Associates, 1992), the California Plumbing Code (California Building Standards Commission, 2001), and the USEPA documents on decentralized wastewater management.

2.4.4.1. Onsite Wastewater Management Plan

The Malibu City Council adopted an Onsite Wastewater Management Plan in October 2001. This document provides a long-term plan and framework for onsite wastewater management. The City has already implemented the following recommendations of this plan:

- A renewable operating permit program for all commercial and multifamily OWTS;
- Secondary treatment plus disinfection requirements for commercial and multifamily occupancies undergoing repair, renovation and new construction;
- A renewable operating permit program for all residential systems that undergo repair, renovation and new construction;
- A training and licensing program for OWTS inspectors; and
- A point of sale inspection program for commercial occupancies.

The plan also provides the framework for future amendments to the Local Plumbing Code including point of sale OWTS inspections. These point of sale inspections will enable the upgrade of inadequate systems and trigger renewable operating permits for all property transactions in the City. The Plan also directs staff to develop programs for training and licensing of OWTS designers, installers, and pumpers, and to develop public outreach program including informational and educational material and workshops for OWTS owners and users.

2.5. Stakeholders

There are many different stakeholders that have an interest in the application of a risk assessment approach to evaluate OWTS and water quality issues in the Civic Center Area of Malibu. Involvement by stakeholders will be crucial throughout the study, from the data collection and analyses, to obtaining approvals for using existing groundwater monitoring wells and locating new wells, and for obtaining input on choosing and prioritizing appropriate wastewater management actions.

These stakeholders may be divided into two general groups, internal and external, as follows:

Internal Stakeholders:

- City Council
- City Departments
- Environmental and Community Planning,
- Public Works
- Engineering
- Wastewater Advisory Committee
- Residents and homeowners
- Homeowners Associations
- Malibu Chamber of Commerce
- Business owners
- Malibu Board of Realtors

External stakeholders:

- Santa Monica Bay Restoration Commission (SMBRC)
- Malibu Creek Watershed Advisory Committee
- SWRCB
- LARWQCB
- California Coastal Commission
- California State Parks Department
- Los Angeles County Environmental Health Division
- State of California (Department of Health Services)
- Santa Monica Bay Keepers
- Natural Resources Defense Council

- Heal the Bay
- Surfrider Foundation

2.6. Prior Local Studies of OWTS and Groundwater Quality

There have been previous investigations into the effectiveness of OWTS in the Civic Center area. These studies have been focused on evaluating the adequacy of OWTS to protect both groundwater quality and surface water quality. Of particular note are: (a) the studies completed by URS Greiner Woodward Clyde (1999 & 2000), titled: *Study of Potential Impacts on Malibu Creek and Lagoon from On-site Septic Systems*; *Study of Water Quality in the Malibu Lagoon Area, City of Malibu, California, Phase II*, respectively; (b) the *Malibu Technical Investigation* (LARWQCB, 2000); and (c) an evaluation of depths to groundwater (Bing Yen and Associates, 2001).

2.6.1. URS Greiner Reports

The first study (1999) evaluated groundwater quality at two locations: (1) the area between the western arm of Malibu Lagoon and the eastern end of Malibu Colony; and (2) the vicinity of the Malibu Creek Plaza Shopping Center. Field work for this phase was completed in 1997, 1998 and 1999. Eleven groundwater monitoring wells were installed in the water table aquifer: three between Pacific Coast Highway and Malibu Colony; and eight north of Pacific Coast Highway. These wells were sampled for bacteria and nutrients. Continuous water level measurements were recorded in three wells to define the water table fluctuations relative to tidal influences. Sediment samples were collected at the outfall of two storm drains and analyzed. Bromide and coliphage tests were conducted to evaluate the rate of groundwater movement and the potential for virus transport in the water table aquifer. The bromide and coliphage tracer tests were conducted under pumping conditions, not natural groundwater flow conditions. In this first phase, the researchers concluded the following:

- Although evidence of fecal contamination was apparent in the storm drain outfall sediments, the source of the contamination was not determined. The authors suggested that the source of the fecal matter was likely to be both animal and human. Septic systems might be a possible source of fecal matter, but additional testing would be needed to resolve this issue.
- Surfactants were also detected in the storm drain sediments indicating the apparent presence of detergents. The authors speculated that the source of the detergents could be from carwashing, parking lot washing, restaurant washing or graywater systems.
- "….nutrients are being effectively removed from the effluent as it passes through the unsaturated soil beneath the septic leachfields. While more study may be necessary to confirm this, it appears that septic systems in the

Civic Center are not adding to the high concentrations of nutrients found in Malibu Lagoon."

- "Provided that adequate unsaturated soil exists between the bottom of the leach field and groundwater (at least two feet for the fine-grained soil identified in the Civic Center commercial area) there is minimal concern for pathogen transport to the Creek or the Lagoon through subsurface pathways." (URS Greiner Woodward Clyde, 1999).

The field work for the second phase of this study by URS Greiner Woodward Clyde was conducted in the latter part of 1999. They utilized seven of the monitoring wells installed during the first phase and augmented that information with sampling at eleven temporary monitoring wells in the beach, each paired with a surfzone water quality sampling site, and surface water sampling in the creek, the Lagoon, and at three storm drain outfalls. Six sets of water quality samples were collected at these locations. Continuous water level measurements were collected before, during and after the autumnal breaching of the Lagoon (URS Greiner Woodward Clyde, 2000). Pressure transducer/dataloggers, installed in monitoring wells and the Lagoon, documented the breaching event and the increased groundwater gradient associated with breached Lagoon condition.

The onshore and beach water quality sampling in the second phase investigation revealed relatively low levels of bacteria in the beach samples while the Lagoon was closed. This is when one would expect that the flooded Lagoon may decrease the vertical separation to groundwater in the Malibu Colony area. After the Lagoon breached, the beach and surfzone sites in the immediate vicinity of the breach (from Malibu Pier to Malibu Point) and west of Winter Canyon had significantly elevated bacteria concentrations with Enterococci and fecal coliform counts exceeding their respective regulatory levels on a few occasions. The generally low levels of bacteria between Malibu Point and Winter Canyon indicate that there did not appear to be a significant impact on the surfzone water quality in this area from OWTS located in Malibu Colony and along Malibu Road.

The groundwater monitoring well on the north side of Malibu Colony closest to Malibu Point had elevated levels of indicator bacteria while the Lagoon was closed. The monitoring well located to the west of Malibu Point on the north side of the Malibu Colony had low bacteria concentrations while the Lagoon was flooded, but elevated bacteria after the Lagoon was breached.

2.6.2. University of California Los Angeles Report

In May of 2000, the University of California Los Angeles released a publication titled: "Lower Malibu Creek and Lagoon Resource Enhancement and

Management" (Ambrose and Orme, 2000). This report was a compilation of field investigations and analyses by a number of investigators. Bacteria loading to the Lagoon from OWTS was addressed in an investigation by Gerba and others; and Suffet and Sheehan addressed nutrient loading.

The bacteria investigation focused on occurrence of pathogens in the surface water and did not specifically address potential pathogen sources in the Civic Center area. Surface water quality samples were collected from six locations along Malibu Creek and Lagoon, and one location in the ocean surfzone. These samples were analyzed for the presence of pathogenic viruses. The only positive virus detection was in the treated effluent of the Tapia Wastewater Reclamation Facility. Twenty-two samples were collected at five locations an analyzed for pathogenic parasites, Giardia and Cryptosporidium during the same time period. Giardia was detected at all locations, although not at every sampling event, including the Tapia discharge. Cryptosporidium was detected less frequently and was not present above the Tapia facility. Regarding the beach sampling, the authors noted: "Giardia and Cryptosporidium were detected in one half of the surfzone samples."

Suffet and Sheehan developed a mass balance model for nutrient loading of the Lagoon. They did not evaluate phosphorus loading from OWTS, as they concluded that the phosphorus mobile in the subsurface soils. They assumed that OWTS in the following four areas were contributing nitrogen to the Lagoon: Malibu County Mart; Cross Creek Plaza; the Civic Center; and Malibu Colony. They used the following assumptions for N loading:

- Commercial nitrogen loading
    - Nitrogen concentration in OWTS effluent was 45 mg/L (based on literature values)
    - Total commercial flows were estimated to be 319 cubic meters per day (84,200 gallons per day)
    - 10% of the nitrogen from OWTS would be removed in septic tanks
    - 50% of the nitrogen in septic tank effluent would reach the groundwater
    - 100% of the nitrogen from the Malibu Country Mart and Cross Creek Plaza would reach the Lagoon
    - 50% of nitrogen reaching the groundwater from the Civic Center would reach the Lagoon
- Residential nitrogen loading
    - Nitrogen concentration in OWTS effluent was 45 mg/L
    - Thirty homes on the inland side of Malibu Colony appeared to be potentially contributing nitrogen to the Lagoon

- The average population in each single family residence was 3.7 persons
- The average flow per person was 0.19 cubic meter per day (50 gallons per day)
- 50% of the nitrogen in septic tank effluent would reach the groundwater
- 50% of nitrogen reaching the groundwater from these single family residences would reach the Lagoon

Based on these assumptions, the total annual dry weather and wet weather loads from these sources were estimated to be 1,096 kg (2,411 lb), and 1,078 kg (2,371 lb), respectively. Dividing the dry weather nitrogen load by 180 days yields a nitrogen load of 13.4 lb per day. Overall, Suffet and others concluded that less than 2% of the wet and dry season nitrogen loading to the Lagoon was due to OWTS.

2.6.3. LARWQCB Report

The LARWQCB's *Malibu Technical Investigation* was conducted concurrently with the second phase of the Greiner study. This field investigation, by the Regional Board, was intended to provide an independent confirmation of the results of the Phase 2 URS Greiner Woodward Clyde study, and to augment that study with additional field sampling and review of previous reports. The preliminary results of the *Malibu Technical Investigation* were released on August 18, 2000.

The *Malibu Technical Investigation* provides an analysis of the data from the two URS Greiner studies, as well as results from a hydrocarbon contamination investigation involving a gas station at the corner of Pacific Coast Highway (PCH) and Cross Creek Road and the Ambrose and Orme (2000) study. The evaluation of previous reports focuses on the potential for OWTS to contribute to surface water contamination through storm drains in the Cross Creek Plaza and the Winter Canyon area. Additionally, the *Malibu Technical Investigation* evaluated the construction of the three major storm drains that empty into Malibu Creek and Malibu Lagoon.

A portion the field work for the *Malibu Technical Investigation* essentially replicated the results of the Phase 2 URS investigation by collecting and analyzing replicate samples. Additional field work involved the collection of septic tank effluent samples from three commercial shopping centers. The sampling of these septic tanks revealed total nitrogen concentrations on the order of 20 to 80 milligrams per liter (mg/l).

2.6.4. Bing Yen & Associates Report

Bing Yen and Associates collected and reported on depths to groundwater and water quality samples from a larger portion of the Civic Center area (2001). Temporary and permanent groundwater monitoring wells were installed along public right of ways on Civic Center Way and Malibu Road. Sixteen temporary monitoring wells were installed in October 2000. Four of these wells were converted to small diameter permanent monitoring wells. Depths to groundwater and bacteria counts were measured in these wells, along with monitoring wells installed by URS Greiner.

The depth to groundwater information identified an area in the vicinity of the Chili Cook-Off parcel that had adequate depth to groundwater for traditional OWTS leachfield. According to the study authors, this was determined to be 9.5 feet. Shallower depths to groundwater were measured in other areas. Depths to groundwater were greater than 5 feet, with one exception in a monitoring well located in the Cross Creek Plaza shopping center that had a 3 foot depth to groundwater. This was an anomaly since numerous nearby wells had greater than 5 feet depth to groundwater under the flooded Lagoon condition. The water quality data revealed 4 out of 4 wells had total coliform exceedances of 1000 MPN/100 mL, but the fecal coliforms ranged from less than 2 to 400 MPN/100 mL. The possibility of the storm drain near the corner of PCH and Cross Creek Road, conveying contaminated Lagoon water back into the groundwater system was suggested as a potential groundwater contaminant pathway during flooded Lagoon conditions.

3. METHODS AND PROCEDURES

The focus of the study is to assess the risk from OWTS from a water quality perspective and prioritize the risks, assess alternatives for mitigating the risks and develop action items. This is a regional study and is not intended to identify individual systems that may be inadequate for the treatment of water quality. In that sense the OWTS will be evaluated in zones, not in groups of parcels.

Following is a description of the stakeholder involvement process, the data management plan including a description of the types of existing and new data collected, procedures for drilling groundwater monitoring wells including soil boring logs, obtaining samples and measurements, laboratory analysis, hydrogeological model application, risk assessment, analysis of mitigation, and development of action items. Results will be presented in Section 4, and Conclusions and Recommendations in Section 5.

3.1. Stakeholder Involvement

Internal outreach and cooperation with a wide range of stakeholders was planned to obtain information, and to elicit support and understanding of project outcomes and recommended actions. Project staff worked closely with various City Departments, the City of Malibu Wastewater Advisory Committee, SMBRC, and LARWQCB and conducted outreach to many external and internal stakeholders. Outreach included three informational workshops, quarterly reports, mailings, newspaper articles, cable television programs, website postings, and Powerpoint™ and paper presentations.

3.1.1. External Outreach

Individual meetings were planned to update stakeholders on the project process and involve stakeholders in the project.

- SMBRC Onsite Wastewater Taskforce
- SMBRC Technical Advisory Committee
- LARWQCB
- Santa Monica Baykeeper
- California Coastal Commission
- Las Virgenes Municipal Water District
- Heal the Bay
- Dr. Anthony Orme, UCLA
- Los Angeles County Health, Building Safety, and Public Works Departments
- Water District #29
- Richard Laton, Consulting Geologist

3.1.2. *Internal Outreach*

Regular communication and meetings are planned with project team members and City staff. Internal outreach includes three workshops in the City of Malibu, and additional meetings with key stakeholders. The workshops' planned agendas are described as follows:

- Workshop #1 - Introduction of project to the community. Project team members and USEPA present the study scope of work and principles of onsite decentralized wastewater management to residents of Malibu in an evening workshop.
- Workshop #2 - Presentation of project overview; draft findings and action items at Malibu Wastewater Advisory Committee meeting; and request review and input on draft report.
- Workshop #3 - Presentation of final project report including project overview, findings, and action items at Malibu Wastewater Advisory Committee meeting.

Additional meetings were planned with local stakeholders:

- Malibu Chapter of Surfrider Foundation
- Pepperdine University
- Malibu Bay Company
- Malibu Colony Homeowners Association
- Malibu Creek Preservation Company
- Don Kovalewski, local geologist
- California State Parks
- local residents

3.2. Documentation of Data Collection and Data Management

Since this study includes a variety of types and forms of data, and before any data were collected, an information management plan was written in order to establish organization, methods, and procedures for all project related data. In addition, a Quality Assurance Project Plan (QAPP) was developed specifically for the groundwater sampling efforts.

3.2.1. *Information Management Plan*

The data requirements for this project were extensive and complex. Data were collected for groundwater modeling /risk assessment, the Integrated Wastewater Information Management System (IWIMS) database, and GIS-based maps for illustrating results. The plan specified what data were needed for each of these efforts, the sources of the data, data collection methods, and how data were to be managed. The plan was reviewed and signed by all project team members prior to the commencement of data collection efforts. The Information Management Plan for this project is available upon request.

3.2.2. Quality Assurance Project Plan (QAPP) for Sampling Program

This document describes the Quality Assurance and Quality Control (QA/QC) requirements for the sampling and analytical activities described in the work plan. Ms. Kim Watson, Quality Assurance Manager at Stone, developed this document, which was reviewed and signed by key project team consultants as well as by City and SMBRC representatives.

The QAPP described the sampling process design including Standard Operating Procedures (SOPs), sample handling and custody, analytical methods, and quality control (QC) to be used during the sampling program. The sampling program included analyzing groundwater flow and quality using a network of existing and newly constructed groundwater monitoring wells. Data from the sampling program was used to develop a computer model of groundwater flow and solute transport. The computer model (described further in Section 3.6) was then used to analyze the impacts from existing septic systems on groundwater quality and indirect impacts on surface water. To ensure that the quality objectives were met, all sampling was documented and occurred in strict accordance with the specifications provided in the QAPP. Copies of this document are available on request.

3.3. Data Collection from Existing Datasets and Records

Available existing records regarding OWTS, hydrogeology and geology of the study area were retrieved and reviewed.

3.3.1. Onsite Wastewater Treatment System (OWTS) Data

Assessor's data for the study area was purchased from the LA County assessor. Parcel and structure data for 592 parcels were imported into an MS Access database to serve as the foundation for collecting and locating existing OWTS data. Using the files from the City of Malibu, including the final approval drawings, the following data were entered into the MS Access database:

- OWTS system and component data
- Structure data not included in the assessor's dataset
- OWTS Permits
- Percolation test results

Final Approval drawings from 143 systems were scanned and the locations of OWTS components were digitized in GIS as shown on Map 3. Boring locations and structure centroids were also digitized in GIS. Table 1 includes a description of each property's use and OWTS system type within the study area.

Data regarding the two dimensional location of many OWTS was available. However, data regarding the vertical dimension of onsite systems was not readily available. No inspections of onsite systems were conducted to assess actual vertical separation. The study did not intend to locate monitoring wells in close proximity to dispersal units, whether they are leachfields or seepage pits. Therefore data regarding the vertical separation to water table on individual systems was not collected.

3.3.2. Water Quality and Hydrogeology

Available data regarding monitoring well construction; depth to groundwater and groundwater quality data was collected and entered into an MS Access database. This included data from WDR compliance files, and previous investigations. Data was entered from:

- 84 monitoring wells
- 143 total sampling events (not per well)
- 1,109 individual analyses

Available locations and stratigraphic logs from soil borings were retrieved from geotechnical and geological reports in the study area. Data for 383 boring locations 628 test pits were entered into Access. Boring locations were also digitized in GIS. Three hundred and twelve logs were associated with the boring locations.

3.3.3. Development of a Web-Based Information Wastewater Management System (IWIMS)

In order to make the data collected above accessible to all of the various project team members and City of Malibu staff, Stone developed a web-based information management system. The system was customized based on Stone's existing Access-based Integrated Wastewater Information Management System (IWIMS). Most significantly, a monitoring well module was added where all well, sample, and analytical result data could be accessed and queried. In addition, all final approval drawings were made accessible through the web-based application.

Data that had been initially imported into the MS Access database was transferred to the IWIMS application once development was complete, including:

- Parcel, structure, and parcel owner information
- OWTS and component data
- OWTS permits
- Final approval drawings
- Monitoring well, sample, and analytical result data

City staff and key project team members were given username and passwords for accessing the web-based IWIMS. The system provided easy and quick access to the study data through on-line forms and reports.

3.4. Conceptual Model Development

A review of existing reports, studies, and other data was used to develop a conceptual understanding of sources and sinks of groundwater, nutrients, and bacteria in the hydrogeologic system. The conceptual model was developed to provide information for the three-dimensional numerical modeling tool used to evaluate the impacts of onsite wastewater treatment systems on groundwater quality and to delineate directions of groundwater flow from major wastewater dispersal areas.

At this stage of model development, the sources of water to the system included recharge from upland runoff, recharge from approximately 430 onsite and offsite OWTS, infiltration of precipitation, and infiltration from Malibu Creek. The sinks for groundwater included discharge to the Pacific Ocean and Malibu Lagoon. More specific information about development of the conceptual model is included in Appendix 3.

3.4.1. Identification of critical data gaps

The following critical data gaps were identified during the development of the preliminary conceptual model:

- The lack of actual data to better estimate indoor water use/wastewater flow data. This data was needed to better quantify the input of water into the groundwater flow system via OWTS. The County of Los Angeles, Public Works Department, Water District #29 was approached to collect batched data for areas and types of water use in the study area.
- The lack of deep borings in the study area. Depth to bedrock information was needed to define the bottom of the alluvial aquifer system. Once the study team members learned that a number of deep water supply wells were located in the study area, local residents were contacted regarding the availability of such data.
- The lack of an understanding of the long-term fluctuation of groundwater levels with tides and Lagoon stage.
    - Continuous groundwater level monitoring would be useful to see how representative a steady state model is of actual groundwater flow conditions. Installation of pressure transducer dataloggers in three monitoring wells was recommended to understand the relationship between groundwater levels, tide and distance to the Lagoon.
    - The lack of complete sets of water table elevations over a very short period of time. The water quality sampling program took two to three

days to visit all of the wells and collect water level data at each well. Synoptic water table elevation measurement events could be used to collect water levels from as many monitoring wells as possible in a matter of a few hours; thus minimizing the effects of tides. If this is done in both open and closed Lagoon conditions, then the resulting water table maps can be used to develop steady state groundwater flow model for each condition.

3.5. Collection of New Data

Most of the new data generated by this study involved the installation and monitoring of groundwater monitoring wells. Information on soils, groundwater and surface water levels, and groundwater quality were collected during this study.

3.5.1. OWTS

No new data was collected for OWTS in the study area. The project relied solely on existing data.

3.5.2. Surface Water

Manual observations of surface water elevations were made in Malibu Lagoon at the Pacific Coast Highway bridge, and in Malibu Creek at Arizona Crossing, at surveyed reference points. Observations of surface water elevation for Malibu Lagoon were collected from the monitoring point on the bridge using weighted tape. Surface water observations for Malibu Creek at Arizona Crossing were collected approximately 100 feet north of Arizona Crossing from the stream bank.

Automated observations of surface water elevations were also intermittently collected by Las Virgenes Municipal Water District (LVMWD) staff at the Malibu Lagoon monitoring point described above. These observations were collected at 15 to 30-minute intervals during parts of 2003 and 2004 using a Troll 9000 probe and a YSI 6920 Sonde datalogger. Raw data files containing water level data as either probe depth below water surface (for the YSI probe) or internal probe pressure (for the Troll probe) were provided to the project by LVMWD. A summary of the data files that were used in this project is available upon request.

The water depths in the raw data files provided by LVMWD were converted to water table elevation using the following process. First, any raw data provided as probe pressure was converted to feet below water surface. The distance between the monitoring point on the PCH bridge and the Lagoon surface (in feet) was then calculated for each observation. Finally, the distance between the monitoring point and the Lagoon surface was subtracted from the monitoring point elevation.

The project team did not collect any new surface water quality data. Surface water quality sampling conducted by the County of Los Angeles and the city of Los Angeles in the surfzone, and by Heal the Bay in Malibu Creek and by Las Virgenes Municipal Water District in Malibu Lagoon, continued throughout the study (County of Los Angeles, 2004; Heal the Bay, 2004; City of Los Angeles, 2004; Orton, 2004).

3.5.3. Groundwater

Collecting new information on groundwater levels and quality was a primary focus of this study. After the initial stakeholder efforts to obtain permission to use existing groundwater monitoring wells, a process for locating and installing new monitoring wells could be developed. Locations were chosen to fill in existing gaps in area coverage, and where information of soils, depth to bedrock, hydraulic conductivity, and groundwater levels and quality would be useful for the hydrogeological model and risk assessment.

3.5.3.1. Rationale for Locating Monitoring Wells

The study team initially had access to collect water level measurements and water quality samples from 23 existing monitoring wells. Access was also verbally granted to collect water level measurements from eight privately owned monitoring wells. The criteria used to narrow the initial list of proposed / potential monitoring well locations to the final list of monitoring wells included in the water quality sampling program included:

1. Utilize existing monitoring wells to the greatest extent possible (BYA, URS, LADPW WW Plans)
2. Complement the groundwater monitoring programs focused on septic systems that are either underway or proposed for septic systems that must meet either General or Specific Waste Discharge Requirements set by the Regional Board. Wells already being monitored include:
    a. Malibu Bay Co.: Winter Canyon
    b. Los Angeles Department of Public Works (LADPW): Winter Canyon
    c. Malibu Creek Plaza: new wells
    d. New wells for WDRs that come on line during study
3. Characterize groundwater quality along the upgradient edge of the alluvial aquifer
4. Fill in gaps in the central portion of the aquifer
5. Collect data in the vicinity of discharge areas of the alluvial aquifer

Once all new monitoring wells were installed (as described in Section 3.5.3.2), the study team decided which existing wells would be utilized for collecting water level measurements and/or water quality samples based on the 5-point rationale for selecting monitoring wells noted above. The final locations of the 20 monitoring wells used for the water quality sampling program are shown on Map 4. The sampling program included six existing monitoring wells and 14 new monitoring wells.

3.5.3.2. Soil Boring and Monitoring Well Installation Procedures

Fourteen groundwater-level observation and monitoring wells were installed throughout the study area between December 26, 2002 and March 25, 2003. The locations of the new monitoring wells (SMBRP-1 through SMBRP-16) are shown on Map 4. Six pre-existing monitoring wells (C-1, C-2, MW-5, P-1, P-7 and P-9) that were used in the sampling program for this study are also shown on this map. Gregg Drilling and Testing of Signal Hill, California installed the new monitoring wells under the supervision of Bing Yen and Associates, Inc. personnel.

Boreholes for the monitoring wells were completed using 8-inch outer diameter hollow stem augers. Each of the boreholes was completed to a depth of at least 20 feet. All 14 borings were bulk sampled to a depth of 5-10 feet, and were sampled using a standard penetration test split spoon at five-foot intervals from 5-10 feet to the bottom of each boring. Soil boring logs for the new monitoring wells and a key sheet explaining the boring log abbreviations and graphic symbols are included in Appendix 1.

The monitoring wells were constructed of two-inch diameter PVC pipe with 5 to 20-foot sections of 0.020-inch slotted screen. The wells were installed into the open boreholes, and a filter pack of #3 sand was poured into the annular space to a depth one to two feet above the top of the screen. A bentonite seal was placed in the annular space above the silica sand to within one foot of the ground surface. Concrete seals and metal locking flush-mounted protective casings were installed in the top foot of each monitoring well. The driller developed each monitoring well prior to hydraulic conductivity testing and water quality sampling. Details of the individual monitoring wells' construction are included with the soil boring logs in Appendix 1. Land and Air Surveying of Malibu, California surveyed monitoring well locations and top-of-casing elevations. Appendix 1 provides a summary of the monitoring well details, including previously installed monitoring wells that were used in the sampling program.

3.5.3.3. Hydraulic Conductivity Testing

Rising head hydraulic conductivity tests, or slug tests, were performed in the 14 monitoring wells installed by Bing Yen and Associates, Inc. according to Stone SOPs, using a Mini Troll pressure transducer and Win-Situ version 2.18.0.0

instrument communication software. Each slug test was conducted using a well-specific disposable bailer to avoid cross-contamination between monitoring wells. Slug test data were transformed and analyzed using the software application AquiferTest (Waterloo Hydrogeologic, Inc.) that utilizes the Bouwer and Rice analysis method (Bouwer, 1989). The data results of the hydraulic conductivity tests are included in Appendix 2.

Most of the slug tests display a double straight-line trend as described in Bouwer, 1989. The initial drawdown readings were assumed to result from drainage of the highly permeable sand pack. The second, less steep line was assumed to be indicative of the undisturbed aquifer surrounding the well screen. To determine hydraulic conductivity, a best-fit line representing the average rate of water level recovery was matched to the second straight-line portion of the normalized head data. Two wells, SMBRP-12 and SMBRP-13, did not display the double straight-line effect. This may be due to the annulus sand pack and the aquifer at SMBRP-13 having similar hydraulic conductivities, resulting in a single straight line. The water levels in monitoring wells SMBRP-2, SMBRP-7b, and SMBRP-10c fluctuated briefly at the beginning of the slug test. The fluctuations are likely the result of a leaking bailer, or of movement of the transducer during bailer removal.

3.5.3.4. Manual Groundwater Level Measurements

Manual groundwater level measurements were taken in conjunction with each of the twelve events in the groundwater sampling program (described in greater detail in Section 3.5.3.6). Measurements were performed according to Stone SOP 6.2.6, which is available upon request. The water level indicator was decontaminated between monitoring wells, and an electric water level indicator was used to measure the water level at the surveyed monitoring point for each well. Water level observations were recorded on the field forms to the nearest 0.01 foot. After each sampling event, the water level measurements were entered into IWIMS for further analysis and reporting. Water level measurements were converted to elevations by subtracting each water level measurement from the elevation of the appropriate monitoring point.

Water level measurements used to construct the water table maps for the hydrogeologic model were collected in two additional events on September 25, 2003 and on March 9, 2004 from a network of monitoring wells that were surveyed to the nearest 0.01 ft. The data were collected within a relatively short time frame (approximately 2 hours) in order to avoid effects of transient water level changes. During these measurement events, observations of surface water stage were also made on Malibu Creek at the PCH highway bridge and at Arizona Crossing at surveyed reference points.   All water level measurements taken during these two events were collected according to Stone SOP 6.2.6.

3.5.3.5. Continuous Groundwater Level Measurements

Automated observations of groundwater levels were collected in monitoring wells MLW-1, P-1, and P-4 during the project. The observations were collected at one-hour time increments using a Global Water WL-15 pressure transducer and datalogger between September 2003 and May 2004. City of Malibu staff downloaded raw data files containing water level data as depth below top of well casing approximately once every six weeks during the reporting period.

A manual water level reading was taken as described in Section 3.5.3.4 prior to each download of raw data from the dataloggers. After the manual reading was recorded, the datalogger's communications cable was connected to a laptop computer and the raw data was accessed using Global Water's "Global Logger v. 1.38" software package. The recalled raw data (including the date, time, and depth in feet) were saved to an "A" drive floppy disk, the save was confirmed, and the datalogger's memory was cleared. The transducer readings were checked to ensure that the transducer was still deployed at the same depth as originally depicted; then the communications cable was disconnected and the well was secured. The raw data files were sent electronically to Stone Environmental for analysis and reporting.

The water depths in the raw data files were converted to water table elevations using the following process. First, the manual water level reading taken when probe transducer data was downloaded was converted to water level elevation by subtracting the manual reading from the monitoring point elevation. A linear correction factor was then determined by subtracting the manual water table elevation from the automatic transducer reading taken at the same time. This linear correction was then applied to the automatic observations during the preceding time interval, converting the raw transducer data to water table elevations.

3.5.3.6. Groundwater Sampling Program

Twenty monitoring wells were sampled on a monthly basis between April 2003 and March 2004. Sampling constituents were developed to match prior and on-going studies, and included bacteriological (total coliform, fecal coliform and Enterococcus) and nitrogen (ammonia-N, nitrate-N, nitrite-N, and total Kjeldahl nitrogen or TKN) constituents, along with chloride. Samples were collected from monitoring wells in accordance with Stone's standard operating procedure for Groundwater Sampling of Monitoring Wells (Stone SOP 6.27.2), which is available upon request. Once each well was sufficiently purged, the sample was taken and shipped in accordance with the protocol outlined in Stone's standard operating procedures for fieldwork. These SOPs are available upon request and controlled at the Stone facility in Montpelier, VT. Upon sample collection, sample containers were immediately placed in a chilled cooler to maintain 4°C. Upon completion of sample collection, the samples and accompanying chain-of-custody records were transported in coolers by the sampler directly to Pat-Chem Laboratories, Inc. of Moorpark, California for analysis with reporting to Stone. Laboratory results were entered into IWIMS for further analysis and reporting.

3.6. Groundwater Model Development

A groundwater model provides a mathematical simulation of groundwater flow and solute transport. Three-dimensional groundwater modeling is an established approach to analyzing the impact of onsite wastewater treatment systems on groundwater quantity and/or quality (USGS, 1999; USGS, 2001; Hinkle, 2004). The groundwater model was developed for this project as a specific tool for assessing the current level of risk based on as much available data that could be readily retrieved and collected within the scope of this project. The model is limited by the amount of data that was used to build, calibrate, and verify the model. The details of model development are described in Appendix 3. This section will briefly describe the modeling methods in general layperson's terms.

3.6.1. Numerical Model Purpose and Construction

The purposes for constructing a groundwater flow model of the Malibu study area were to develop a water budget, to determine directions of groundwater flow, to identify which parts of the study area contribute groundwater flow to the surfzone and to Malibu Lagoon, to estimate how long it takes groundwater from various parts of the study area to reach the surfzone and the Lagoon, and to estimate how much nitrate is transported by the groundwater from OWTS to the Lagoon and to the ocean.

The extent of the model was designed to simulate groundwater flow in the alluvial deposits that underlie the Malibu Civic Center area along Malibu Creek and Lagoon. The model domain also includes the alluvial deposits in Winter Canyon and sections of shoreline east and west of the main body of the alluvium. The groundwater model used for this investigation is MODFLOW, which was developed by the U.S. Geological Survey (McDonald and Harbaugh, 1988). MODFLOW requires that the study area be subdivided into blocks. For this model, the study area was divided into a grid of rectangles that are 50 feet long and 50 feet wide. The grid was divided vertically into four layers. The thickness of these layers varied from a few feet or less near the edges of the model to a maximum of about 50 feet where the alluvial deposits are thickest. The properties of the groundwater aquifer were described for each block within the study area. The flow conditions along each boundary of the study area are described in the model.

3.6.2. *Model Calibration*

The model was calibrated using two steady-state simulations based upon water levels and streamflow data collected on September 25, 2003 for a flooded Lagoon condition, and on March 9, 2004 for a breached Lagoon condition. During model calibration, average annual rates of recharge for all sources were specified in the model and adjustments were made to conductivity values in order to match measured water levels. Model hydraulic conductivity values were adjusted to improve the match between observed water levels and those calculated by the model.

Calibration was first conducted for the flooded Lagoon condition. The model calibration resulted in model-calculated water levels that reasonably represent measured water levels. There is no significant areal bias in residuals and the model does a good job of reproducing the vertical head differences observed at the multi-level piezometers (monitoring wells) located in the Civic Center area.

Additional calibration was accomplished using the groundwater conditions observed during the March 9, 2004 water level measurement event. On this date the Lagoon was breached and flow in Malibu Creek was continuous across the alluvial deposits from Malibu Canyon to the Ocean. Although this match was not quite as good as that obtained for the flooded Lagoon condition, it is still a reasonable representation of observed groundwater elevations.

3.6.3. *Model Application*

Once the model is calibrated, it can be used to determine the direction and speed of groundwater flow, and to simulate nutrient transport and loading to surface waters. The groundwater direction information will help to determine the contributing areas discharging to Malibu Creek and Lagoon or directly to the ocean surfzone.

3.6.3.1. Contributing Areas and Travel Times for the Ocean and Lagoon

Results from the flow modeling were used as a basis to evaluate directions of groundwater flow, groundwater travel times in the flow system, and the capture zones for the Lagoon and ocean. In order to accomplish these specific objectives the particle-tracking model MODPATH was used. MODPATH is a software package that was developed to calculate three-dimensional flow paths using output from the MODFLOW model. Particle paths are computed by tracking particles from one cell of the model grid to the next until the particle reaches a boundary or an internal sink or source (Pollock, 1994).

In these analyses particles were placed at the water table in each active cell in the model grid and tracked forward. The starting and interim locations of each particle that ultimately travels to either the ocean or to Malibu Creek and Lagoon are then plotted.

3.6.3.2. Solute Transport Model

The purpose of the solute transport modeling analyses was to estimate loading of nutrients to the ocean and to Malibu Creek and Lagoon. Transport modeling was done with the program MT3DMS. MT3DMS can be used to simulate changes in concentrations of miscible contaminants in groundwater considering advection, dispersion, diffusion and some basic chemical reactions, with various types of boundary conditions and external sources or sinks. The chemical reactions included in the model are equilibrium-controlled or rate-limited linear or non-linear sorption, and first-order irreversible or reversible kinetic reactions (Zheng and Wang, 1999).

MT3DMS calculations are based upon the groundwater flows calculated with the MODFLOW model described in Section 3.6.1. The same grid system that was used for the flow calculations is utilized in MT3DMS along with all the same hydraulic properties and stresses. In addition to the flow data, the solute transport model requires assignment of values to parameters that control transport. These include diffusion, dispersion, porosity, source concentrations, retardation and any chemical reactions that can act to vary concentrations of chemical constituents as they move through the flow system.

The transport simulation was run for the period from 1930 through 2090, a total of 160 years. The hydraulic stresses assigned to the model are the same throughout time and are identical to those specified for the steady-state simulations of flooded and breached Lagoon conditions. The stress periods were designed to represent general changes in source loading to the system as follows:

- Stress period 1 (1930 to 1964). Source loading during this period is from Malibu Colony only.
- Stress period 2 (1965 to 1974). During this stress period source loading is simulated from the Colony, from residential areas in uplands adjacent to the alluvium, residences in Winter Canyon, residences in the northern part of the alluvium near Serra Retreat, Malibu Pier, and from the LA county wastewater treatment plant in Winter Canyon.
- Stress period 3 (1975 to 1989). Includes all sources active in stress period 2 plus commercial systems in the main body of alluvium.
- Stress Period 4 (1990 to 2090). Includes all sources active in stress period 3 plus loading from wastewater disposal at the Malibu Bay Colony plant. This run assumes all stresses remain the same into the future. Because of

the lag effect caused by groundwater travel times this simulation was run until 2090 in order to see the maximum impacts of loading.

This model setup is an approximation of actual conditions because the start up dates of each wastewater system is not modeled precisely. Furthermore, this simulation assumes that hydraulic stresses are consistent throughout each time period. In actuality, there were Malibu Water Company wells active during the early stress periods that may have affected the flow system, but there are no records of timing or amount of pumping at these wells so they have not been included. For the purpose of estimating gross loading rates to the Lagoon and ocean, these assumptions are considered to be reasonable.

Source concentrations of nitrate from OWTS were assumed to be 20 mg/l from domestic wastewater disposal systems and 50 mg/l from commercial systems. The basis of these concentrations is described below.

Nitrogen concentrations for commercial and multifamily systems were based on the average of monthly measurements of total nitrogen concentrations in septic tank effluent collected from wastewater systems serving large shopping centers that are located in the study area (Malibu Creek Plaza and Malibu Colony Plaza) between 2001 and 2003 (Malibu Creek Preservation Company, 2003 and 2004; Malibu Bay Company, 2002 and 2003).

Nitrogen concentrations from single family residences were based on local census data, local water use data, and a conservative estimate of nitrogen loading per person. The average household size in the 90265 area code (where the study area is located) is approximately 2.4 people per house hold (US Census, 2000b). The Water District Number 29 water use data revealed an average apparent indoor water use of 500 gallons per day (County of Los Angeles, 2001). The mean mass of nitrogen generated per person is approximately 11.2 grams per day (US EPA, 2002). Based on these data and assumption, the nitrogen concentration is approximately 20 mg/L.

Transport model simulations were run with the steady-state hydraulic stresses for flooded and breached Lagoon conditions in order to estimate nitrate loading to the ocean and Lagoon from wastewater disposal. Although no attempt was made to do a rigorous calibration of transport model results, the calculated nitrate levels were compared with average nitrate levels observed at each of the project wells in the monthly monitoring network. In the base run it was assumed that there is no degradation of nitrate in the flow system. A rigorous calibration of calculated and observed nitrate was not attempted because the exact timing and strength of each nitrate source was not known and de-nitrification processes were not fully understood. However, for the purposes of predicting gross loading rates to the Lagoon and Ocean the model was considered to be acceptable. Sensitivity analyses were conducted to investigate the effect of chemical degradation on model predicted nitrate levels.

3.6.3.3. Management Alternatives Analyses

A simulation was run in which nitrate concentrations were reduced to zero in 2004, assuming that all hydraulic stresses remain the same into the future and that there is no degradation of nitrate. The purpose of this simulation was to evaluate the amount of time it would take for nitrate mass that has accumulated in the flow system to "flush out" to the ocean and Lagoon. Another series of simulations was run to evaluate the effect of decreasing nitrate loading from all disposal systems to 10 mg/l.

3.7. Risk Assessment

The level of risk of onsite systems having an unacceptable impact on water quality was evaluated for two constituents of wastewater: bacteria and nitrogen. The first step in risk assessment is to define what levels of risk are appropriate. Ideally, one would define what risks are acceptable and which are not acceptable. However, because of the variability inherent in natural systems and in OWTS loading the risks are not clear-cut and a prioritization of risk levels are necessary.

Hoover, et al (1997) developed a technique for assessing the risk of water quality impacts from onsite systems in the context of local community decision making. Hoover and others applied this method in a community on Martha's Vineyard, in Massachusetts (NDWRCDP, 2002). The University of Rhode Island developed a spreadsheet/GIS-based program to assess risk based on land use and soils (Joubert, 2001).

This project assessed risk by collecting and evaluating groundwater flow data toward particular water bodies (contributing areas) and groundwater quality data. One level of risk was defined as the sensitivity of the receiving water to a particular pollutant – bacteria or nitrogen. The potential for that pollutant to be transported to the receiving water was assessed, and the areas that are most prone to contributing specific concentrations or are not likely to provide for attenuation of that pollutant were identified.

The three-dimensional computer model described in Section 3.6 was used to develop a steady state simulation of groundwater flow conditions based on measured groundwater conditions. The Basin Plan objectives and the evolving TMDLs for bacteria and nitrogen were used as benchmarks in the risk assessment process.

3.7.1. *Bacteria*

The level of risk for bacterial impacts on water quality depends on subsurface conditions that affect the attenuation of bacteria. Specific risk factors include: (1) the vertical separation between the infiltrative surface of the dispersal system and the water table; and (2) the time of travel in the groundwater prior to reaching a particular receiving water resource location. Due to the variability of bacteria loading in wastewater and the variability in the treatment of bacteria in dispersal units, the bacteria data from the water quality sampling program were not compared to the hydrogeologic model results. Instead, the time of travel in the groundwater flow system between the bacteria source and the receiving waters was calculated. Time of travel is a method used for establishing separation distances between OWTS and drinking water wells, and for other water use areas (Freeze and Cherry, 1979; NYCDEP, 2001; State of California – SWRCB, 1963; and State of California - DHS, 1999). Specifically, the New York City Department of Environmental Protection has established a 60 day time of travel zone around its drinking water supply reservoirs, in which septic systems are inspected and repaired or replaced, if necessary (NYCDEP, 2001).

3.7.2. *Nitrogen*

The level of risk for nitrogen impacts is dependent on the mass loading of nitrogen and the degree of degradation that occurs between the source and the receiving water. The nitrogen loading to surface waters was calculated using a range of attenuation factors (half-lives) and no attenuation for calibration against measured values. The model calibration process is described in greater detail in Appendix 3.

3.8. Analysis of Mitigation

Potential mitigation of the high risk of onsite systems' impacts on water quality was evaluated by identifying and assessing viable OWTS management alternatives, including onsite wastewater treatment, offsite wastewater treatment, institutional changes, and regulatory changes.

The feasibility of the mitigation alternatives was evaluated. Preliminary cost estimates and energy consumption estimates of feasible alternatives for mitigation of high risks will be conducted after receiving comments on the alternatives in the draft report.

3.9. Development of Action Items

Recommended action items were developed and are included in the draft report. The action items are based on the risk assessment, the analysis of mitigation alternatives, and water quality objectives. The intent of these action items is to elicit comment, suggestions, concerns, and feedback from both technical perspectives and from the local perspective of those who live and or work in Malibu, particularly those in the Civic Center area. Based on input received through the end of the comment period, these action items will be reconsidered and revised as necessary.

4. RESULTS AND ANALYSIS

This section presents the results of the study, including information from both existing and new data sources, the groundwater model, and the risk assessment process.

4.1. Stakeholder Involvement

Workshops and meetings were held to engage, inform, educate, learn from and listen to internal and external stakeholders. This was accomplished through a series of outreach and communication initiatives.

4.1.1. External Stakeholder Outreach

Individual meetings were held to update stakeholders on the project process on the following dates:

- December 11, 2001 - Project team delivered presentation to SMBRC Onsite Wastewater Taskforce and members of Technical Advisory Committee
- December 12-13, 2001 - Study team members met with the following stakeholders: Malibu Bay Company, Santa Monica Baykeeper, SMBRC, LARWQCB, Pepperdine University, and Malibu Chapter of Surfrider Foundation.
- March 2002 - California Coastal Commission sponsored a 2-day event including all of the grantees in the Proposition 12 grant funding. Tomales Bay Project team members attended and made a presentation on this study.
- June 12, 2002 - Presented Draft Conceptual Hydrogeologic Model to SMBRC Onsite Wastewater Taskforce/ and members of the Technical Advisory Committee
- January 8 & 9, 2003 - Met with Randal Orton, Las Virgenes Municipal Water District; Mark Abramson, Heal the Bay; Dr. Anthony Orme, UCLA; Don Kovalewski, local geologist
- January 8, 2003 - Meeting with City Manager and Regional Board members Susan Cloke and Francine Diamond.
- February 21, 2003 - Meeting, in the field, with California State Parks District Supervisor and Senior Ecologist regarding monitoring well locations and sampling on State Land.
- May 5, 2003 - City of Malibu's City Manager and project team members met with Dennis Dickerson and Regional Board Staff to discuss project status in relation to regional board's priorities.
- May 16, 2003 - City of Malibu presented project overview and status in a meeting with Mark Gold of Heal the Bay and others.
- June 11, 2003 - City of Malibu presented project overview and status in a meeting with Steve Fleischli of Santa Monica Baykeeper.

- June 5, 2003 - City of Malibu presented project status report during public comment period at meeting of the LARWQCB.
- September 23, 2003 - Meeting with representatives from Los Angeles County Health, Building Safety, and Public Works Departments to present project status.
- March 23, 2004 - Project team members presented professional paper in Sacramento, California at the Tenth National Symposium on Individual and Small Community Sewage Systems, sponsored by the American Society of Agricultural Engineers. The paper was titled: Risk Assessment Of Decentralized Wastewater Treatment Systems In High Priority Areas In The City Of Malibu, California – Conceptual Hydrogeologic Model. The authors were Dan Morrissey, Mary K. Clark, , Bruce Douglas, Amy Macrellis, Vic Peterson, and Chris Dean.
- May 19, 2004 - Project team members met with SMBRC OWTS Task Force and Technical Advisory Committee to present project overview, draft findings and action items; and to request review and input on draft report.
- July 22, 2004 – Project team members presented draft findings to Santa Monica Bay Restoration Commission.

4.1.2. Internal Stakeholder Outreach

Internal Outreach was accomplished by conducting three workshops in the City of Malibu:

- December 11, 2001 - Bob Rubin of USEPA and project team members presented the study scope of work and principles of onsite decentralized wastewater management to residents of Malibu in an evening workshop.
- May 20, 2004 - Presentation of project overview, draft findings, and action items at Malibu Wastewater Advisory Committee meeting; requested review and input on draft report.
- June 14, 2004 - Presentation of draft project report including, project overview, findings, and action items at Malibu City Council meeting.

The slides used for these three workshops are included as Appendix 4 to this report. The following meetings in Malibu supplemented the workshops with internal stakeholders:

- December 12, 2001 - Project Team members initially met with LADPW staff regarding cooperation on use of Civic Center property for installation of monitoring wells.
- September, 2002 through February, 2003 - Project Team members talked with and met with a number of property owners in the study area

informing them of the study and requesting permission to install a monitoring well on their property.

- January 9, 2003 - Project Team members met with Malibu Bay Company representatives and LADPW staff at Maison DeVille Wastewater Treatment Plant staff to request permission to measure water levels in existing monitoring wells.
- January 14, 2003 - Project Team members met with Malibu Colony Homeowners Association Board to request permission to install monitoring wells along Malibu Colony Road.
- April 10, 2003 - Project Team members met with Mario Quiros, Jr. to obtain Malibu Bay Water Company maps with locations of historic water supply wells in study area.
- July 3, 2003 - Project Team members met with Malibu Creek Preservation Company representatives to request use of property for continuous water level recording devices and synoptic water levels.
- September 24, 2003 - Water District #29 regarding water use data; Richard Laton, Consulting Geologist; and Grant Adamson and Tom Doyle, local residents to discuss Malibu Bay Water Company well records.

4.1.3. Outcomes

The stakeholder participation process allowed the project team to present technical aspects of the project and receive constructive review comments and increased stakeholder buy-in regarding the siting of wells and data adequacy. The stakeholder outreach may not have caused an overwhelming change in attitudes, and consensus was not always obtained. Many agreements were reached, however, on obtaining permission to retrieve data, gaining access to existing monitoring wells, and increasing the project team's access to limited-access data.

Initial responses to the presentation of study findings, alternatives, and potential action items obtained during the second workshop were incorporated into the draft report, which will be available for a 30-day review and comment period.

4.2. Existing Data

A critical element of this project was to obtain and organize existing data to help guide the investigation and to supplement new information. Existing data includes information about onsite systems, water use, and hydrogeology. This information is stored in IWIMS and as GIS data, and is summarized below.

4.2.1. Onsite Wastewater Treatment Systems (OWTS)

Approximately 396 parcels with OWTS are located in the study area (Table 1 and Map 3). There are three offsite wastewater treatment systems that are located on parcels separate from the wastewater generation sources. Two of these systems are in Winter Canyon and one is the Los Angeles County Complex on Civic Center Way.

Approximately 349 OWTS serve single family residential dwellings and 47 OWTS serve commercial and multifamily occupancies. One hundred and six residential and eight commercial/multifamily OWTS are located in the bedrock uplands and 243 residential and 39 commercial/multifamily systems are in the alluvial lowlands (Table 1).

Permit data was available for 93 (or approximately one quarter) of these systems. Seven of the 93 OWTS with recent permits utilized advanced treatment as part of an alternative system. The remaining 86 OWTS utilized traditional septic tanks and either drainfields or seepage pits.

4.2.1.1. Data Sources

The data sources were primarily City of Malibu Environmental and Community Development Department files. Some data for older systems that have not been repaired, renovated, or upgraded after 1991were available from the Malibu office of the County of Los Angeles Department of Environmental. Data for OWTS and offsite wastewater treatment systems serving commercial and multifamily properties were available from WDR files at the LARWQCB offices in Los Angeles.

4.2.1.2. Wastewater Flows

Water uses in households in Malibu are highly variable, partly due to the large size of houses, the intermittent occupation of some houses, and the large gatherings that are occasionally held at some houses (Peter Warshall and Associates, 1992). These factors have led to appropriately conservative design flow standards for residential properties in the City to ensure that individual systems have the capacity to accommodate peak daily flows (City of Malibu, 2002). Typical average wastewater flows are generally considered to be 70 gpd/capita (AWWA, 1999). The 2000 census revealed an average household size of 2.4 persons (US Census Bureau, 2002). This would result in an average indoor water use of only 168 gallons per household. This level of water use is not borne out by the data as noted below. The Warshall report analyzed responses to a 1991 survey of homeowners in Malibu and compared those responses to a 1989 survey conducted in the Malibu area by Los Angeles County. The daily average of winter water used for single family residences with no irrigation and year-round occupancy ranged from 273 gpd in 1989 to 351 gallons per day in 1991 (Warshall and Associates, 1992). For this study, more specific estimates of water use and discharges to OWTS were necessary.

As noted in Section 4.2.1, information on the design of OWTS in the study area was only available for 93 specific systems. Information on design flows was not readily available because systems are typically sized based on fixture units as described in the Uniform Plumbing Code, and design flows are not calculated.

Aggregated water use data were provided by the County of Los Angeles Department of Public Works Water District #29 (County of Los Angeles, 2001). These data were aggregated by subareas within the study area to provide a more accurate estimate of actual wastewater flows. The aggregated data were then evenly distributed over the parcels with OWTS in each subarea, proportional to design flows. For example, if the sum of water meter data for 10 commercial lots was 120% of the sum of the design flows for those parcels, then the design flow for each of developed parcels in that subarea was increased by 20%.

The water use data were adjusted to account for irrigation and other outdoor use by using average water use data from Malibu Colony as an indicator of indoor water use. Malibu Colony was used to represent indoor water use because landscape irrigation is minimal due to the general built-out nature of the parcels. The residential water recharge from OWTS based on indoor water use was estimated to be 500 gpd per household.

4.2.2. Surface Water

Wherever possible, data associated with existing surface water monitoring programs were reviewed to supplement new information generated during this study, These programs are briefly summarized below. Although climatological data analysis was not included in the project scope, it should be noted that the study period was during dryer than normal conditions – with the 12 month rainfall between April 2003 and March 2004 at approximately 69% of normal rainfall approximately 25 miles west of the study area in downtown Los Angeles (NOAA, 2004).

4.2.2.1. Malibu Creek Quality

Water quality is measured monthly in surface water at the Arizona Crossing on Cross Creek Road by the Heal the Bay Stream Team (Heal the Bay, 2004). The data from the 12 months coincidental with this study were reviewed for Station HtB-1. During the period from April 2003 to March 2004, nitrate-N concentrations in the creek generally ranged from 3 to 7 mg/L in the winter months, and 0.005 to 0.34 mg/L in the summer months. Ammonia-N concentrations were between 0.02 and 0.11 mg/L over this year-long interval. Enterococcus counts were typically between 5 and 10 MPN/100 mL between April and June, 2003, and increased to between 20 and 63 MPN/100 mL from July, 2003 through March, 2004. E. coli and total coliform counts typically paralleled the Enterococcus trends over this period.

However, Total Coliform count ranged from 934 to 10,462 MPN/100 mL over this period, exceeding the single sample water quality standard of 1,000 MPN/100 mL in all but one month.

4.2.2.2. Lagoon Water Quality

Las Virgenes Municipal Water District samples water quality in the Lagoon on a regular basis. Heal the Bay reported water quality in the Lagoon (station HtB-20) on three occasions between April 2003 and September 2003. During that period, the combined nitrate-N plus nitrite-N concentration ranged between 0.10 to 2.5 mg/L, and ammonia-N ranged from 0.005 to 0.1 mg/L.

The Malibu Creek Preservation Company, LLC (2003) conducted surface water quality monitoring in the Lagoon west of the Malibu Creek Plaza from February 2003 to December 2003. The Enterococcus counts ranged from 52 MPN/100 mL to greater than 2419.2 MPN/100 mL, with the highest counts occurring in June, July, and August of 2003. Four samples were collected from this location in February, October, November, and December of 2003 and were analyzed for nitrogen species. The total N concentrations ranged 1 mg/L to 4 mg/L.

4.2.2.3. Beach Water Quality

The County of Los Angeles monitors beach water quality at Malibu Point and Malibu Pier (County of Los Angeles, 2004). The City of Los Angeles monitors beach water quality at Surfrider Beach (City of Los Angeles, 2004). Single sample exceedances of REC-1 standards will be briefly discussed to provide context for the groundwater quality data. Rolling geometric means were not calculated as part of this study.

The City of Los Angeles collected daily samples in the ocean at Surfrider Beach. These samples were analyzed for *E. coli* and Total Coliform. The REC-1 single sample limit for Total Coliform was exceeded at this location on 55 days during the sampling period (April 1, 2003 to March 30, 2004). Weekly samples were analyzed for Enterococcus at Surfrider Beach during this period. The REC-1 single sample limit for exceeded on 17 days and no exceedances were reported in June, September and March. There is no REC-1 standard for *E. coli*.

The County of Los Angeles Department of Health Services ocean monitoring data (County of Los Angeles, 2004) for Malibu Point and Malibu Pier were reviewed for the monitoring period of April 2003 through March 2004. These data revealed 13 days with exceedances in this period and 9 months with rolling geometric mean exceedances. All of these exceedances involved Enterococci counts, either as the only indicator exceedances or in combination with other indicator organisms.

4.2.2.4. Lagoon Breaching

Lifeguards keep daily records of the condition of the Lagoon, whether it is open or closed (Los Angeles County, 2003 and 2004). At the beginning of the monitoring period (March 1, 2003) the Lagoon was open to the ocean. The Lagoon remained open through July 9, 2003 with the following exceptions: the Lagoon was closed for all or part of the day on May 2nd, June 8th and June 9th. The Lagoon remained closed from July 10, 2003 through November 1, 2003. The Lagoon opened on November, 1 2003 and remained open until April 25, 2004. The Lagoon was closed from April 25th through April 27th, and then opened until May 1, 2004. The Lagoon was closed from May 1, 2004 through the end of data collection (May 7, 2004).

4.2.3. Hydrogeology

The conceptual model section of Appendix 3 provides integration of and references for the existing hydrogeologic data for the study area. The key findings of this investigation are based on existing data regarding the physical groundwater flow regime:

- Collection of existing soil borings, deep well information, and water quality data
- Determination of the extent of the alluvial aquifer system, including the contours of the bedrock surface beneath the alluvial aquifer
- Construction of a preliminary water table contour map
- Development of preliminary wastewater flows
- Development of a rationale for selecting locations for new monitoring wells in the water quality sampling program

4.3. New Data

4.3.1. Onsite Wastewater Treatment Systems (OWTS)

This study primarily focused on assembling and organizing OWTS data already existing in a variety of sources. No new data regarding OWTS were created or collected as part of this study.

4.3.2. Surface Water

Surface water levels were measured in the Lagoon and in Malibu Creek upstream of the Arizona Crossing (Cross Creek Road) on an approximately monthly basis from July 2003 through March 2004. The water level appeared to be influenced by the constriction of the flow through the culvert at the Arizona Crossing. Water level elevations ranged from 14.08 ft AMSL to 16.34 feet AMSL (Table 3 and Figure 3). The lowest levels were in September and October, while the highest levels were measured in December, January, and March.

During breached conditions (from November 1, 2003 through the last monthly data collected in May, 2004), the water level elevations in the Lagoon ranged from an elevation of 3.13 feet AMSL to 4.11 feet AMSL. During flooded conditions (from July 18, 2003 to October 31, 2003), the water level elevations in the Lagoon ranged from 6.45 feet AMSL to 8.08 feet AMSL. Although these measurements do not take the tidal levels into account, the difference in the measured Lagoon water level elevations from October 30, 2003 to November 4, 2003 was 4.9 feet AMSL (Table 3).

The continuous water level data from Malibu Lagoon provided by LVMWD revealed an approximately 3.3-foot difference in the average water table between breached and flooded Lagoon conditions (Table 4). The breached Lagoon condition had the largest average daily range in water level, 1.66 feet, compared to a 0.17-foot average daily range in the flooded Lagoon condition.

4.3.3. Hydrogeology

4.3.3.1. Soil Borings

Soil borings advanced near the shoreline at the southern edge of the study area (SMBRP-1, SMBRP-11, SMBRP-12, SMBRP-13, and SMBRP-14) revealed beach deposits composed primarily of sand and silty sand with minor gravel, clayey silt, and clay. The rest of the borings were advanced into alluvium, which was composed primarily of gravelly sand and silty sand, interbedded with sandy silt, silt, and clay. The first soil boring advanced at the SMBRP-15 site collapsed before a monitoring well could be installed. In this case, the monitoring well for the site was installed a few feet from the original boring at location SMBRP-15b. The results of these borings agree well with previous work completed in the study area (Yerkes and Campbell 1980, Ambrose and Orme 2000) and with the study's conceptual hydrogeologic model. The soil boring logs for new monitoring wells are included in Appendix 1.

4.3.3.2. Hydraulic Conductivity Testing

Hydraulic conductivity estimates for the 14 new monitoring wells ranged from 0.0797 feet/day at SMBRP-10c to 123 feet/day at SMBRP-13, with a geometric mean of 2.61 feet/day (Appendix 2). The hydraulic conductivity values for SMBRP-1, SMBRP-7b, and SMBRP-13 are the average of two slug tests. Analyses of all slug tests are presented in Appendix 2.

The hydraulic conductivity estimates for wells agree well with published average values for similar sedimentary deposits (Freeze and Cherry, 1979). There are few previous analyses of monitoring wells in the study area with which to compare Stone's hydraulic conductivity estimates. Laboratory testing of clay samples collected from borings near the City of Malibu offices along Civic Center Way produced hydraulic conductivity estimates of 0.00014 and 0.00076 ft/d. Stone's hydraulic conductivity estimate for monitoring well SMBRP-10, west of the City of Malibu offices, was 0.0797 ft/d. Slug tests conducted on five wells located near a septic disposal system at Cross Creek Plaza gave hydraulic conductivity estimates that ranged from 0.6 to 4 ft/d (URS Greiner Woodward Clyde 1999). While new monitoring wells were not installed in the immediate vicinity of Cross Creek Plaza, the nearest new wells (SMBRP-2, SMBRP-7b, SMBRP-14, and SMBRP-15) gave hydraulic conductivity estimates that range from 0.231 ft/d to 9.40 ft/d, agreeing reasonably well with previously published estimates.

4.3.3.3. Extent of the alluvial aquifer system

The depth to bedrock in the alluvial aquifer was not known at the beginning of this study. Using the logs from deep water supply wells, drilled as far back as 1902, and the stratigraphic logs from geotechnical borings in the study area, the study team was able to build a three dimensional model of the aquifer shape and stratigraphy.

4.3.4. Water Level Data

Water level measurements can be used to understand the groundwater flow directions and gradients by preparing water table contour map from synoptic water levels. Water level measurements can also be used to understand the physical response to:

- Seasonal changes in water level readings or measurements at an individual well;
- The amount of water recharging the aquifers and flowing past the monitoring well location;
- Variation in the Lagoon level in some areas; and
- Tidal conditions

4.3.4.1. Water Table Contour Maps

The goal of the synoptic water level measurement events was to minimize the impact of tidal fluctuations on ground water levels. Synoptic water level data were collected on September 25, 2003 (closed Lagoon) and March 9, 2004 (open Lagoon) (Tables 5 and 6). Water table contour maps (Maps 5 and 6) show the overall water table contours under open and closed Lagoon conditions. The water table contour maps can be used to differentiate the area that recharges Malibu Creek and Malibu Lagoon from the area that recharges the ocean (Map 7).

The synoptic data included measuring water levels in three pairs of monitoring wells to understand the vertical component of groundwater flow. The lower well in each pair is screened in the Civic Center Gravels; and the upper wells are screened in the water table aquifer (Earth Consultants International, Inc. 2000a). The water table elevations in the shallower of the pair of wells were consistently higher than the water level elevations in the deeper of the pair. This indicates that there is an apparent downward vertical gradient in this area.

4.3.4.2. Monthly Water Table Measurements

Water table measurements were also collected prior to every water quality sampling event. Since it took two to three days to complete the sampling, the monthly water table data do not account for tidal or other short-term variations in water levels. A summary of the water table measurements taken during the water quality sampling program is included as Table 7; graphs showing the changes in water level at each monitoring well during the sampling program are shown in Figures 4-22.

Monitoring wells SMBRP-2, P-1, P-9, C-1 and, C-2 are located near the Lagoon and showed distinct water level responses to the closing and opening of the Lagoon. The increase in water level elevation in these wells occurred within one month after breaching and remained fairly steady until the Lagoon breached and dropped. The most extreme response to the Lagoon closing was evident at well P-9, located 250 feet from the Lagoon; this well had a 4-foot increase in water level in the month following closing of the Lagoon.

Monitoring wells C-1 and C-2 are located approximately 50 feet south of the west arm of the Lagoon. C-1 and C-2 had roughly a 2.4-foot and 2.8-foot rise in water table, respectively, after the Lagoon closed. Monitoring well SMBRP-14 is located near the east end of Malibu Colony Road, approximately 250 feet south of the Lagoon, and had an approximately 1.6-foot rise in water level following closing of the Lagoon. Southwest of the Lagoon, SMBRP-13 had an approximately 1-foot rise in water table in response to the Lagoon closing. Further to the west, SMBRP-12 had an approximately 0.4-ft response to the Lagoon closing.

Located on either side of Malibu Creek in the vicinity of the Arizona Crossing, SMBRP-2 and SMBRP-6 had a similar gradual drop in summer water table elevations, followed by a gradual recovery in the fall. The magnitude of this drop was on the order of 2 feet in SMBRP-6 and 1.4 feet in SMBRP3c. It is likely that this drop is due to the lack of recharge during the dry season (June- September) and rise in water table levels in October when autumn rains began.

Monitoring wells P-7 and C-1 had a approximately 2-foot drop in water levels between May and June, 2003, followed by a 4-foot rise in water level, for a net 2-foot rise in water level from open to closed condition. Both of these wells are located near the west arm of the Lagoon; however, C-1, which is also along the west arm, did not have an abrupt drop just before the Lagoon closed. The furthest well to exhibit a response to Lagoon opening and closing, SMBRP-15b is located 900 feet from the Lagoon and had an almost 2-ft raise in water levels after the closing of the Lagoon. This variability in response with distance indicates that distance is not the lone factor in determining the magnitude of Lagoon fluctuations, it is likely that the continuity, or lack of continuity, of alluvial, fluvial and estuarine deposits likely plays a role.

Monitoring wells SMBRP-7b and SMBRP-16 are both located along Civic Center Way near the County Administration buildings. Both of these wells had relatively consistent water level elevations throughout the study, with generally less than 1-foot variation. These two wells had the least overall difference between the minimum and maximum water level measurements over the course of the study.

Monitoring wells SMBRP-8 and SMBRP-9 are both located towards the inland edge of the alluvial aquifer. Between April, 2003 and January 2004, the water table elevation in SMBRP-8 declined approximately 5 feet. The water table elevations in SMBRP-9 increased approximately 1.4 feet between April, 2003 and July 2003, then declined 2 feet in water table elevations from July 2003 through January 2004.

Monitoring well SMBRP-10c, is located along Civic Center Way, west of Webb Way. Water levels in this monitoring well dropped 5.5 feet between May and September of 2003. In October 2003, the water level rose 2 feet and then continued to drop towards a low in December 2003. This monitoring well had the greatest overall difference, approximately 6 feet, between the minimum and maximum water level measurements over the course of the study. The water level fluctuations in this monitoring well are potentially related to the wetland located in the undeveloped property directly to the northwest from SMBRP-10c.

4.3.4.3. Continuous Water Table Measurements

During the study, it became apparent that there was a need to better define the extent of water table fluctuations over time and over increasing distance from the Lagoon. The pressure transducers with dataloggers installed in three monitoring wells near the Lagoon revealed the approximate variation between low and high tide conditions (Table 4). Figure 3 provides a continuous view of how breached and flooded Lagoon conditions and tides affect the water table. Monitoring well P-4, located approximately 250 feet from the Lagoon, appears to have the greatest response to the transitions from flooded to breached and breached to flooded—on the order of 3 to 4 feet in variation while the Lagoon has an approximately 5 foot variation in water level at these transitions. Monitoring well P-1, located 500 feet from the Lagoon, has a more subdued response to fluctuations in Lagoon water levels.

4.4. Water Quality Data

Water quality data will be discussed first by individual constituent and then by contributing areas and the monitoring wells located in each contributing area. Details of the water quality sampling results organized by sampling date are included in Tables 8-19.

4.4.1. Water Quality by Constituent: Nitrogen

Nitrogen species in groundwater are a result of percolating water containing residual nitrogen typically derived from a variety of sources, including atmospheric deposition, decomposition of organic matter, fertilizer, stormwater or stream infiltration, leaking sanitary sewers, animal wastes, and sewage discharges to land, including OWTS.

Total nitrogen is the sum of all nitrogen species present, including ammonia-nitrogen and organic nitrogen (reported as Total Kjeldahl Nitrogen or TKN), nitrate-nitrogen and nitrite-nitrogen. The water quality objectives for total nitrogen and for nitrate-nitrogen are both 10 mg/L as nitrogen. The water quality objective for nitrite-nitrogen is 1.0 mg/L as nitrogen. These standards are established for the protection of drinking water uses (LARWQCB, 1994).

Nitrogen is present in high concentrations in raw sewage and in septic tank effluent. In septic tanks nitrogen occurs primarily as ammonium nitrogen (75-80%), with organic nitrogen making up the remainder. Nitrogen does not occur or remain in the nitrate form in septic tanks due to the anaerobic environment that readily consumes the oxygen associated with nitrate molecules. Total nitrogen concentrations in septic tank effluent vary typically from about 20 mg/L to more than 100 mg/L. The mass loading of nitrogen is determined by the type of facility and degree of use (e.g., population). The resulting concentration of nitrogen can be influenced by the amount of water used.

The mean total nitrogen concentrations at individual monitoring wells ranges from 0.80 mg/L at monitoring well P-7 to 44 mg/L at SMBRP-8 (Table 20). The composition of nitrogen in the groundwater beneath the study area ranges from predominantly nitrate-N in SMBRP-8, to predominantly ammonia-N in SMBRP-13, to predominantly organic N in SMBRP-2 (Figure 23). The spatial distribution of mean nitrate-N and TKN is shown in Map 8. The distribution of high, medium and low total N concentrations are shown on Map 9.

4.4.1.1. Ammonia

In a developed area such as the study area, likely sources of ammonia in groundwater include fertilizer applications, stormwater infiltration, Lagoon sediments, or discharges from OWTS where there is insufficient exposure to aerobic soil conditions to allow the ammonia to be nitrified, i.e., oxidized to nitrate. Ammonia makes up part of the total nitrogen concentration, and is included as part of the reported value for Total Kjeldahl Nitrogen (TKN) analysis, along with organic nitrogen.

In the study area, ammonia concentrations expressed as nitrogen (ammonia-N) were found to range from not detected to 23.8 mg/L (Table 21 and Figure 24).

- High Ammonia-N Concentrations. SMBRP-14 was inadvertently installed directly through a corner of an existing leachfield serving a single family residential dwelling; this explains the unusually high ammonia values at this monitoring well. High levels of ammonia-N (>10 mg/L) were also detected in SMBRP-12. Monitoring wells SMBRP-16 and C-1 had significantly elevated levels of ammonia-N, in the range of 5 to 9.9 mg/L.
- Medium Ammonia-N Concentrations. Monitoring wells SMBRP-1, SMBRP-2, SMBRP-8, SMBRP-7b, SMBRP-15b, and P-9 had apparently elevated concentrations of ammonia-N in the range of 1 to 4.9 mg/L.
- Low Ammonia-N Concentrations. The remaining wells monitored during the study had ammonia-N concentrations of less than 1 mg/L, apparently indicating background levels.

4.4.1.2. Total Kjeldahl Nitrogen and Organic Nitrogen

Total Kjeldahl Nitrogen (TKN) measures the organic nitrogen (N) and ammonia-N. Therefore, subtracting the ammonia-N from the TKN yields the organic nitrogen concentration. The organic nitrogen is typically due to an organic source of nitrogen, such as animal feces, human wastes (other than ammonia) or vegetable matter.

- TKN concentrations ranged from not detected to 100 mg/L (Table 22 and Figure 25).
- High TKN Concentrations. Mean TKN concentrations greater than 10 mg/L are considered high for the purpose of this assessment (Table 22 and Map 8). The highest TKN concentration was in SMBRP-14. This monitoring well was inadvertently installed directly through an existing leachfield; therefore, it is sampling relatively undiluted effluent. Since the

ammonia-N concentration was 20.4 mg/L on the same day, the organic N concentration was 80 mg/L. Other monitoring wells where the 10 mg/L water quality standard for nitrogen was exceeded were: SMBRP-2, SMBRP-12, SMBRP-15b and C-1. SMBRP-12 and C-1 are located in, or near, Malibu Colony; the elevated ammonia-N appears to account for most of the TKN concentration in these two monitoring wells. High TKN concentrations may indicate insufficient nitrification of N-loading from OWTS. SMBRP-15b is not located near any OWTS and the TKN is exceeded by the ammonia-N for two readings. It is likely that there is a local source of ammonia-N and organic N, possibly fertilizer or stormwater runoff, in the vicinity of SMBRP-15. SMBRP-2 had relatively small proportion of TKN measured as ammonia-N, therefore appears to be predominantly organic N. Since there is no OWTS in the vicinity, it could be influenced by ranch activities associated with a nearby barn foundation and trail where horseback riding has been observed.

- Medium TKN Concentrations. Monitoring wells SMBRP-1, SMBRP-10c and P-9 had mean TKN concentrations between 5 and 10 mg/L. All of these wells had mean concentrations greater than 1 mg/L, but no concentrations greater than 10 mg/L during the sampling period. The mean ammonia-N measured in samples from SMBRP-1 and P-9 appears to account for most of the TKN in these samples. SMBRP-10c had low ammonia-N and therefore the TKN in this monitoring well appears to be predominantly organic N.
- Low TKN Concentrations. The remainder of the monitoring wells sampled in this study had mean TKN concentrations of less than 1 mg/L.

4.4.1.3. Nitrate

Nitrate is not found in septic tanks, but it is commonly found in high concentrations in the oxidized effluent from OWTS, as well as in fertilizer. In properly operating OWTS, virtually all of the organic nitrogen and ammonia in septic tank effluent is converted to nitrate during percolation through the unsaturated soil zone. Conversion to nitrate is also achieved where the OWTS includes an aerobic treatment process prior to dispersal to the receiving environment. Nitrate is a stable anionic species and moves readily through the vadose zone, ultimately reaching the groundwater below. Within the groundwater and, to some extent, during percolation through the vadose zone, nitrate can be reduced to nitrogen gas and released to the atmosphere by a microbial process called denitrification. The process of denitrification requires anaerobic conditions and a source of carbon in the saturated soil or groundwater environment. As stated before, the nitrate-nitrogen water quality standard for drinking water protection is 10 mg/L as nitrogen.

Background concentrations of nitrate-N in groundwater due to natural sources are typically less than 1 to 2 mg/L. In the groundwater samples collected in this study, nitrate-N concentrations range from not detected to 63.8 mg /L (Table 23 and Figure 26).

- High Nitrate Concentrations. Mean nitrate-N concentrations greater than 10 mg/L are considered high for the purpose of this assessment (Table 23 and Map 8). The highest nitrate-N concentration found was at SMBRP-8, at 63.8 mg/L. Recent samples of septic tank effluent from commercial uses in the study area revealed an average nitrogen concentration of approximately 50 mg/l. Therefore, the high nitrate-N reading at SMBRP-8 is most likely the result of essentially undiluted wastewater collected at this monitoring well location. The 10 mg/L water quality standard for nitrate-N was also exceeded at SMBRP-9. SMBRP-8 and SMBRP-9 are both located near the upper extent of the alluvial aquifer, where the saturated aquifer thickness is small and percolation return flow is estimated to make up a significant percentage of the aquifer volume. Natural dilution effects are limited in this area. Nitrate concentrations decrease downgradient of both of the wells as noted in SMBRP-10c and SMBRP-7.
- Medium Nitrate Concentrations. Mean nitrate-N concentrations ranging from 5 to 10 mg/L are considered medium for the purpose of this assessment (Table 23 and Map 8). Although monitoring well MW-5 exceeded the 10 mg/L standard for nitrate-N on at least one occasion, the mean nitrate-N concentration over the sampling period was less than 10 mg/L. MW-5 is located in the upper part of Winter Canyon and is downgradient of several nearby OWTS. This well is also immediately upgradient of, but in close proximity to, a large wastewater dispersal field for the Los Angeles County Maison de Ville treatment facility.
- Low Nitrate Concentrations. SMBRP-16 and P-1 had mean nitrate-N concentrations between 2 and 5 mg/L. The remainder of the monitoring wells sampled in this study had mean nitrate-N concentrations of less than 2 mg/L.

The apparent decrease in nitrate-N concentrations in groundwater as monitoring wells are located farther away from leachfields appears to be significantly greater than can be accounted for by dilution (see Appendix 3). Therefore, it is likely that some denitrification may be occurring.

4.4.1.4. Nitrite

Nitrite ($N0_2^-$) is a species of nitrogen that also can be attributed to either fertilizer or OWTS. It is an intermediate product of the nitrification process. Normally, nitrite converts readily to nitrate. An elevated nitrite concentration (>0.1 mg/L) is often indicative of a close connection to a source of contamination. The water quality standard for nitrite expressed as nitrogen (nitrite-N) is 1.0 mg/L.

In this study, no samples exceeded the water quality standard for nitrite-N (Table 24 and Figure 27). Nitrite-N was elevated in SMBRP-16 on five sampling events. Elevated concentrations of nitrite-N were also detected in wells MW-5 and P-9, in one sampling event each. The source of these elevated nitrite-N concentrations was not apparent.

4.4.2. Water Quality by Constituent: Bacteria

Three indicator bacteria were measured in this study: total coliform, fecal coliform and Enterococcus. These bacteria were measured because they are used for the marine recreational water quality standard (Table 2).

4.4.2.1. Total Coliform

The presence of coliform bacteria (expressed as total coliform) is used to indicate water quality with respect to turbidity and organic matter content, as well as to indicate the possible presence of the fecal coliform group of bacteria. Total coliform are a group of bacteria that are widespread in nature and are not a good means to identify a particular contamination source (e.g., human, animal, soil, etc). However, total coliform is a standard test and is used widely to characterize the presence and magnitude of a contamination condition, especially with respect to water supply impacts. In a drinking water supply, the presence of total coliform is an indicator that some type of foreign material is present in the water.

4.4.2.2. Fecal Coliform

Fecal coliform bacteria, a subset of total coliform bacteria, are a group of bacteria found in the intestinal tract of mammals and enter the environment from the feces of mammals. This group of bacteria is a common indicator of bacterial pathogens in water.

4.4.2.3. Enterococcus

Enterococci are a subgroup of bacteria within the fecal streptococcus group, distinguished by their ability to survive in salt water and their tendency to mimic the behavior of many pathogens better than other indicators. They are typically more human-specific than the larger fecal streptococcus group and thus are recommended by the USEPA as the best indicator organism for health risks in salt water used for recreation. They are also useful as a measure of the contamination threat in fresh water.

4.4.2.4. Results of Bacterial Water Quality Sampling Program

The geographical distribution of geometric mean Enterococcus concentrations is shown on Map 10. The results for total coliform, fecal coliform, and Enterococcus are summarized for each monitoring well on Tables 25-27 and Figures 28-30. The distribution of high, medium and low indicator bacteria concentrations is shown on Map 11.

- High Bacteria Counts. Since both geometric means and single sample exceedances are included in the marine recreation water quality standards, the exceedance of both geometric mean and single sample criteria defines the high level of bacterial contamination in this discussion. Eight monitoring wells had high bacteria counts for Enterococcus, Fecal Coliform or Total Coliform: SMBRP-1, SMBRP-2, SMBRP-7b, SMBRP-8, SMBRP-9, SMBRP-11, SMBRP-14, and P-7. All of these wells had Enterococcus exceedances (Table 27). As mentioned above, SMBRP-14 was apparently installed in the corner of an OWTS. High levels of indicator bacteria were found in two wells in close proximity to OWTS (SMBRP-1 and SMBRP-8). However, it is significant to note that high counts of indicator bacteria were evident in two locations (SMBRP-2 and SMBRP-7b) that are not associated with nearby OWTS. Overall, bacteria counts appear to be generally higher in the summer and early autumn sampling events.
- Medium Bacteria Counts. The exceedance of single sample marine recreational water quality criteria defines a medium level of indicator bacteria counts for the purpose of this study. Seven wells were included in this category: SMBRP-3c, SMBRP-10c, SMBRP-15, SMBRP-16, MW-5, C-1 and C-2. It is significant to note that SMBRP-3c, SMBRP-10c, SMBRP-15b and SMBRP-16 are not located in close proximity to an OWTS. Therefore there is likely to be another source of indicator bacteria affecting these monitoring wells. Well MW-5 is located in the proximity of OWTS in Winter Canyon. Monitoring wells C-1 and C-2 are located between the east end of Malibu Colony and Malibu Lagoon.
- Low Bacteria Counts. The following monitoring wells had no single sample or geometric mean exceedances of indicator bacteria: SMBRP-6, SMBRP-12, SMBRP-13, P-1, and P-9. It is very significant to note that all of these are located near the ocean (SMBRP-12 and SMBRP-13) or the Lagoon (SMBRP-6, P-1 and P-9).

As noted previously, the Malibu Valley is designated as MUN – suitable for "beneficial use of groundwater, existing or future drinking water supply". No existing drinking water supply wells were documented in this study area. However, as noted in the Waste Discharge Requirements for the Malibu Creek Plaza, Ocean Plan water quality requirements are used in this vicinity (MCPC, 2000).

4.4.3. Water Quality by Constituent: Chloride

Chloride is a conservative ion that is present in significant concentrations in wastewater, commonly at concentrations over 100 mg/L. The magnitude of the chloride concentration depends on the quality of the water supply, combined with additions from domestic sewage wastes. Chloride is the dominant mineral in seawater, occurring at concentrations of 15,000 to 20,000 mg/L. In groundwater, chloride concentrations are the result of leaching of minerals from sediments or geologic formations of marine origin, along with percolation from surface sources.

- Monitoring wells along the ocean or Lagoon (C-1, C-2, SMBRP-1, SMBRP-2, and SMBRP-13) reported chloride concentrations greater than 1,000 mg/L (Table 28 and Figure 31). One of the monitoring wells not near the Lagoon, SMBRP-10c, also had chloride concentrations consistently greater than 1,000 mg/L. The source of this apparently anomalous condition was not identified.
- Medium chloride concentrations were evident in MW-5, P-7, SMBRP-7b, SMBRP-9, SMBRP-11, SMBRP-12, and SMBRP-16.
- The lowest chloride concentrations were evident in SMBRP-3c, SMBRP-6, SMBRP-8, SMBRP-14, SMBRP-15b, P-1, and P-9. Background concentrations of chloride in the groundwater in the study area appear to be on the order of 100 to 200 mg/L. The lowest chloride concentration found in this study was 61 mg/l, based on a sample collected from P-1.

Trends in chloride concentrations were generally consistent over time during the sampling period. Trends in chloride concentrations were generally sub-parallel to the trends in ammonia-N concentrations in SMBRP-1, SMBRP-12, SMBRP-13, C-1, and C-2. These are typically the monitoring wells with high chloride concentrations. However, SMBRP-10c had high chloride concentrations that did not follow trends in ammonia-N concentrations.

4.4.4. Water Quality by Contributing Areas

The water quality data will be briefly described based on contributing areas:

- the area contributing to the ocean
- the area contributing to Malibu Creek and Malibu Lagoon

In this section, the nitrogen discussion will focus on the predominant species of nitrogen detected in each monitoring well. Graphs showing the nitrogen water quality results for each monitoring well are presented in order by monitoring well identification in Figures 32-51. The bacteria discussion will primarily focus on Enterococcus, since that indicator bacterium was the most prevalent in the study area. Graphs showing the bacteria water quality results for each monitoring well are presented in the same order as the nitrogen results in Figures 52-71.

4.4.4.1. Ocean Contributing Area

The ocean recharge area is shown on Map 7. For the purpose of this discussion, the ocean contributing area will be divided into two sub-areas: Winter Canyon, and the remainder of study area that lies over the alluvial aquifer.

4.4.4.2. Ocean Contributing Area: Winter Canyon

In the Winter Canyon groundwater flow system, the mean nitrate-N concentrations decreased from approximately 9 mg/L near Pacifica Drive to less than 2 mg/L along Malibu Road. Fecal coliform bacteria concentrations were typically less than 10 MPN/100 mL in both MW-5 and SMBRP-11. Total coliform concentrations in MW-5 had a pattern of peaks similar to Enterococcus, although consistently lagging behind one month. Downgradient in SMBRP-11, fecal coliform concentrations peaked between 100 and 300 MPN/100 mL in July and August, again following the general pattern of Enterococcus concentrations in this well.

Monitoring well MW-5 is located in Winter Canyon, apparently upgradient of the Los Angeles County (Maison DeVille) Treatment Facility seepage pits and potentially downgradient of OWTS serving the commercial and institutional buildings on Winter Canyon Road (Map 4). Nitrate-N concentrations at this location ranged from a peak of 28.5 mg/L on December 27, 2003 to a low of 1.31 mg/L on January 20, 2004. The water quality standard of 10 mg/L was exceeded on May 30, 2003 (15.3 mg/L), July 24, 2003 (14.9 mg/L), and on December 27, 2003 as previously noted. Indicator bacteria concentrations were generally higher along Malibu Road. This increase in bacteria levels may be due to loading from the two large off-site wastewater dispersal systems or to the existence of one or two leachfields south of PCH and potentially upgradient of the monitoring well. Enterococcus concentrations ranged from not detected to 6.0 MPN/100 mL, with the exception of 1553 MPN/100 mL on October 20, 2003. Fecal coliform concentrations ranged from not detected to 8 MPN/100 mL; with the peak occurring on November 18, 2003. Total coliform concentrations ranged from not detected to 23 MPN/ 100 mL; with the peak also occurring on November 18, 2003.

Monitoring well SMBRP-11 is located along Malibu Road near the mouth of Winter Canyon. Nitrate-N concentrations at this well were below the water quality standard for the entire study. The Nitrate-N concentrations tended to decline from 5.66 mg/L on April 25, 2003 to a low of 0.09 mg/L on November 18, 2003; then generally increased to 3.43 mg/L at the end of the study (March 16, 2004). Total N did not exceed 10 mg/L. Enterococcus concentrations exceeded the marine contact recreation standard in SMBRP-11 on three occasions: May 28, 2003 (2419.2 MPN/100 mL), July 21, 2003 (1203.3 MPN/100 mL), and August 18, 2003 (2419.2 MPN/100 mL). Fecal coliform concentrations ranged from not detected to 4 MPN/100 mL, with the only three detections occurring in July, August and September.

4.4.4.3. Ocean Contributing Area: Main Alluvial Aquifer

This area contributing to the surfzone west of Malibu Lagoon extends from the valley wall in the vicinity of the Malibu Tennis Club and the Vineyard Community Church to the surfzone between Winter Canyon and Malibu Point. On the east side of the Lagoon, this area extends to Sweetwater Canyon.

Monitoring well SMBRP-9 is located near the upper (northern) edge of the alluvial terrace and near the toe of the bedrock slope. The well was located to be in the alluvium and to encounter the water table. Geotechnical borings located upslope of this location did not always encounter groundwater before reaching bedrock. This well was located with the anticipation that it would be cross-gradient to the groundwater flow path from the nearby leachfield. However, based on the water quality sampling results, it is likely that this monitoring well is located downgradient of a commercial/multifamily discharge. Monitoring wells SMBRP-10c, SMBRP-15b, and SMBRP-16 are not located near any existing leachfields. At the bottom of this groundwater flow path, three monitoring wells along Malibu Colony Road (SMBRP-12, SMBRP-13, and SMBRP-14) indicate that groundwater flows from the Colony to the ocean. These wells are located amidst single family residences. Unfortunately, SMBRP-14 was apparently installed through a leachfield and therefore the water quality results are not indicative of nearby groundwater quality. SMBRP-1 was located on the east side of the Lagoon, in the Malibu Pier parking lot. SMBRP-1 was accidentally destroyed due to construction in the parking area after being sampled in July.

Enterococcus concentrations at SMBRP-9 were elevated, and occasionally exceeded the single-sample water quality standard. However, the geometric mean concentration for monthly samples within the scope of the sampling program was 36 MPN/100 mL. Bacteria concentrations along Civic Center Way are only slightly lower (geometric means of 34 MPN/100 mL and 25 MPN/100 mL, respectively) although the wells are located over 800 feet away from the nearest apparently upgradient leachfield. It is therefore likely that OWTS are not the source of the bacteria at this location. Further downgradient in this flowpath, well SMBRP-15b is located along Malibu Road and has similar Enterococcus concentrations (geometric mean of 16 MPN/100 mL) with no apparent upgradient OWTS for over 1500 feet. This well also has low N concentrations (less than 2 mg/L). Both of the wells located in Malibu Colony, SMBRP-12 and SMBRP-13, had low bacteria concentrations. As noted, before, the bacteria concentrations in SMBRP-14 are apparently indicative of wastewater quality, not groundwater quality. On the east side of Malibu Lagoon, SMBRP-1 had a geometric mean Enterococcus concentration of 163 MPN/100 mL over four sampling events.

In SMBRP-9, fecal coliform concentrations had peaking patterns generally similar to the Enterococcus concentrations, with a geometric mean of 64 MPN/100 mL. In distinct contrast with Enterococcus concentrations at these wells, geometric mean fecal coliform concentrations were less than 2 MPN/100 mL in SMBRP-10c, SMBRP-15b, and SMBRP-16. Near the ocean, fecal coliform geometric means were 2 MPN/100 mL in both SMBRP-12 and SMBRP-13.

Similar to fecal coliform concentrations, total coliform concentrations dropped from 71 MPN/100 mL in SMBRP-9 to single digits in the monitoring wells in the middle and bottom of the flow path. On the east side of the Lagoon, SMBRP-1 had geometric means of 7 and 17 MPN/100 mL for fecal and total coliform, respectively.

The Nitrate-N concentrations near the beginning of the flow path in this contributing area, along Stuart Ranch Road at SMBRP-9, were very high (mean of 23 mg/L) due to an apparent minimum of dilution. Moving down the flow path to SMBRP-16, SMBRP-10c and SMBRP-15b, the mean total nitrogen concentrations ranged from 1.07 to 5.03 mg/L and nitrate-N was the predominant nitrogen species present. At the lowest part of this contributing area, along Malibu Colony Road, the mean total N concentrations ranged from 0.83 mg/L in SMBRP-13, to 11.95 mg/L at SMBRP-12. In SMBRP-12, the predominant nitrogen species are ammonia-N and organic N, which may be caused by OWTS with insufficient thickness of unsaturated soil resulting in insufficient nitrification. The mean total N in SMBRP-14, installed in a leachfield, was 32.63 mg/L with a maximum of 100 mg/L.

4.4.4.4. Malibu Creek and Malibu Lagoon Contributing Area

The area contributing to Malibu Creek and Malibu Lagoon is on both sides of the Creek and Lagoon. On the west side, monitoring well SMBRP-8 is the most upgradient, and SMBRP-7b is along Civic Center Way in the middle of the flow path. SMBRP-6, P-1, P-9, and P-7 are along the west side of the Lagoon. Wells C-1 and C-2 are on the south side of the west arm of the Lagoon, where the flow is toward the Lagoon when the Lagoon is breached and toward the ocean when the Lagoon is flooded. On the east side of the creek, SMBRP-3c is located north of the Arizona Crossing and about 100 feet from the creek. SMBRP-2 is located in Malibu Creek State Park, approximately 150 feet from the Lagoon, with no apparent sources of contamination except that it is located along what is apparently a hiking trail, although horseback riding was observed on this trail during field reconnaissance for this study.

Monitoring well SMBRP-8 had Enterococcus concentrations that exceeded the single sample marine contact recreation standard of 104 MPN/100 mL on five occasions. SMBRP-8 had a geometric mean Enterococcus concentration of 55 MPN/100 mL. Approximately 400 feet down gradient, SMBRP-7b had a geometric mean Enterococcus concentration of 83 MPN/100 mL with two single sample exceedances of the water quality standard. At the bottom of this contributing area, along the west side of the creek and Lagoon, SMBRP-6, P-1 and P-9 had geometric mean Enterococcus concentrations in the range of 3 to 10 MPN/100 mL with no exceedances. Well P-7, which is located over 300 feet from any leachfield, had a geometric mean Enterococcus concentration of 38 MPN/100 mL with two exceedances. Fecal coliform and total coliform concentrations in monitoring well SMBRP-8 had similar peaks and valleys as Enterococcus, with generally lower concentrations.

Monitoring well SMBRP-8 had nitrate-N concentrations in excess of the drinking water standard (10 mg/L) for 11 of the 12 monthly samples. The nitrate-N concentration in SMBRP-8 ranged from 2.61 mg/L on December 16, 2003 to a high of 61.5 mg/L on July 24, 2003 with a mean total N concentration of 44 mg/L. Well SMBRP-7, however, had a mean total N concentration of less than 1 mg/L. Towards the bottom of this flow path, SMBRP-6 and P-1 had mean total N concentrations of less than 5 mg/L with no exceedances. Monitoring well P-7 also had a mean total N concentration of less than 1 mg/L. On the east side of the Lagoon, SMBRP-3c had a mean total N concentration of 2.2 mg/L with no exceedances of the nitrogen standards. SMBRP-2 had a mean total N concentration of 7.3 mg/L with two water quality exceedances. The predominant nitrogen species in SMBRP-2 is organic N.

4.4.4.5. Malibu Creek and Lagoon Contributing Area: Inland Side of Malibu Point

The groundwater flow direction on the eastern end of the inland side of Malibu Point is dependent on whether the Lagoon is open or closed. The last few houses on the north side of Malibu Colony Road are in this area. When the Lagoon is closed, or flooded, the groundwater beneath these lots flows toward the ocean. When the Lagoon is open, or breached, the groundwater flows toward the Lagoon.

The monitoring wells in this area, C-1 and C-2, are both on the inland side of the Lagoon and have water quality exceedances of indicator bacteria. Monitoring well

C-1 is downgradient of the Lagoon for both open and closed conditions (Maps 5 and 6). Fecal coliform and total coliform concentrations were less than 22 MPN/100 mL throughout the sampling period, complying with marine recreational water quality standards. The single sample marine recreational water quality standard for Enterococcus was exceeded on two occasions: 648.8 MPN/100mL on May 30, 2003, and 178.5 MPN/100mL on July 24, 2003. All bacteria indicators from samples collected at this well from October 2003 through April 2004 had concentrations less than 32 MPN/100 mL. The bacteria concentrations in monitoring well C-2 exceeded the single sample recreation water quality standard for Enterococcus on four occasions: 200 MPN/100mL on April 4, 2003; 2419.5 MPN/100 mL on July 24, 2004; 1203.3 MPN/100 mL on August 19, 2003; and 571.7 MPN/100 mL December 16, 2003. The total coliform concentrations ranged from not detected to 50 MPN/100 mL, and fecal coliform concentrations ranged from not detected to 8 MPN/100 mL.

Monitoring well C-1 had consistent nitrate-N concentrations less than 1 mg/L and a mean TKN concentration of 7 mg/L, below the water quality standard of 10 mg/L. The nitrogen at this well was primarily in the form of ammonium and organic N. The initial TKN concentration of 4.1 mg/L at this well exhibited a drop on May 11, 2003. After the Lagoon closed, the TKN steadily rose to a peak of 8.9 mg/l in October 2003. With Lagoon breaching, the total N concentration fell to approximately 6 mg/l. The total N concentrations remained below10 mg/L. Monitoring well C-2 had consistent concentrations of nitrate-N, ammonium-N and TKN less than 1 mg/l from April through December 2003. Total N concentrations were highest (1.2 mg/L) on April 11, 2004.

4.5. Groundwater Flow Model

A numerical model was constructed to simulate ground-water flow in the alluvial deposits along Malibu Creek and Malibu Lagoon near the Malibu Civic Center area. The objectives of the modeling were to develop a quantitative water budget for the flow system, delineate directions of ground-water flow, identify contributing areas for the surf zone and the Lagoon, estimate ground-water travel times, and estimate nitrate loading to the Lagoon and the ocean. The following sections summarize the application of the hydrogeologic model, which is discussed in greater detail in Appendix 3.

4.5.1. Contributing Areas and Travel Times for the Ocean and Lagoon

Directions of ground water flow in the alluvial aquifer are generally to the south and southeast toward the Pacific Ocean and Malibu Lagoon. The contributing areas for the ocean and Lagoon are shown in Map 7 for the breached Lagoon condition. The contributing area for the ocean includes the entire shoreline area, Winter Canyon, and the west side of the main body of alluvium. The divide between flow to the ocean and the Lagoon in the main body of alluvium runs along the west side of the Cross Creek Plaza area and extends across the southern part of the Lagoon. Model results show that conditions in the Lagoon have an effect on its contributing area. When the Lagoon is breached it has a slightly larger contributing area than when it is flooded.

Groundwater travel times to the ocean and Lagoon vary from less than one-half year at locations immediately adjacent to these features to more than 50 years at locations near the valley wall in the main body of alluvium. Average groundwater travel times to the Lagoon and creek are generally faster than to the ocean because of the high hydraulic conductivity of subsurface materials near the Lagoon and creek. Travel times from locations of wastewater dispersal plants in Winter Canyon are calculated to be approximately 3 years.

Examination of groundwater level data did not indicate that underground utilities with high permeability backfill were causing significant "conduits" for ground water flow therefore they were not simulated in the model. The fact that such features did not appear to affect the water table may be partly due to a lack of data density that would allow such an observation. Under the breached lagoon condition, in which the maximum extent of the Lagoon contributing area is predicted, groundwater levels are low and are most likely beneath shallow utility conduits.

4.5.2. Solute Transport Model

Transport model simulations were run with the steady-state hydraulic stresses for flooded and breached Lagoon conditions in order to estimate nitrate loading to the ocean and Lagoon from wastewater disposal (Figures 29-33 in Appendix 3). Depending upon the assumptions involving degradation of nitrate, the maximum model calculated nitrate loading to the ocean resulting from wastewater dispersal ranges from 60 lbs/day (flooded Lagoon with no degradation) to 21 lbs/day (flooded Lagoon with two-year half life). The model calculated loading to the Lagoon varies from 31 lbs/day (breached Lagoon with no degradation) to 8 lbs/day (flooded Lagoon with two-year half life). The true answer probably lies somewhere within these ranges. Depending upon the degradation, the maximum loading rate caused by present activities may not be realized until 2010 or much later.

Model simulations were run to evaluate the effect of reducing nitrate concentrations in treated wastewater effluent to 10 mg/l from all disposal systems and the cessation of nitrogen loading. Original values were assumed to be 50 mg/l for commercial systems and 20 mg/l for domestic systems. In these simulations the model predicts that a change in source concentration to 10 mg/l would cause a 66% decrease in nitrate loading to both the ocean and Lagoon over a twenty-year period.

4.6. Risk Assessment

The risk assessment was conducted to evaluate the potential impact that OWTS may have on water quality. Specifically, the purpose of the risk assessment was to assess the risk of onsite systems' potential impact on public health through bacterial contamination and on environmental quality through nitrogen contamination. The risk assessment is fact-driven and outcome-based. The intended outcome was to determine the areas it was necessary to protect in order to meet water quality objectives for the respective receiving waters. The TMDLs for Malibu Creek Watershed and the Santa Monica Bay Beaches are based on receiving environment vulnerability, and these TMDLs provide the targeted water quality outcomes.

4.6.1. Nitrogen

The possible attenuation steps for nitrogen, working backwards from surface water to the OWTS, include:

- Denitrification
- Dilution
- Nitrification
- Advanced Treatment (Including Denitrification)

4.6.1.1. Mass loading of nitrogen

Previous studies in the Malibu Lagoon subwatershed assumed different levels of nitrogen attenuation in the groundwater. Ambrose and Orme (2000) assumed 50-75% of the nitrogen was removed in prior to reaching surface water; while TetraTech (2002) assumed that on the order of 13-44% of residential nitrogen was removed. The total dry season daily nitrogen mass loadings of the UCLA and TetraTech studies was 13.4 and 62.4 lbs/day respectively.

The approach used in this study was to first assume no degradation in the groundwater and then try to match actual concentrations using different degrees of attenuation using a half-life approach. Using the computer modeling of the area contributing to Malibu Lagoon, the total mass nitrogen loading to the Lagoon under flooded conditions has been estimated to be 28 lb/day, or approximately 5.8 mg/L (Table 29 and Appendix 3 - Figure 29). Similarly, under breached conditions, the mass nitrogen loading to the Lagoon is estimated to be 31 lb/day, or approximately 4.0 mg/L (Table 29 and Appendix 3 - Figure 30). The lower concentration associated with higher load under breached conditions are due to the greater dilution from a larger area contributing to the breached Lagoon, relative to the flooded Lagoon. However, in most instances, the measured nitrogen concentrations were less than the nitrogen concentrations estimated using the model when no attenuation was assumed (Appendix 3, figure 28 – No half-life scenario).

The mass loading of nitrogen from OWTS was calculated using measured concentrations for commercial/multifamily uses and estimated concentrations for single family residences. The commercial/multifamily loading was based on metered flows, as described previously, and 50 mg/L nitrate-N concentrations. The concentration times the volume equals a mass loading per unit time. The single family residential nitrogen mass loading (11 grams per person per day) was based on the mean of the typical range of nitrogen produced by residential sources (USEPA, 2002) and 2.4 persons per household (US Census Bureau, 2002).

Using the 500 gpd average flow rate for single family residences and these nitrogen loading assumptions yields a 20 mg/L total nitrogen concentration, or 0.08 lb/day per household. For comparison, the UCLA study assumed 185 gpd per household with a 45 mg/L nitrogen concentration, yielded a septic tank effluent nitrogen load of 0.7 lb/day/household (Ambrose and Orme, 2000). TetraTech (2002) assumed the daily nitrogen loading in septic tank effluent was 0.14 lb/day per household.

The half-life approach yielded slightly better matching of predicted and measured values (Appendix 3, Figure 28). Based on a 2-year half-life assumption, the flooded and breached conditions yield an estimated nitrate load of 8 to 11 lb/day. The lack of a match is likely to be a result of a number of factors:

- Incomplete nitrification indicated by the detection of organic nitrogen and ammonia nitrogen in the groundwater (Figure 23);
- Heterogeneity of the aquifer characteristics such as carbon concentration, hydraulic conductivity, and dispersivity;
- Lack of documentation of specific locations of most OWTS in the study area.

Therefore, it is likely that the actual value of nitrogen loading is between the attenuated load estimates and the unattenuated 28 to 31 lb/day load estimates (Appendix 3). It should be noted that this maximum nitrogen load without attenuation estimated by this project is approximately one half of the 64.2 lb/day summer nitrogen load estimated by the USEPA (2003) for the Nutrient TMDL (see section 2.4.2.4 above).

4.6.1.2. Nitrogen Removal Rates and Removal Mechanisms

Denitrification rates have been shown to vary with soil organic carbon concentration (Anderson, 1998). A mass balance approach to estimate denitrification was applied by Anderson in Florida, USA. Hardin et al (1986) provides data regarding organic carbon in alluvial soils near Ventura, California. Hardin's data for unweathered C soil horizons and the calculation of a simple mass balance for a single family home reveal that the nitrogen from a single family OWTS could be denitrified within 20 meters of the system, depending on upgradient flows and background nitrogen concentrations.

The groundwater quality sampling program results indicate that nitrogen is being attenuated to a greater degree in the groundwater than can be accounted for by dilution in the computer model, and that denitrification is the most probable explanation. The time it takes for half of the nitrate present in groundwater to be denitrified (or the nitrate half-life) has been estimated at 1.2 to 4 years in Germany (Kunkel et al., 2004) and 3 to 5 years in the Netherlands (Uffink and Romkens, 2001). Doubling of the denitrification rate can occur with every 10 degree centigrade temperature increase (Hiscock, 1991).

For this assessment, the groundwater model was run with nitrate half-life assumptions of 2 years, 5 years, and without any assumed attenuation, to bracket the denitrification range reported in the Northern European studies. The groundwater model results are discussed in Appendix 3. Comparing the temperatures of Southern California with those of the Rhine Valley of Germany and the Netherlands reinforces the use of these assumptions. Groundwater temperature generally correlates with average annual air temperature plus 1.4 degrees Centigrade (°C) (NAVFEC, 2000). Since the average air temperature in Los Angeles is approximately 15°C, and the average air temperature in Rhine Valley (Germany and Netherlands) is approximately 8°C, we can infer an approximate difference of 7° C in groundwater temperature. Therefore, using nitrate half-life values from cooler climates will result in conservative estimates of denitrification in coastal areas of southern California.

4.6.1.3. Current OWTS Program Elements to Achieve Nitrogen Outcomes

- City of Malibu
    - Utilize groundwater model as a tool to evaluate nutrient TMDL objectives
    - Renewable operating permits for commercial/multifamily occupancies
    - Renewable operating permits for all single family and duplex occupancies with repair, upgrade, or new construction
- LARWQCB
    - Require nitrogen removal to achieve effluent limit of 10 mg/L total N for advanced treatment under general and individual WDRs
    - Developing nutrient TMDL for Malibu Creek watershed

4.6.1.4. Groundwater Vulnerability to Nitrogen

Total nitrogen concentrations in approximately 30% of the monitoring wells exceeded the Basin Plan's 10 mg/L water quality criteria (Table 20 and Map 9). Total nitrogen concentrations appear to be elevated above background levels in 40% of the monitoring wells. Although there does appear to be a degree of nitrogen attenuation in the subsurface environment, the groundwater appears to be vulnerable to nitrogen loading. The alluvial aquifer is not used for drinking water, and the apparent connection to and influence from surface waters precludes the groundwater's beneficial use as a municipal or individual drinking water supply. The monitoring data revealed that nitrogen is present in the groundwater in areas with OWTS and appears to be attenuated in the groundwater flow system. The study did not evaluate either the potential removal of nitrogen in the riparian buffer along the creek and Lagoon or removal in the hyporheic, or sediment, zone that is being studied by Sutula and Kamer (2004).

4.6.2. Bacteria

The water quality outcome for bacteria is the reduction of occurrences of recreational water quality standard exceedances to comply with the TMDLs. In Malibu Creek, the freshwater bacteria standards are used. For Malibu Lagoon and the surfzone, the marine water quality standards are used. The water quality vulnerability is seasonal in nature and therefore each TMDL has wet weather and dry weather standards (Table 2).

Potential sources of indicator bacteria in the groundwater include OWTS, stormwater infiltration, and surface water infiltration in the study area. The impact of wastewater and runoff is illustrated by a recent study where urban runoff, untreated sewage, and treated sewage were mixed with fresh water from Malibu Creek and seawater from Malibu Beach to evaluate indicator bacteria survival times (Noble, Lee, and Schiff 2004). It has been widely documented that two feet of unsaturated soil, uniformly receiving septic tank effluent at an appropriate application rate for the soil conditions (typically less than 1.2 gpd/ft^2), provides attenuation of coliform bacteria to non-detectable concentrations (USEPA, 1978; USEPA, 2002).

One of the City of Malibu's objectives is for all OWTS to provide adequate treatment of bacteria prior to reaching the groundwater. This is the case for renovations, repairs, and new installations of OWTS. To address existing systems, the City's Wastewater Management Plan proposes a citywide point of sale OWTS inspection program that will affect most of the OWTS in the City over the next 10 years. The point of sale inspection program is planned to be in place by the end of 2004 (Peterson, 2004)

For sites lacking adequate vertical separation to groundwater, the major determinant of receiving water bacteriological effects is the time of travel in groundwater. It is widely accepted that pathogenic bacteria can survive on the order of 30 to 90 days outside of their hosts (Gerba, et al, 2004). If the maximum survival time is doubled to provide a factor of safety, a 180-day, or 6-month, time of travel can be used as a conservative criterion to determine where the risk from OWTS with insufficient depth to groundwater may require disinfection or other treatment strategies to protect surface water quality.

4.6.2.1. Mass Loading

OWTS discharge bacteria into the soil environment or geologic strata. Properly designed, installed and operated OWTS can provide adequate treatment of bacteria and have a negligible impact on groundwater and surface water quality. Systems with high loading rates or inadequate vertical separation to groundwater may discharge bacteria to groundwater.

4.6.2.2. Removal Rates and Removal Mechanisms

The attenuation of bacteria in unsaturated soil is caused by physical filtration, biologic predation, and natural die-off. In groundwater, bacterial attenuation relies primarily on travel time, since pathogenic bacteria can only survive on the order of one to three months outside the host. Based on the hydrogeologic characteristics of the aquifer, much of the alluvial aquifer system underlying the study area has very long times of travel.

4.6.2.3. Current Programs to Manage OWTS for Bacteria Attenuation

- City of Malibu
    - Current code requires vertical separation to groundwater
        - 10 feet for seepage pits
        - 5 feet for drainfields
    - Develop TMDL Implementation Plans
    - Renewable operating permits for commercial/ multifamily occupancies
    - Advanced treatment and disinfection for commercial/multifamily
    - Renewable operating permits for all single family and duplex occupancies at time of repair, upgrade or new construction
- LARWQCB
    - General WDRs require vertical separation to groundwater for Commercial/multifamily occupancies (less than 20,000 gpd)
        - 10 foot separation to groundwater with groundwater monitoring

    - 5 foot separation to groundwater with advanced treatment and groundwater monitoring
  - Individual WDRs for commercial or multifamily require disinfection

4.6.2.4. Groundwater Vulnerability to Bacteria

The monitoring data revealed that bacteria were present in the groundwater in areas with and without any OWTS in the vicinity of the monitoring location. This leads to the possibility that there are other significant sources of indicator bacteria in the study area that may be carried to the groundwater via percolation from the land surface such as stormwater infiltration or infiltration from Malibu Creek or Malibu Lagoon. Based on water quality findings, the shallow depth (less than 10 feet) to the water table in most of the study area, and connection to the influence of the Lagoon, the study indicates that a large portion of the groundwater is essentially under the influence of surface water. Therefore, a use attainability analysis should be conducted to determine whether this beneficial use of the Malibu Valley's groundwater should be dedesignated. In the meantime, the designated beneficial use sets a higher standard for water quality than is currently being followed by the Regional Board (LARWQCB, 2001a).

There is precedent for dedesignating beneficial use of groundwater in the San Francisco area (California Regional Water Quality Control Board – San Francisco Bay Region, 1999), where a basin plan amendment was considered based on new information regarding exemption criteria in State Board Resolution 88-63, Sources of Drinking Water Policy. This policy states that groundwater can be exempted from existing municipal and domestic beneficial use where: "There is contamination, either by natural processes or by human activity (unrelated to the specific pollution incident), that cannot reasonably be treated for domestic use using either Best Management Practices or best economically achievable treatment practices" (State of California, 1988).

4.6.3. Surface Water Vulnerability

The vulnerability of surface water depends on its ability to assimilate a pollutant with out causing an unacceptable outcome. For bacteria, an unacceptable outcome is an exceedance of the REC-1 water quality criteria (Table 2) due to OWTS or stormwater contributions. For nutrients, an unacceptable outcome is algae growth or scum accumulation. This outcome is currently being translated into water quality objectives for the Malibu Creek Watershed in the TMDL process.

The fate of nitrogen in groundwater discharging to surface waters through riparian soils and sediments (carbon-rich alluvial and/or wetland soils adjacent to streams and water bodies) is important to characterizing the impact that groundwater has on surface water quality. Concurrent with this study, the LARWQCB sponsored an evaluation of nutrient cycling associated with sediment in Malibu Lagoon (Sutula and Kamer, 2004). Preliminary information from that study indicates a significant potential for removal of nitrogen in the groundwater that flows into the Lagoon via denitrification. Denitrification is a natural process that converts nitrate ions (NO_3^-) to nitrogen gas (N_2), thereby removing the nitrogen from a water quality perspective. This is consistent with literature on denitrification in the riparian and hyporheic (generally speaking, bottom sediments) zones (Robertson et al. 1991, Wilhelm et al. 1996, Hill 1996, Mengis et al. 1999). The attenuation of nitrogen flowing into the Lagoon through the hyporheic zone could have a significant impact on the vulnerability of the Lagoon to nitrogen loading via groundwater.

4.6.3.1. Nutrients

Malibu Creek Watershed has been listed as impaired by the USEPA due to nutrient contamination. Santa Monica Bay is not impaired due to nutrients, nor is it considered sensitive to nutrient enrichment. The nutrient TMDL for the Malibu Creek Watershed is being developed. In the meantime, the risk assessment will be based on three objectives:

- Groundwater concentration of 10 mg/L total nitrogen.
- Surface water concentrations of:
    - 8 mg/L total nitrogen in the winter
    - 1 mg/L total nitrogen in the summer

As noted in the modeling report, the total nitrogen loading to the Lagoon was estimated under flooded and breached Lagoon conditions (Appendix 3, Figures 29 and 30). The range of half-lives discussed in Section 4.6.1.2 provide for a conservative bracketing of the range of potential nitrogen removal. Assessment of current total nitrogen loading under flooded Lagoon conditions ranges from 8 to 25 lb/day total nitrogen; and the loading under breached Lagoon conditions ranges from 11 to 31 lb/day total nitrogen. These estimates assume no nitrogen attenuation in riparian zone and Lagoon sediments.

Assessment of mitigation alternatives in groundwater modeling (Appendix 3), assuming no attenuation in riparian zone and Lagoon sediments, produced the following results:

- Mitigation: Reduce total nitrogen in all OWTS to 10 mg/L in the Lagoon contributing area (Map 12)
    - Estimated result: Total OWTS nitrogen loading in Lagoon at 3 to 10 lb/day by 2024

- Mitigation: Eliminate all nitrogen discharge from OWTS in the Lagoon contributing area
    - Estimated result: Total OWTS nitrogen loading in Lagoon at 1 lb/day by 2034 to 2054

The higher nitrogen allocation for Malibu Creek during wet weather conditions is due to the variable nature of flows in the creek during wet weather (USEPA, 2003). As mentioned earlier in this report (Section 2.4), the dry weather allocation for OWTS is a mass loading of 10.79 lb/day, with a required 93 % reduction (resulting in a 0.74 lb/day nitrogen load) to meet the 1 mg/L target. However, it is worth noting that the average summer nitrogen concentration in Malibu Lagoon has been calculated to be approximately 1.4 mg/L – apparently requiring only a 30% reduction in loading to get to less than 1 mg/L average nitrogen concentration at the same flows. The average nitrogen concentration due to OWTS was calculated using the current nitrogen load estimated by the groundwater model (Appendix 3, Figures 29- 31) and the results are shown in Table 29. The average nitrogen concentration due to OWTS in the Lagoon contributing area (Map 12) ranges from 1.7 to 5.2 mg/L under dry weather conditions, based on a range of no nitrogen attenuation to a 2-year nitrate half-life in the soil/groundwater system. Therefore only a 40 to 80 % nitrogen reduction would be required to meet this standard with the conservative assumption that there is no nitrate attenuation in the riparian/sediment zone.

4.6.3.2. Bacteria

Malibu Creek watershed and Surfrider Beach have been listed as impaired by the USEPA due to bacteria contamination. The Santa Monica Bay wet weather and dry weather TMDLs are in place, and the Malibu Creek watershed bacteria TMDL was adopted by the LARWQCB. The Malibu Creek watershed bacteria TMDL and the Santa Monica Bay bacteria TMDL both use the same water quality standards – the marine water contact recreation standard. An acceptable goal for groundwater and surface water quality is to achieve marine water contact recreation water quality standards in the groundwater prior to reaching the surface water. This can be met either by using adequately sited, designed, installed and operated systems utilizing traditional soil-based treatment, or by using advanced treatment with disinfection.

The portions of the study which have OWTS located within the areas with less than 6 month time of travel to surface water (Map 13), and that also have inadequate separation to groundwater or excessive wastewater loading rates, pose the greatest risk of water quality impacts.

The results of this study appear to show that shallow groundwater in the area is significantly influenced by bacteria from sources other than OWTS. Stormwater infiltration and direct percolation from the land surface in sandy soil areas are likely to be significant potential sources of contamination.

4.7. Analysis of Mitigation Options

Mitigation options for alleviating water quality problems and achieving water quality outcomes are proposed as infrastructure alternatives. Some of the alternatives involve managing and upgrading existing infrastructure (OWTS), and others involve constructing new infrastructure, such as cluster or community wastewater collection, treatment, and dispersal systems.

4.7.1. Evaluation of Advantages and Disadvantages of Infrastructure Options

The mitigation options were reviewed and evaluated for the desired water quality outcomes for bacteria and nitrogen.

4.7.1.1. Bacteria

Onsite disinfection is presently required for all commercial and multifamily occupancies in the City of Malibu that are subject to permitting for repair, upgrade, or construction of a new OWTS. The disinfection treatment standard in the Malibu Plumbing Code is 200 MPN/100 mL fecal coliform or less and 104 MPN/100 mL Enterococcus or less. For most of the study area, the current OWTS management program appears to be adequate for water quality protection.

There are approximately ten single family dwellings that appear to be in the 0 to 6 month time of travel zone in proximity to the Lagoon. Along the south side of Malibu Road all lots have a 100-foot wide zone where there is less than 6-months time of travel to the surf zone. This 6-month time of travel area widens to approximately 200 to 300 feet near the mouth of Winter Canyon. There are approximately 18 properties along the south side of Malibu Road at the outlet of Winter Canyon.

A six-month time of travel zone was delineated based on the groundwater model (Map 13). It appears that approximately 10 single family homes in the Serra Road area are in this zone. For the systems located within the 6-month time of travel to surface water there are the following options:

- Compliance with current City Code – this means confirming loading rate, vertical separation to groundwater, horizontal separation to surface water and upgrading systems as necessary.

- Provide advanced treatment with disinfection prior to discharge via OWTS, cluster system(s), or a community system.

The advantages and disadvantages of the bacteria attenuation infrastructure alternatives are presented in Table 30.

4.7.1.2. Nitrogen Attenuation Alternatives

The Malibu Lagoon contributing area (Map 12) should be the focus of the action items for attenuating nitrogen loading into the Lagoon. The options include onsite and offsite infrastructure as well as water resource management alternatives (Table 31). Onsite options may include inspection and, if necessary, upgrade of OWTS to provide for nitrogen attenuation, as follows:

- Confirm vertical separation to groundwater and horizontal separation to surface water in City of Malibu and LA County files
- In properly functioning and sited traditional OWTS, field inspection to confirm vertical separation to groundwater and upgrade as necessary
- Upgrade traditional systems by adding horizontal setback to surface water and/or separation to water table
- Provide advanced treatment with denitrification prior to discharge

Off-site options include collection and nitrogen removal prior to discharge either in the contributing area or outside the contributing area.

4.7.2. Analysis of Specific Infrastructure Options

This section explains the range of options and associated costs and energy consumption requirements for onsite wastewater treatment system (OWTS) improvements to achieve the nitrogen and/or bacteria removal objectives recommended in this report.

Two portions of the study area were found that potentially contribute wastewater constituents to surface waters: one area where nitrogen is contributed to Malibu Creek and Malibu Lagoon (Map 12); and a second area where bacteria may be contributed to Malibu Creek, Malibu Lagoon, or the surfzone (Map 13). There is a small overlap area where existing OWTS may contribute both nitrogen and bacteria to Malibu Creek and Malibu Lagoon.

Single family residences and commercial and multifamily properties in the study area are generally served by individual conventional septic tank-drainfield systems. The commercial and multifamily property owners are already applying for operating permits from the City and complying with the Los Angeles Regional Water Quality Control Board (LARWQCB) Waste Discharge Requirements, resulting in the evaluation, monitoring, and upgrade of many of these systems. Table 32 provides a breakdown of the types of OWTS in each contributing area. There are a total of 82 OWTS in the nitrogen contributing area, of which 14 are commercial or multifamily. There are 161 OWTS in the bacteria contributing area, 10 of which are commercial or multifamily. There are 8 additional OWTS in both contributing areas, all of which are single family residences.

The recommended action items include inspection of existing systems in the respective contributing areas and, if necessary, upgrading or replacing the OWTS to provide adequate treatment of the specific constituent(s) of concern for that contributing area. The City of Malibu has trained and registered private sector OWTS inspectors. Inspections of existing OWTS in the contributing areas would determine whether the existing systems have adequate depth to groundwater and separation to surface water, along with other aspects of system siting, construction, and condition of the components. Bacterial removal can be accomplished by using systems that comply with the loading rates, depths to groundwater, and horizontal separations to surface water specified in Malibu Ordinance 242. Some nitrogen removal occurs in the soil and groundwater, as discussed earlier in this report; however, additional nitrogen removal from OWTS effluent will be necessary to meet the anticipated criteria of the Malibu Creek Watershed Nutrient TMDL.

Implementation of the elements in the City of Malibu's Wastewater Management Plan will result in all systems in Malibu providing adequate wastewater treatment in regard to bacteria removal. The impairment of surface waters for bacteria in the Civic Center area heightened the need to address this issue in a timely fashion. If a system located within the bacteria contributing area meets the criteria in Malibu Ordinance 242, or can be upgraded to do so using traditional dispersal technologies or a bottomless sand filter, then no further treatment will be necessary. If these criteria were not met, then some form of advanced treatment plus disinfection will be necessary. A secondary treatment system is required ahead of the disinfection component to minimize the organic strength, suspended solids, and turbidity entering disinfection unit and to ensure reliable bacteria removal.

The specific water quality limits for the nitrogen contributing area will be developed along with the nutrient TMDL for the Malibu Creek Watershed. The groundwater modeling in Appendix 3 predicted nitrogen loading based on two assumptions: commercial or multifamily OWTS would be required to be upgraded to provide 80% nitrogen removal on a mass loading basis at time of operating permit renewal; and single family residential systems would be required to provide 50% nitrogen removal on a mass loading basis at time of sale, upgrade, or repair. The recommended difference in treatment standard is due to the generally greater consistency in effluent quality and therefore treatment performance in commercial or multifamily systems, compared to single family residential systems that typically have greater fluctuations in wastewater flows and composition throughout the day, week, and year. These also are the approximate levels of reduction used in the groundwater modeling projection of future scenarios of groundwater contribution to the lagoon under differing OWTS management strategies.

There are several different treatment systems or technologies that can be used to meet site-specific needs. This section provides a comparative review of three different commonly used and viable treatment alternatives for nitrogen removal and for disinfection. For each alternative, a narrative description is provided along with a schematic diagram identifying the key design features and facilities that would be needed for a project. A preliminary construction cost estimate is presented for each alternative. The cost estimates cover the treatment system and dispersal fields.

The last part of this section presents a comparative review of the different treatment alternatives relative to a variety of feasibility, operational, environmental impact, and cost factors. The information is summarized in a table for easy comparison between alternatives. A narrative is provided explaining some of the findings regarding each comparative factor.

4.7.2.1. Onsite Secondary Treatment and Nitrogen Removal

Nitrogen in raw sewage and septic tank effluent is primarily organic nitrogen and ammonia nitrogen. The removal of this nitrogen from the hydrologic cycle involves conversion to nitrogen gas, via a two-step process: (1) the organic and ammonia nitrogen need to be converted to nitrate; (2) the nitrate is converted to nitrogen gas. These processes are called nitrification and denitrification. Both are biological processes carried out by microorganisms. Nitrification is an aerobic process and denitrification is an anaerobic process.

Based on the ground water modeling analysis, it was determined that significant reduction in nitrogen loading could reasonably be achieved under the following two-tiered approach. For single family residences, the treatment system should be capable of reducing the total nitrogen content of the single family residential wastewater by 50% over typical nitrogen concentrations found in septic tank effluent. Systems serving commercial or multifamily occupancies should be capable of providing an 80% nitrogen reduction on a mass loading basis.

As indicated in Table 32, there are a total of 90 OWTS in the nitrogen contributing area, of which 14 are commercial or multifamily systems. There are several different systems or technologies that can be used to meet the treatment requirements.

Following is a brief description of four treatment alternatives for a typical single family residence in the Malibu Civic Center Area, along with energy consumption and preliminary construction estimates. Commercial and multifamily systems have a lesser degree of variability due to wastewater flow rates and the regular use of the facility. Commercial and multifamily systems are addressed using an approximate cost and energy consumption estimates per gpd of wastewater flow.

The technologies discussed do not represent an exhaustive list of available technologies, rather a short list of technologies that are currently in use in Malibu or are proven to be effective in providing nitrogen removal in OWTS.

Alternative N1 - Recirculating Sand Filter

The recirculating sand filter (RSF) consists of a recirculation tank and a coarse sand filter. The recirculation tank receives septic tank effluent, which is pumped to the sand filter bed(s). The pumps operate on a timer, providing uniform dosing to the sand filter. Effluent is dosed to the filter through a pressure-distribution network constructed on top of the sand filter bed; the piping is covered by about 12 inches of river run rock. The effluent percolates through the sand media (24 inches deep) and is collected in an underdrain for return to the recirculation tank. The effluent mixes with incoming flow in the recirculation tank and is again recycled to the sand filter, according to the programmed dosing schedule. A small amount of treated effluent leaves the recirculation process at the end of each dosing cycle, when the floating ball valve in the recirculating tank shuts the opening in the return line to bypass the remaining flow to the disposal system. When there is no inflow (e.g., during the middle of the night), the effluent will be recycled repeatedly through the sand filter with no (or very little) bypass to the disposal system. RSF are non-proprietary systems, and are in use in many California counties.

Alternative N2 – Continuous Flow Suspended Growth with Internal Packing

There are many combined suspended and attached growth aerobic treatment systems on the market, some of which are presently in use in the City of Malibu. MicroSepTec and BioMicrobics manufacture treatment units that provide for nitrogen removal.

The BioMicrobics FAST® system consists of two tanks in series (or a two-compartment septic tank) with a unit installed inside the second tank or compartment. The first compartment/tank provides normal primary treatment functions, including gravity separation of solids from the liquid, floating scum accumulation, and anaerobic and facultative decomposition of the organic material in these layers. Aerobic treatment occurs in the second compartment/tank. This system makes use of the septic tank as the treatment reactor. The nitrogen removal of FAST® systems has been reported to be between 34% and 76% (SWRCB, 2002). Units are used for single family residences and large commercial/multifamily systems in the City of Malibu.

The MicroSepTec EnviroServer® is a pre-engineered, automated, computer controlled wastewater-processing tank that provides greater than secondary levels of treated water. Telemetry and UV disinfection are options for these systems. The EnviroServerâ removes nitrogen and fecal coliform through its multiple processing chambers. The nitrogen removal of EnviroServer® systems ranges from 47 to 79% nitrogen removal (SWRCB, 2002). This system does not require a separate septic tank. EnviroServer® units are used for single family residences and large commercial/multifamily systems in the City of Malibu.

Alternative N3 – Synthetic Packed Bed Filter

A synthetic packed bed filter (SPBF) a system that operates on the same principle as a recirculating sand filter, except that it uses a synthetic textile media in place of the sand. Examples of this technology include the Waterloo Biofilter and OSI's AdvanTex® system. A primary treatment tank is required for these systems.

The OSI AdvanTex® units are also pre-engineered, automated computer controlled wastewater treatment units. They are designed as pods that are loaded in parallel to meet wastewater flow demands and site configuration needs. OSI requires that telemetry be installed with each AdvanTex® system. AdvanTex® units are being used for single family residences and large commercial/multifamily systems in the City of Malibu.

Alternative N4 – Anoxic Treatment

Post-treatment anoxic systems such as the Nitrex® system can provide significant nitrogen removal from nitrified secondary treatment system effluent (SWRCB, 2002). These systems utilize a proprietary media to enhance denitrification. As described by the SWRCB (2002):

> "The Nitrex filter was developed at the University of Waterloo and is effective for the removal of nitrate from wastewater. The unit is filled with a proprietary wood byproduct mixture that promotes nitrogen removal. Typically the units are single-pass and do not require pumping."

A design using the Nitrex® system is being designed to serve a major shopping center in the study area. If preceded by an adequate upstream aerobic treatment process (e.g., trickling biofilter, sand filter, aerated treatment unit), total nitrogen removal may be expected to be greater than 95% (SWRCB, 2002). Data from the LaPine Oregon Demonstration Project indicates 90% nitrogen removal from single family residential systems (Lombardo Associates, 2003).

4.7.2.2. *Onsite Alternatives for Bacteria Removal*

As indicated in Table 32, there are a total of 161 OWTS in the bacteria contributing area, of which 10 are commercial or multifamily. Provided here is a review of methods to address bacteria removal objectives on individual sites.

Soil absorption dispersal systems (Alternatives B-1, B-2 and B-3) are the preferred method of providing bacterial removal. The siting, design, installation, and operating criteria for OWTS provide a robust and reliable mechanism of bacteria removal via physical filtration and biological processes. The application of UV radiation or chlorination should be used on developed sites where constraints prevent appropriate siting criteria, including vertical separation to groundwater, from being met.

Alternative B-1 – Traditional Drainfield System

Malibu Ordinance 242 applies the California Plumbing Code to provide for protection of public health and water quality. A system that complies with the siting and design requirements of this environmental health ordinance is presumed to provide adequate bacteria removal for septic tank effluent. Specifically, the application rate, uniform distribution, vertical separation to groundwater, and horizontal separation to surface water provide for adequate bacteria removal to protect water quality. This is a very simple and effective system with the least maintenance requirements of any bacteria removal option.

Alternative B-2 – Drip Dispersal

Some parcels in the bacteria contributing areas have high groundwater levels that limit or preclude their ability to achieve adequate bacteria removal through soil treatment processes. In some cases, there is sufficient suitable soil permeability in the topsoil to remove bacteria. These properties may be suited for the use of subsurface drip irrigation-dispersal (also known as “subsurface drip”).

Onsite wastewater dispersal using subsurface drip has progressed significantly in recent years. Its acceptance as a viable method for dispersal of secondary-treated effluent has grown, especially for situations constrained by shallow soils. There is now an increasing base of scientific information documenting the treatment effectiveness of subsurface drip methods and providing evidence that the wide dispersion of treated effluent through drip systems achieves better pathogen and nutrient removal than traditional gravity, pressure-dosed leaching trenches, or mound systems.

Subsurface drip is accomplished using a specially manufactured dripline that has been developed for wastewater applications. The dripline consists of 1/2-inch diameter polyethylene tubing with pressure-compensating emitters spaced 24 inches apart. The driplines can be installed at a depth of 8 to12 inches, following the landscape contours, and the lines spaced roughly 24 inches apart. The dripline is impregnated with bactericide and root intrusion inhibitors.

The use of subsurface drip for wastewater disposal will require the incorporation of an enhanced treatment system to produce an effluent of reasonably high quality – secondary or better. Drip systems are used in the City of Malibu for OWTS. Within the study area, they may be particularly suitable for larger lots in Serra Road area.

Alternative B-3 – Intermittent Sand Filters

Intermittent sand filters (ISF) are used in Malibu to provide adequate separation to groundwater and uniform dispersal of effluent in a raised fill system with vertical side walls (USEPA, 2002). These systems are also called "single-pass sand biofilters" (SWRCB, 2002). They are used in Malibu and are locally referred to as "bottomless sand filters". The principles of sand filtration date back to the 1800s, and the technology has been used for onsite wastewater systems for decades. In the late 1970s and early 1980s, the State of Oregon developed design criteria for single family homes. Uniform distribution of septic tank effluent is accomplished by pressurized distribution system over a manufactured sand bed. A two- to three-log removal (99 to 99.9%) of fecal coliform bacteria has been documented in these systems (SWRCB, 2002).

Alternative B-4 – Ultraviolet Radiation

Disinfection of treated wastewater can be achieved by ultraviolet (UV) radiation. There are, for example, systems developed specifically to disinfect gravity flow from a small (e.g., residential) secondary treatment unit. The UV unit is installed following a secondary treatment unit and before the dispersal system. UV disinfection systems are installed below grade with easily removable components. An advantage of UV is the lack of moving parts. It is important, however, that the secondary treatment unit provides adequate treatment to decrease turbidity of the effluent and that the bulbs are inspected regularly and cleaned or replaced as needed.

Alternative B-5 – Stack-Feed Chlorination

Chlorination is a simple method of disinfecting secondary treated effluent. A stack-feed chlorinator typically consists of a chamber with a vertical pipe containing calcium hypochlorite tablets that provide the chlorine dosage. A baffled basin allowing a 20 to 40- minute contact time following chlorination should be included to ensure disinfection (SWRCB, 2002; USEPA, 2002). An advantage of this system is the lack of an energy requirement. A disadvantage is the residual chlorine and organic compounds that result from the chlorination. The tablets can potentially become jammed in the feed tube, and the performance of the secondary treatment unit also affects the performance of the chlorination system.

4.7.2.3. Community Wastewater Reclamation System

One other way of achieving nitrogen and bacteria removal objectives would be through the development of a community wastewater system in the Civic Center Area to replace existing OWTS. The feasibility and costs associated with a community wastewater reclamation system in the Civic Center area contributing to Malibu Lagoon watershed were evaluated for the City of Malibu in conjunction with the possible purchase of the Chili Cook-Off site in 2003. This was a preliminary study of a conceptual plan that included a pressure sewer collection system, tertiary recycled water treatment (disinfection to 2.2 MPN/100 mL) plus nitrogen removal to 10 mg/L, and redistribution of the recycled water for landscape irrigation and subsurface dispersal in the Civic Center area. The smallest system included in that evaluation was a system with an estimated cost of approximately $9 million excluding cost of land acquisition. The estimated cost of a 200,000 gpd community reclamation system was approximately $12 million dollars. These flows are approximately equal to the 103,000 gpd estimate of wastewater generated in the nitrogen contributing area and the 207,000 gpd estimate for the combined nitrogen and bacteria contributing areas (Table XX-1). Excluding the cost of land, total costs for a community wastewater reclamation system for these flows would be approximately $9 and $12 million dollars, respectively. At the time, the cost of acquiring the Chili Cook-Off parcel for the reclamation facility was $25 M, for a total estimated project cost of $34 to $37 million.

No evaluation of offsite reclamation and dispersal was conducted during this study, as no potential dispersal sites were located and nitrogen objectives in the TMDL have not been defined sufficiently to require dispersal outside of the nitrogen contributing area. Property acquisition and the length of piping required to convey the reclaimed or untreated effluent to the dispersal site cannot be estimated without defining the dispersal site.

The possibility of collecting the wastewater and piping it to the sewer line that runs up the Pacific Coast Highway to Pacific Palisades has been considered in the past.

The end of the current sewer line on PCH is approximately 8 miles west of the study area. The focus of this study was to evaluate decentralized wastewater options; therefore, the Pacific Coast Highway sewer extension was not explored further.

4.7.2.4. Comparative Review of Alternatives

This section reviews and compares the advantages and disadvantages of the wastewater treatment alternatives with respect to a variety of construction and operational issues. All of the options are feasible, are compatible with the use of traditional distribution systems including subsurface drip dispersal, and can meet the specific wastewater treatment needs of the contributing area. However, there are slight to significant differences among the alternatives in regard to land area requirements, visual impact, odors, noise, effluent quality, maintenance needs, energy requirements, and construction costs. Tables 33 and 34 present and summarize the various requirements and impacts of the different treatment alternatives with respect to these various issues. This is not an exhaustive list of issues; however, it encompasses most of the factors commonly used as a basis for comparison and selection of a wastewater treatment system for a single family residential system. A detailed evaluation of property-specific site, soil, and wastewater needs should be conducted to determine the most appropriate solution for each parcel.

Annual Energy Requirements and Costs

Many of the alternatives use electrical energy for pump operation; the continuous flow suspended growth systems also require energy for blower operation. The energy needs for the recirculating sand filter and synthetic media trickling biofilter systems are similar and are greater than the single-pass filtration systems due to multiple-pass cycling through the treatment unit. The most significant energy requirements for nitrogen removal systems are for the continuous flow suspended growth with internal packing systems, because of their reliance on continuous operation of the air blower. The ultraviolet radiation system for bacterial removal requires electricity, while traditional drainfields and stack-feed chlorinators do not.

Estimated Construction Costs

The estimated costs for construction of single family residential OWTS are summarized in the last column of Tables 33 and 34. These costs do not include collection piping from buildings, engineering costs, or permitting fees. The figures represent our best engineering estimates based on experience with other recent small wastewater system construction projects, and on communication with local OWTS installers (Sherman, 2004; Weidmann, 2004) and OWTS technology distributors (Braband, 2004; Lombardo, 2004; and MicroSepTec, 2004). Septic tanks were included as appropriate in the cost estimates, to provide comparison between technologies that do not require septic tanks. When repairing or upgrading a system, the septic tank would be evaluated and either reused or replaced as appropriate. The cost of septic tank replacement may range from $5,000 to $15,000 for a single family residence, depending on the size of the tank and ease of installation. Actual costs would ultimately be determined by specific site conditions, system design, and contractor bids. The cost estimates provided here are an indication of the probable cost and the relative differences between alternatives. For consistent comparison, the installation costs were based on a range from 100% to 200% of the material cost, assuming the higher cost of material would require more installation time.

Average daily flows from commercial and multifamily systems within the nitrogen and bacteria contributing area range from less than 1000 gpd to over 20,000 gpd. Wastewater strength in commercial establishments varies based on the type of business. For example, restaurants generate a higher strength waste with a higher proportion of fats, oils, and grease. Due to the wide range in flows, it is appropriate to address cost for construction of these systems based on a cost per flow unit, such as gpd. For the handful of commercial and multifamily OWTS where costs were available, approximate costs for systems with lower flows (2,000 to 10,000 gpd) ranged from $25/gpd to $150/gpd. Systems between 10,000 gpd and 70,000 gpd generally had a narrower range in approximate cost from $25/gpd to $50/gpd.

The cost of an inspection for a single family residential OWTS could range from $500 to $5,000, depending on the level of background research and the difficulty in accessing the system to perform an onsite investigation. For commercial and multifamily systems, the inspection costs are likely to be greater. In the bacteria contributing area, the inspection may be sufficient to confirm that the system meets the current requirements of Ordinance 242.

The estimated costs for a adding a secondary treatment component capable of achieving a 50% to 75% nitrogen removal to a residential onsite treatment system (including a 25% contingency factor) ranges from about $28,000 to $68,000 gpd (Table 33). To achieve 80% - 90% nitrogen removal, with secondary treatment plus an anoxic system, an additional estimated cost of $16,000 to $38,000 would be incurred - resulting in a total estimated cost of $44,000 to $106,000 for treatment components alone.

As indicated in Table 34, the estimated costs for adding bacterial removal components to a residential onsite treatment system range from $1,000 to $5,000 (to add a disinfection to an existing treatment system), to $10,000 to $20,000 per single family residence. If an entire system needs to be replaced, then the cost could range from $20,000 to $30,000 for a traditional septic tank leachfield system with easy access for construction and minimal landscaping requirements, to $40,000 to $50,000 for a new septic tank, advanced treatment system followed by denitrification, disinfection, and a new drainfield. The $40,000 to $50,000 cost can more than double for a site with significant access limitations and landscaping requirements (Sherman, 2004).

4.7.2.5. Summary

Preliminary analysis identified several viable wastewater treatment alternatives for the Malibu Civic Center Area to meet specific nitrogen and/or bacteria treatment criteria. These are not the only available options; however, they cover technologies that seem well suited to the area needs and are currently used or will soon be used in the area.

Operation and maintenance will be required of all onsite treatment systems once an operating permit is issued. The cost of operation and maintenance ranges from less than $100 per year for septic tank pumpouts every three to five years, to $1000 per year for an annual maintenance contract and for the electricity required for energy intensive advanced treatment systems.

4.8. List of Potential Action Items

General Management Action Items

- Require operating permittees to submit all ongoing hydrogeologic and water quality results from WDR groundwater monitoring program to the City of Malibu.
    - Enter data into IWIMS to share results with LARWQCB staff (underway)
- Update and run groundwater model on annual basis to increase understanding of groundwater flow system and revise predictions of water quality enhancement and outcome achievements
- Implement point of sale inspection program for entire City of Malibu to accelerate the process of determining compliance and/or implementing upgrades.

Bacteria Management Action Items

- Develop implementation plan for Malibu Creek watershed bacteria TMDL (required)
- Develop implementation plan for Santa Monica Bay bacteria TMDLs (underway)
- Evaluate systems within 6-month time of travel to surface water
- Conduct evaluation of potential stormwater infiltration
- Conduct microbial source tracking analyses on groundwater quality samples

- Conduct detailed needs assessment and feasibility study on infrastructure management alternatives
- Reevaluate and revise Basin Plan domestic and municipal water supply beneficial use designation for Malibu Valley groundwater as appropriate

Nitrogen Management Action Items

- Work with Regional Board on development of nutrient TMDL for Malibu Creek watershed (underway)
- Denitrification for all commercial and multifamily systems in Malibu Creek/Lagoon contributing areas
- Denitrification for all residential systems in Malibu Creek/Lagoon contributing areas
- Conduct detailed needs assessment and feasibility study on infrastructure and wastewater management alternatives

4.9. Prioritization of Action Items

The apparent ability of these action items to achieve water quality outcomes is assessed in the matrices of Tables 30 and 31. These matrices include the following information for each action item: associated water quality outcome; the estimated time required to implement, the estimated time required to achieve water quality objectives; the uncertainty regarding the likelihood of achieving targeted water quality outcomes, and the associated estimated cost. Tables 30 and 31 list achievable water quality targets based on specific corrective actions. The implementation times are estimates that do not take into account overlapping implementation programs, nor available staff resources. The time to achieve water quality benefits for nitrogen is based on the computer modeling described in Appendix 3. The time to achieve water quality benefits for bacteria is based on the significantly less than 0.5 year survival times of pathogenic bacteria, as discussed previously in this report. The uncertainty is based on an understanding of nitrogen and bacteria attenuation process associated with OWTS and groundwater flow systems, as well as an understanding of the limitations of the applicability of the data collected in this report to a wider range of hydrologic conditions than were encountered during the study.

The final selection, prioritization, and cost estimates of action items were developed based on the comments received during the stakeholder review and comment period. Each action item was re-evaluated for relevance and preliminary feasibility based on input from stakeholders. Estimates of energy requirements of the final action items will be included in the final report as appropriate.

5. CONCLUSIONS AND RECOMMENDATIONS

The extensive nature of this project resulted in many specific conclusions that have been reported in previous sections. This section will be used to provide an overview of the report and focus on the highlights and more salient conclusions developed from this risk assessment.

5.1. Risk Assessment Overview

The risk assessment approach in this study was undertaken as a 6-step process:

1. **Define receiving waters and objectives**. The first step involved defining the receiving waters of concern and their associated water quality objectives for key constituents. In this case the receiving waters of concern are Malibu Creek and Lagoon and the Pacific Ocean. The key water quality constituents affecting the beneficial uses of these receiving waters are pathogens and nitrogen for Malibu Creek and Lagoon, and pathogens for the Pacific Ocean. The water quality objectives (i.e., numerical limits) for these constituents define the accepted levels that protect water contact recreation uses and aquatic habitat values. The numerical objectives were established in the RWQCB Basin Plan and are also addressed in the TMDLs for these specific receiving waters.
2. **Identify sources and levels of contamination contributed by OWTS**. The second step involved identifying the location and concentrations of pathogen and nitrogen discharges in the contributing areas that drain to Malibu Creek/Lagoon and the Ocean. Although there are a variety of sources, this study focused specifically on the contribution from OWTS in the City of Malibu Civic Center area. The locations of OWTS were identified and mapped, and the total discharges were quantified based on estimated wastewater flows and associated concentrations of pathogens and nitrogen in the discharges. At this step, the concentrations and loadings were adjusted to reflect the type of facility served (e.g., residential or commercial), as well as the level of treatment provided before discharge to the soil absorption system.
3. **Evaluate the hydrogeologic conditions**. In the third step, the information from the hydrogeologic investigation was evaluated to determine several key issues: (1) the groundwater elevations and gradients that govern the directions of groundwater flow and distinguish the geographic areas that contribute flow to Malibu Creek/Lagoon and areas where the flow is toward the Ocean; (2) groundwater velocity and inferred travel times for constituent migration from the discharge sources toward the receiving water bodies; and (3) groundwater depths affecting constituent removal processes.
4. **Estimate the assimilative capacity of unsaturated and saturated zones**. This step in the assessment accounts for the reduction or assimilation of pathogens and nitrogen as a result of percolation through the unsaturated soils and subsequent

pathogen die-off and denitrification during transport within the groundwater. Vertical depth between the bottom of the OWTS dispersal field and the water table is the primary determinant of the amount of bacterial assimilation in the unsaturated zone. In the groundwater, bacteria have a limited life expectancy, which is translated to a travel distance based on the rate of groundwater movement from Step 3. Nitrate-nitrogen is subject to removal by biological denitrification processes, which may be approximated in terms of a "half-life".

5. **Delineate specific OWTS locations and conditions posing unacceptable risks to the receiving waters**. Based on information from the preceding steps, the contribution of bacteria and nitrate-nitrogen to the respective waters (Malibu Creek/Lagoon and the Ocean) and the levels of risk associated with these contributions were defined. With respect to bacteria, unacceptable risks are posed by OWTS that provide an insufficient combination of unsaturated depth and groundwater travel time needed for pathogen die-off prior to reaching either the Creek/Lagoon or the near shore Ocean waters. Nitrate-nitrogen risks are a function of the collective contribution from all OWTS and were evaluated through mathematical modeling of the cumulative effects from all areas contributing flow to the Creek/Lagoon.
6. **Identify and evaluate alternative corrective strategies to reduce risks to acceptable levels**. The last step in the process involved identifying alternative measures or strategies to reduce the bacteria and nitrogen contributions from OWTS, and then evaluating/comparing the different approaches to determine which approaches appear to be most effective in reducing the risks to acceptable levels and achieving receiving water quality objectives.

5.2. Overview of Findings

The following findings are significant and informed the risk assessment process.

5.2.1. Stakeholder Involvement

Stakeholder involvement is critical to ensure that the process, information, and analysis is grounded in the local, environmental, regulatory and business community stakeholders.

- A number of very active internal and external stakeholder groups are very engaged with this issue.
- The results and analysis will be helpful in enabling the City of Malibu to work with the LARWQCB in developing the nutrient TMDL for the Malibu Creek Watershed, General Waste Discharge Requirements for individual OWTS, and an MOU between the City and the Regional Board.

5.2.2. Information Management

Existing and new groundwater quality data was stored, organized and retrieved using a web-based Integrated Wastewater Information Management System (IWIMS).

- Extensive planning, quality control, and quality assurance was essential in developing, storing, and reporting reliable data.
- This project brought together a wide range of data from multiple sources, ranging from geotechnical borings to water use data, to develop as comprehensive a picture of the groundwater flow conditions as possible within the scope of the project.
- The collection, organization, and accessibility of hydrogeologic and water quality data was very important to share with regulatory agencies (City of Malibu and LARWQCB).
- IWIMS was effective in allowing the sharing of groundwater quality data among the project team on a long term (two year) basis.

5.2.3. Water Quality Monitoring

Groundwater quality monitoring included field measurements of groundwater flow conditions throughout the study area under breached and breached conditions, as well as continuous groundwater level monitoring in three monitoring wells near the Lagoon. Water quality monitoring addressed nitrogen concentrations and indicator bacteria counts in the groundwater. Key findings include:

- Groundwater flow conditions
    - Contributing areas for Malibu Lagoon and the Ocean/surfzone were defined for breached and flooded Lagoon conditions.
    - A water balance was estimated for the study area, revealing that 42% of the groundwater flowing into of the study area is from OWTS. The groundwater leaving the study area appears to be distributed between the Creek and Lagoon (61%); the ocean (31%) and evapotranspiration (8%). Groundwater discharges to the Lagoon at a rate of roughly 78,000 cubic feet per day under flooded Lagoon conditions and 127,000 cubic feet per day under breached Lagoon conditions.
    - A slightly larger area contributes to the Lagoon under breached conditions. Under breached conditions, the Malibu Lagoon contributing area is approximately 0.5 square miles, and the Ocean contributing area is approximately 0.25 square miles.
    - Only a few developed parcels in Malibu Colony appear to be located where groundwater flows toward the Lagoon

- Groundwater flow under breached and flooded Lagoon conditions revealed a very slow moving groundwater flow system with up to more than 50-year time of travel from some leachfields to the Lagoon and/or ocean.
- Of the twenty monitoring wells where monthly water quality samples where collected:
  - Nine monitoring wells were located in the Ocean contributing area
    - One of these wells, located in the Malibu Pier parking lot, was destroyed after four sampling events.
    - One of these wells, located in Malibu Colony, appears to have been inadvertently installed in a drainfield
  - Eleven monitoring wells were located in the Lagoon contributing area

- Nitrogen
  - Monitoring wells with high, medium and low mean total nitrogen concentrations were located in each contributing area. High nitrogen concentrations were typically, although not exclusively, associated with proximity to one or more specific onsite systems.
  - In a properly functioning traditional OWTS, nitrogen is transformed to nitrate in the unsaturated soil above the water table.
  - The concentrations and distribution of nitrogen in the groundwater indicates a high likelihood of denitrification (conversion of nitrate to nitrogen gas) occurring in the soil/groundwater system.
  - Monitoring wells with high total nitrogen that is primarily ammonia-N, indicate localized areas of either excessive loading rates, or insufficient vertical separation to groundwater, or both.
  - The overall nitrogen loading to the Lagoon has been conservatively estimated to be between 11 and 32 lb/day for breached conditions; and between 8 to 25 lb/day for unbreached conditions.
  - Using the water balance from the model, the N load translates to an average N concentration in groundwater flowing to the Lagoon ranging from 1.7 to 5.2 mg/L in flooded (dry weather) conditions; and 1.4 to 4.0 mg/L in breached (wet weather) conditions. Therefore the wet weather nitrogen target concentration of 8 mg/L

appears to be met under conservative assumptions of no nitrogen attenuation in the soil groundwater system. However, the dry weather nitrogen target concentration of 1 mg/L requires adequate nitrogen removal in the riparian/sediment zone, advanced treatment to remove approximately 40 to 80 percent of the nitrogen load, or a combination of these nitrogen removal processes.

- Bacteria
    - Monitoring wells with high, medium, and low indicator bacteria counts are located in contributing areas to both Malibu Lagoon and the ocean.
    - Some monitoring wells registering high and medium bacteria counts are located in areas with no nearby OWTS.
    - Potential sources of indicator bacteria include OWTS, infiltration of stormwater runoff, and surface water recharge (where the Creek, Lagoon, or a wetland area flows into the groundwater).
    - The alluvial aquifer area has less than 50-foot depth to groundwater and significant areas with less than 10-feet to groundwater and apparently under the influence of and connection to surface water. Based on water quality data collected during this study, it is recommended that further evaluation be conducted to determine whether the following exemption criteria for beneficial use is met in the Malibu Valley: "There is contamination, either by natural processes or by human activity (unrelated to the specific pollution incident), that cannot reasonably be treated for domestic use using either Best Management Practices or best economically achievable treatment practices." (State of California, 1988). This appears to conflict with the Basin Plan's beneficial use designation of an existing or potential drinking water source and should be subjected to a use attainability analysis.

5.2.4. Risk Assessment

The water quality constituents of concern for Malibu Creek, Malibu Lagoon and the ocean are nitrogen and bacteria. A three-dimensional computer model was used to simulate the groundwater flow system and evaluate potential approaches to water quality enhancement in light of nitrogen and bacteria outcomes.

- Nitrogen
    - Malibu Creek and Lagoon are impaired with respect to nutrient loading as determined by the USEPA, and preliminary nitrogen targets have been set at 1 mg/L total nitrogen for dry weather conditions.

- The contributing area for Malibu Lagoon was identified as the area on which to focus outcome-based OWTS management for nitrogen
    - Due to low groundwater velocities, nitrogen removal is likely to require decades to achieve significant water quality changes in the Lagoon.
    - Modeling of nitrogen removal did not account for potential nitrate attenuation in the Creek and Lagoon riparian zone, nor Lagoon sediments, although a study of those processes is currently underway.
- Bacteria
    - Water quality in Malibu Creek, Malibu Lagoon and Surfrider Beach has been identified as impaired because bacteria levels exceed water quality standards. The standards for marine water contact recreation include single sample limits and rolling geometric means.
    - Pathogenic bacteria typically survive only for a few weeks to a few months outside of their hosts. The occurrence of indicator bacteria in areas located ten or more years' time of travel from OWTS precludes OWTS as potential sources of those organisms.
    - A six-month time of travel area has been identified as the area on which to focus outcome-based OWTS management for bacteria in surface waters.
    - The beneficial use of groundwater in the Malibu Valley as an existing and future drinking water source does not appear to be achievable due to the influence of surface water and possible natural sources of bacterial contamination of shallow groundwater.
- Identification and evaluation of potential mitigation strategies
    - Strategies or options available to achieve water quality outcomes include both infrastructure and resource management approaches. Viable alternatives are listed below.
- Draft report recommendations
    - Receive stakeholder input on analysis and alternatives
    - Develop action items based on stakeholder input

5.3. Action items

Action items include corrective actions that include upgrading or installing wastewater treatment infrastructure, OWTS management strategies, and water resource management strategies.

- Corrective Actions Involving Infrastructure

Onsite wastewater infrastructure initiatives should be developed as close to the source of the wastewater as possible. Individual property owners can carry out onsite infrastructure solutions. Cluster and community systems require additional engineering studies addressing site-specific evaluation of need and feasibility of various wastewater collection, treatment or reclamation, and dispersal or reuse options.

  - Onsite Disinfection And Denitrification For Large Commercial And Multi-Family Occupancies In Malibu Lagoon Contributing Area
  - Onsite Denitrification For All Systems In Malibu Lagoon Contributing Area
  - Onsite Or Cluster Advanced Treatment And Disinfection For Systems With Inadequate Separation To Groundwater Within 6 Month Time Of Travel
  - Community Wastewater Reclamation System With Onsite Dispersal
  - Community Reclamation And Dispersal Outside Of Contributing Area
  - Combination Of Above

- OWTS Management Strategies

Both the LARWQCB and the City of Malibu are conducting intensive regulatory programs to manage OWTS. The following strategies are intended to focus those efforts on fact-based outcome-driven approaches to OWTS management.

  - Site Specific Groundwater Monitoring for Large Commercial and Multifamily Systems (ongoing)
  - Operating Permits for Commercial and Multifamily Occupancies (ongoing)
  - Point of Sale Inspections with Operating Permits for all systems
  - Mandatory Inspections for OWTS in Malibu Lagoon Contributing Area with operating permits for all systems
  - OWTS with Regional Groundwater Quality Monitoring in Malibu Lagoon Contributing Area Sampling for Nitrogen constituents and Microbial Source Tracking for Bacteria identification
  - Combination of above

- Water Resource Management Strategies

Effective water resource management involves monitoring and use of monitoring data to provide feedback on the effectiveness of water quality infrastructure changes or management strategies in achieving water quality outcomes. The following is a list of strategies that have been developed in the preparation of this report, or can be pursued to improve TMDL compliance. These strategies can be continued to develop and continuously improve the sustainability of the City's and LARWQCB's water quality management programs.

- City of Malibu
  - Continue to work with other local agencies to develop implementation plan for Santa Monica Bay bacteria TMDL incorporating findings of this report as appropriate.
  - Continue regional groundwater quality sampling program in the Civic Center area on sites where permission to access existing monitoring wells can be extended.
  - Maintain and collect data continuous groundwater level from data loggers on sites where permission to access existing monitoring wells can be extended.
  - Conduct synoptic water level measurements twice a year (in flooded and breached Lagoon conditions)
  - Require all hydrogeologic data associated with OWTS be submitted to the City as a condition of operating permits and enter that data into IWIMS.
  - Evaluate Civic Center area groundwater quality data and Malibu Creek, Malibu Lagoon and surfzone surface water quality data on an annual basis to develop understanding of the relationships between the groundwater and surface water systems.
  - Update the three dimensional computer model with new data once a year and run model to refine estimates of contributing area extent, time of travel, existing nitrogen loading, and effect of nitrogen reduction actions.
- City of Malibu and LARWQCB
  - Enter into MOU regarding delegation of responsibility of single family residential and small commercial OWTS management to the City of Malibu
  - Reassess nitrogen TMDL for the Malibu Creek subwatershed in light of new data and analysis.
  - Reassess beneficial use designation of groundwater in Malibu Valley or at least clarify applicability of marine water contact recreation standard for groundwater
  - Coordinate results of ongoing sediment study with this report.

5.4. Overall Conclusions

The risk posed by OWTS to groundwater and surface water quality was assessed relative to bacteria and nitrogen outcomes. Now that the contributing areas have been characterized, the City of Malibu and the LARWQCB can utilize the data to implement the action items involving consideration of new infrastructure, OWTS management, and water resource management from a common perspective.

Individual OWTS are capable of providing bacteria reduction to marine water contact recreation quality standards using either adequate separation to groundwater or disinfection. Although many systems are providing adequate bacteria reduction, some systems do not appear to be currently meeting these standards. Although adequate bacteria attenuation from all OWTS is important, OWTS that are within a 6-month time of travel from surface water should be considered a high priority. Other sources of indicator bacteria in the study area should be characterized to develop appropriate TMDL implementation strategies for Malibu Lagoon and Surfrider Beach.

The area contributing groundwater to the Lagoon is much smaller than was previously assumed based on surface topography. The overall nitrogen loading estimated in this study is generally consistent with previous studies. Any nitrogen reduction strategy will have a substantial lag time in producing significant water quality changes due to the slow travel time in the groundwater flow system. However, it is important to note that the nitrogen loading is diffuse and that some nitrogen reduction appears to be occurring naturally in the groundwater. A concurrent study of nutrient cycling in Malibu Lagoon sediments may be useful in characterizing the flux of nitrogen from the groundwater through the sediments and into the Lagoon.

The action items developed from this study will be brought to the City Council with a recommendation for adoption as amendments to the City of Malibu's Wastewater Management Plan.

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9. MAPS

August 30, 2004

VOLUME 2: FINAL REPORT APPENDICES

Risk Assessment of Decentralized Wastewater Treatment Systems in High Priority Areas in the City of Malibu, California

Stone Project Number 011269-W

This project has been funded wholly or in part by the Santa Monica Bay Restoration Commission and the California State Coastal Conservancy using state bond funds from the Safe Neighborhood Parks, Clean Water, Clean Air, and Coastal Protection Act of 2000.

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APPENDICES

Appendix 1: Monitoring Well Construction Logs

Appendix 2: Hydraulic Conductivity Testing Results

Appendix 3: Hydrogeology Model Report

Appendix 4: Materials from Stakeholder Presentations

Appendix 5: Draft Report Comments Received and Responsiveness Summary

APPENDIX 1: MONITORING WELL CONSTRUCTION LOGS

Project: Santa Monica Bay Restoration Project
Project Location: City of Malibu, Civic Center Area
Project Number: 49.17691.0033

Key to Logs

Surface Elev., feet	Depth, feet	SAMPLES: Type	SAMPLES: Number	SAMPLES: Penetration Resistance, Blows / 6 in.	Graphic Log	Unified Soil Classification System	MATERIAL DESCRIPTION	Well Completion Diagram	WELL CONSTRUCTION DETAILS
1	2	3	4	5	6	7	8	9	10

COLUMN DESCRIPTIONS

1 **Surface Elev.:** Elevation in ft. referenced to mean sea level (MSL); obtained from GPS surveyed locations, rounded to nearest 0.01 foot.

2 **Depth:** Depth, measured in feet, below the existing ground surface.

3 **Sample Type:** Type of soil sample collected at depth interval shown; sampler symbols are explained below.

4 **Sample Number:** Sample indentification number and Pocket Penetrometer Test results, abbreviated pp, if applicable.

5 **Blows / 6 in.:** Number (N) of blows required to advance driven sampler 18- in., recorded each 6-in. drive interval, or dist. noted, using a 140-lb sampler hammer, dropping 30-in. (unless otherwise noted).

6 **Graphic Log:** Graphic depiction of subsurface material encountered; typical symbols are explained below.

7 **Unified Soil Classification:** Unifed Soil Classification System (USCS) code for assoc. soil stratum and/or geologic unit, see below.

8 **Material Description:** Description of material encountered; may include color, moisture, grain size, and density/consistency.

9 **Well Completion Diagram** Well installation schematic; materials are listed in header, graphics are explained below.

10 **Well Construction Details** Typical well detail providing description of materials used during original well installation

UNIFIED SOIL CLASSIFICATION SYSTEM (USCS)

Major Divisions					Group Symbol	Typical Names
Coarse-grained Soils (> 50 % passing No. 200 Sieve) (The No. 200 sieve size is about the smallest particle visible to the naked eye.)	Gravels % of coarse fraction is > 1/4in.	<= 5% fines	5 - 12 % fines dual i.d. (e.g. GW-GC or GP-GM)		GW	*Well-graded gravel, gravel-sand mixtures, little of no fines.*
					GP	*Poorly-graded gravel, gravel-sand mixtures, little of no fines.*
		>= 12% fines			GM	*Silty gravel, gravel-sand-silt mixt.*
					GC	*Clayey gravel, gravel-sand-clay mixture*
	Sands % of coarse fraction is > 1/4in.	<= 5% fines	5 - 12 % fines dual i.d. (e.g. SW-SC or SP-SM)		SW	*Well-graded sand, gravely sand*
					SP	*Poorly-graded sand, gravely sand*
		>= 12% fines			SM	*Silty sand, sand-silt mixture*
					SC	*Clayey sand, sand-clay mixture*
Fine-grained Soils (< 50 % passing No. 200 Sieve)	Silts/Clays	Liquid limit < 50	slight - medium plasticity		ML	*Silt, Clayey Silt, Silty or Clayey very fine Sand, slight plasticity*
					CL	*Clay, Sandy Clay, Silty Clay, lean clay, low - medium plasticity*
					OL	*Organic Silts or Silty Clays of low plasticity*
	Silts/Clays	Liquid limit > 50	high plasticity		MH	*Silt, Clayey Silt, Silty or Clayey very fine Sand, high plasticity*
					CH	*Clay, Fat Clays, high plasticity*
					OH	*Organic Clays of medium to high plasticity*
Highly Organic Soils					Pt	*Peat and other highly organic soil*

TYPICAL MATERIAL GRAPHIC SYMBOLS

- **Poorly graded GRAVEL (GP)**
- **Silty SAND with gravel (SM)**
- **Well-graded SAND (SW)**
- **Clayey or sandy SILT (ML)**
- **Poorly graded SAND (SP)**
- **Lean sandy or silty CLAY (CL)**
- **Poorly graded SAND with gravel (SP)**
- **Lean CLAY with gravel (CL)**
- **Silty SAND (SM)**
- **Fat sandy or silty CLAY (CH)**

TYPICAL WELL GRAPHIC SYMBOLS

- ***Blank well casing in filter sand***
- ***Blank casing in cement grout***
- ***Blank well casing in bentonite chips***
- ***Blank casing in cased-hole, concrete on outside, bent./cement grout on inside***
- ***Slotted well casing in filter sand***
- ***Bottom-cap for slotted well casing***

MATERIAL STRENGTH PROPERTIES

	Consistency-(SILT/CLAY) OR Density-(SAND)	Blows / Foot (12")	Pocket Penetro. Test (pp) (TSF)
SILT & CLAY[1]	Very Soft	< 2	< 0.25
	Soft	2 - 4	0.25 - 0.5
	Medium Stiff	4 - 8	0.5 - 1
	Stiff	8 - 16	1 - 2
	Very Stiff	16 - 32	2 - 4
	Hard	> 32	> 4
SAND[2]	Very Loose	0 - 4	Not Applicable
	Loose	4 - 10	
	Medium Dense	10 - 30	
	Dense	30 - 50	
	Very Dense	> 50	

[1]NAVFAC DM-7.1, 1982; [2] Terzaghi and Peck, 1967

TYPICAL SAMPLER GRAPHIC SYMBOLS

- **Standard Penetration Test (SPT)- split spoon**
- **Bulk and/or bag sample**

OTHER SYMBOLS

- pp **Pocket Penetrometer Test- TSF units**
- **Static water level measured at specified time after drilling**
- **Bedrock Unit: CLAYSTONE**
- **Bedrock Unit: SILTSTONE**

Project: Santa Monica Bay Restoration Project
Project Location: 22300 PCH, Malibu, CA
Project Number: 49.17691.0033

Log of SMBRP-1

Date(s) Drilled	3/24/03	Logged By	AS	Checked By	CD
Drilling Method	Hollow-Stem Auger	Drill Bit Size/Type	8 inches- O.D.	Total Depth of Borehole	25.0 feet
Drill Rig Type	Track-mounted limited access, D25	Drilling Contractor	Gregg Drilling and Testing	Approximate Surface Elevation	20.77 feet
Groundwater Level(s)	15 feet	Sampling Method	Standard Penetration Test (SPT)	Top of Casing Elevation	20.77 feet
Well Details	Monitoring Well Installed; Refer to Right-Hand Column(s) for Details			Hammer Data	Automatic; 140 lbs, 30 in. drop

Surface Elev., feet	Depth, feet	Samples: Number	Penetration Resistance, Blows / 6 in.	Unified Soil Classification [Geologic Unit]	MATERIAL DESCRIPTION
21	0				**ASPHALT (0-2.5")**
		B-1 B-2		SM	**FILL (af)- (2.5"-4')** silty SAND: dark brown, moist, loose
		B-3			
		B-4			Silty SAND: dark brown, moist, loose, some yellow SAND towards bottom
16	5	SPT-1	3 2 3	SP	**BEACH DEPOSITS (Qbs)- (4-25')** SAND: brown, moist, loose
11	10	SPT-2	1 4 5		SAND: brown, moist, loose; dark brown silty SAND at tip of sampler
6	15	SPT-3	7 32 37	SM	Groundwater at ~15' Silty SAND: brown, wet, loose near top, dense at tip, gravel/rock fragment in tip of sampler
				SP	
1	20	SPT-4	18 50		SAND: brown, wet, dense to very dense (top 8"), grades to silty SAND, rock fragments near tip of sampler
					SAND: brown, wet, dense, bedrock encountered at tip of sampler; black SHALE
-4	25	SPT-5	25(6")		**Total Depth Drilled- 25 feet** Total Depth Sampled- 26.5 feet Groundwater encountered at ~15 feet.
-9	30				
-14	35				

WELL CONSTRUCTION DETAILS

WELL MATERIALS

Casing Installed:

-10 feet of 2-inch diameter blank PVC casing between 0-10' (bgs)

-15 feet of 2-inch diameter .020 slotted PVC casing between 10-25' (bgs)

Backfill Materials:

-1 bag of bentonite chips placed around casing between 1-8' (bgs)

-5 bags of #3 sand placed around casing between 8-25' (bgs)

Surface Completion (0-1' bgs):

-2 bags ready mix concrete
-1 bag of Portland quick set cement
-Well box and locking cap

Project: Santa Monica Bay Restoration Project
Project Location: South of 23705 Stuart Ranch Rd., Malibu, CA
Project Number: 49.17691.0033

Log of SMBRP-10c

Sheet 1 of 1

Date(s) Drilled	12/30/02	Logged By	JW	Checked By	CD
Drilling Method	Hollow-Stem Auger	Drill Bit Size/Type	8 inches- O.D.	Total Depth of Borehole	25.0 feet
Drill Rig Type	MST-D25	Drilling Contractor	Gregg Drilling and Testing	Approximate Surface Elevation	16.03 feet
Groundwater Level(s)	4 feet	Sampling Method	Standard Penetration Test (SPT)	Top of Casing Elevation	16.25 feet
Well Details	Monitoring Well Installed; Refer to Right-Hand Column(s) for Details			Hammer Data	Automatic; 140 lbs, 30 in. drop

Surface Elev., feet	Depth, feet	SAMPLES Type	Number	Penetration Resistance, Blows / 6 in.	Graphic Log	Unified Soil Classification [Geologic Unit]	MATERIAL DESCRIPTION
16	0						Hand-auger used between 0-5', groundwater measured at 4' in boring
11	5	SPT	SPT-1 pp=1.25	2 2 3		ML	**ALLUVIUM (Qal)- (5-25')** sandy SILT: dark brown, silghtly moist, soft
6	10	SPT	SPT-2 pp=0	push			sandy SILT: very moist to wet, very soft
1	15	SPT	SPT-3 pp=1.0	push			sandy SILT: dark brown, silghtly moist, soft
-4	20	SPT	SPT-4 pp= 1.0-1.5	push			sandy SILT: very fine-grained, moist to wet
							sandy SILT: dark gray to dark gray, wet, very fine-grained, trace clay, little to no binder
-9	25	SPT	SPT-5 pp= 1.25-1.5	2 2 2			**Total Depth Drilled- 25 feet** Total Depth Sampled- 26.5 feet Groundwater encountered at 4 feet.
-14	30						
-19	35						

Well Completion Diagram

WELL CONSTRUCTION DETAILS

WELL MATERIALS

Casing Installed:

-10 feet of 2-inch diameter blank PVC casing between 0-10' (bgs)

-15 feet of 2-inch diameter .020 slotted PVC casing between 10-25' (bgs)

Backfill Materials:

-4 bags of bentonite placed around casing between 1-8' (bgs)

-6 bags of #3 sand placed around casing between 8-25' (bgs)

Surface Completion (0-1' bgs):

-1 bag ready mix concrete
-2 bags of Portland quick set cement
-Well box and locking cap

Report: HSA_W_SANTA MONICA BAY; File: 49.17691.0033 SMBRP- REVISED.GPJ; 6/3/04; ID SMBRP-10c

Project: Santa Monica Bay Restoration Project
Project Location: 23910 Malibu Road, Malibu, CA
Project Number: 49.17691.0033

Log of SMBRP-11

Date(s) Drilled	2/4/03	Logged By	AH	Checked By	CD
Drilling Method	Hollow-Stem Auger	Drill Bit Size/Type	8 inches- O.D.	Total Depth of Borehole	20.0 feet
Drill Rig Type	Track-mounted limited access, D25	Drilling Contractor	Gregg Drilling and Testing	Approximate Surface Elevation	17.94 feet
Groundwater Level(s)	7.5 feet	Sampling Method	Standard Penetration Test (SPT)	Top of Casing Elevation	18.35 feet
Well Details	Monitoring Well Installed; Refer to Right-Hand Column(s) for Details			Hammer Data	Automatic; 140 lbs, 30 in. drop

Surface Elev., feet	Depth, feet	SAMPLES Number	Penetration Resistance, Blows / 6 in.	Unified Soil Classification [Geologic Unit]	MATERIAL DESCRIPTION
18	0	B-1		SM	**ASPHALT (0-2.5")** **FILL (af)- (2.5"-1.5')** gravelly silty SAND: black, damp, medium dense
		B-2		SM	**BEACH DEPOSITS (Qbs)- (1.5'-21.5')** silty SAND: dark brown, moist, appears loose, medium-grained, trace gravel to 2" diameter, massive
13	5	B-3			
		SPT-1	2 4 4		silty SAND: dark yellowish brown, moist, loose
		SPT-2	1 5 7		groundwater @ ~7.5' as above; medium- to coarse-grained, wet, loose to medium-dense
8	10	SPT-3	6 12 10	SM-SP	as above; minor gravel, gradational contacts observed
3	15	SPT-4	5 9 4		SAND: dark yellowish brown, wet, medum-dense, minor gravel and silt, crude bedding observed
				SP-CL	SAND and sandy silty CLAY: dark yellowish brown, wet, medium dense/ medium stiff, medium- to coarse-grained, low to medium plasticity
-2	20	SPT-5	3 6 9		**Total Depth Drilled- 20 feet** Total Depth Sampled- 21.5 feet Groundwater encountered at ~7.5 feet.
-7	25				
-12	30				
-17	35				

WELL CONSTRUCTION DETAILS

WELL MATERIALS

Casing Installed

-5 feet of 2-inch diameter blank PVC casing between 0-5' (bgs)

-15 feet of 2-inch diameter .020 slotted PVC casing between 5-20' (bgs)

Backfill Materials:

-1.5 bags of bent. chips placed around casing bet. 0.5-3' (bgs)

-5 bags of #3 sand placed around casing between 3-20' (bgs)

Surface Completion (0-0.5' bgs):

-1.5 bags ready mix concrete
-1.5 bags of Portland quick set cement
-Well box and locking cap

BING YEN & ASSOCIATES, INC.
Geotechnical & Environmental Consultants

Project: Santa Monica Bay Restoration Project
Project Location: 23635 Malibu Colony Dr., Malibu, CA
Project Number: 49.17691.0033

Log of SMBRP-12

Date(s) Drilled	**3/20/03**	Logged By	**JW**	Checked By	**CD**
Drilling Method	**Hollow-Stem Auger**	Drill Bit Size/Type	**8 inches- O.D.**	Total Depth of Borehole	**25.0 feet**
Drill Rig Type	**Track-mounted limited access, D25**	Drilling Contractor	**Gregg Drilling and Testing**	Approximate Surface Elevation	**12.12 feet**
Groundwater Level(s)	**7 feet**	Sampling Method	**Standard Penetration Test (SPT)**	Top of Casing Elevation	**12.62 feet**
Well Details	**Monitoring Well Installed; Refer to Right-Hand Column(s) for Details**			Hammer Data	**Automatic; 140 lbs, 30 in. drop**

Surface Elev., feet	Depth, feet	Sample Number	Penetration Resistance, Blows / 6 in.	Unified Soil Classification [Geologic Unit]	MATERIAL DESCRIPTION
12	0	B-1, B-2, B-3, B-4		ML	**ASPHALT (0-2.5")** **FILL (af)- (2.5"-2')** clayey SILT: dark red brown, moist, dense
				SM	**BEACH DEPOSITS (Qbs)- (2-25')** silty SAND: tan, dry, dense
7	5	SPT-1	3 2 3		groundwater @ ~7'
2	10	SPT-2	3 4 7	SP	SAND: gray-green, wet, dense @ 10' Heaving sands in auger
-3	15	SPT-3	Push	ML	@ 15' same as described above; ~4-inch thick gray-green clayey SILT layer in tip of sampler
-8	20	SPT-4	1 3 2		clayey SILT: gray-greeen, wet, stiff, bottom 1' of sample, remainder of sample composed of gray-tan SAND.
					clayey SILT: gray-green, wet, stiff (ML from 25-26.5')
-13	25	SPT-5	1 1 3		**Total Depth Drilled- 25 feet** Total Depth Sampled- 26.5 feet Groundwater encountered at ~7 feet.
-18	30				
-23	35				

WELL CONSTRUCTION DETAILS

WELL MATERIALS

Casing Installed:

-10 feet of 2-inch diameter blank PVC casing between 0-10' (bgs)

-15 feet of 2-inch diameter .020 slotted PVC casing between 10-25' (bgs)

Backfill Materials:

-2 bags of bentonite chips placed around casing between 1-8' (bgs)

-4 bags of #3 sand placed around casing between 8-25' (bgs)

Surface Completion (0-0.5' bgs):

-2 bags ready mix concrete
-2 bags of Portland quick set cement
-Well box and locking cap

Report: HSA_W_SANTA MONICA BAY; File: 49.17691.0033 SMBRP- REVISED.GPJ; 6/3/04; ID SMBRP-12

BING YEN & ASSOCIATES, INC.
Geotechnical & Environmental Consultants

Project: Santa Monica Bay Restoration Project
Project Location: 23526 Malibu Colony Dr., Malibu, CA
Project Number: 49.17691.0033

Log of SMBRP-13

Date(s) Drilled	2/5/03	Logged By	AH	Checked By	CD
Drilling Method	Hollow-Stem Auger	Drill Bit Size/Type	8 inches- O.D.	Total Depth of Borehole	20.0 feet
Drill Rig Type	Track-mounted limited access, D25	Drilling Contractor	Gregg Drilling and Testing	Approximate Surface Elevation	13.30 feet
Groundwater Level(s)	8 feet	Sampling Method	Standard Penetration Test (SPT)	Top of Casing Elevation	13.58 feet
Well Details	Monitoring Well Installed; Refer to Right-Hand Column(s) for Details			Hammer Data	Automatic; 140 lbs, 30 in. drop

Surface Elev., feet	Depth, feet	Sample Number	Penetration Resistance, Blows / 6 in.	Unified Soil Classification [Geologic Unit]	MATERIAL DESCRIPTION
13	0	B-1		SM	**ASPHALT (0-3.5")** **FILL (af)- (3.5"-1.5')** gravelly silty SAND: black, damp, medium dense
		B-2		SP	**BEACH DEPOSITS (Qbs)- (1.5'-21.5')** SAND: light yellowish brown to olive brown, slightly moist, loose
		B-3			as above, olive brown, fine- to medium-grained
8	5	SPT-1	3 3 3		SAND: light to dark yellowish brown, moist, loose, very fine- to medium-grained; very moist very fine-grained silty SAND @ the bottom of sample
		SPT-2	1 3 4	SM-ML	interbedded silty SAND and SILT: dark yellowish brown to very dark gray, wet, loose/ medium-stiff
3	10	SPT-3	2 5 7	SP	SAND: gray, wet, loose, medium-grained, trace gravel
				GP	gravelly zone @ 14'
-2	15	SPT-4	1 2 5	SP	as above, minor gravel
					SAND and sandy GRAVEL: as above, wet, medium dense
-7	20	SPT-5	2 6 6		**Total Depth Drilled- 20 feet** Total Depth Sampled- 21.5 feet Groundwater encountered at ~8 feet.
-12	25				
-17	30				
-22	35				

WELL CONSTRUCTION DETAILS

WELL MATERIALS

Casing Installed:

-5 feet of 2-inch diameter blank PVC casing between 0-5' (bgs)

-15 ft of 2-inch diam., .020 slotted PVC casing between 5-20' (bgs)

Backfill Materials:

-1 bag of bentonite chips placed around casing between 0.5-3' (bgs)

-4 bags of #3 sand placed around casing between 3-20' (bgs)

Surface Completion (0-0.5' bgs):

-2 bags ready mix concrete
-2 bags of Portland quick set cement
-Well box and locking cap

Project: Santa Monica Bay Restoration Project
Project Location: 23316 Malibu Colony Dr., Malibu, CA
Project Number: 49.17691.0033

Log of SMBRP-14

Sheet 1 of 1

Date(s) Drilled	**2/5/03**	Logged By	**AS**	Checked By	**CD**
Drilling Method	**Hollow-Stem Auger**	Drill Bit Size/Type	**8 inches- O.D.**	Total Depth of Borehole	**20.0 feet**
Drill Rig Type	**Track-mounted limited access, D25**	Drilling Contractor	**Gregg Drilling and Testing**	Approximate Surface Elevation	**11.53 feet**
Groundwater Level(s)	**4 feet**	Sampling Method	**Standard Penetration Test (SPT)**	Top of Casing Elevation	**11.87 feet**
Well Details	**Monitoring Well Installed; Refer to Right-Hand Column(s) for Details**			Hammer Data	**Automatic; 140 lbs, 30 in. drop**

Surface Elev., feet	Depth, feet	SAMPLES: Type	SAMPLES: Number	Penetration Resistance, Blows / 6 in.	Unified Soil Classification [Geologic Unit]	MATERIAL DESCRIPTION
12	0	Bag	B-1		SM	**ASPHALT (0- 2")** **BEACH DEPOSITS (Qbs)- (2"-10')** silty SAND: brown, moist, loose, medium- to coarse-grained, few to little gravel
		Bag	B-2			silty SAND: strong brown, moist to wet, loose, medium-grained, few gravel to 2" in diameter (leach line gravel?)
						groundwater @ ~4'
7	5					
		SPT	SPT-1	6 2 5		silty SAND: very dark gray, wet, loose, medium-grained, gravel observed in top of sampler, trace clay
		SPT	SPT-2	6 3 9		silty SAND: dark red gray, very moist, fine- to medium-grained
2	10	SPT	SPT-3	3 7 8	Tr	**BEDROCK: TRANCAS FORMATION (Tr)- (10'-21.5')** clayey SILTSTONE: dark red brown, damp, hard, massive, faint petroliferous odor
-3	15	SPT	SPT-4	3 6 9		sandy CLAYSTONE: dark brown, damp, hard
						bag sample taken from tip of auger
-8	20	Bag	B-3			CLAY: dark reddish brown, wet, high plasticity
						Total Depth Drilled- 20 feet Total Depth Sampled- 20 feet Groundwater encountered at ~4 feet.
-13	25					
-18	30					
-23	35					

WELL CONSTRUCTION DETAILS

WELL MATERIALS

Casing Installed:

-5 feet of 2-inch diameter blank PVC casing between 0-5' (bgs)

-5 ft of 2-inch diam., .020 slotted PVC casing between 5-10' (bgs)

Backfill Materials:

-1 bag of bentonite chips placed around casing between 0.5-3' (bgs)

-3 bags of #3 sand placed around casing between 3-10' (bgs)

Surface Completion (0-0.5' bgs):

-2 bags ready mix concrete
-2 bags of Portland quick set cement
-Well box and locking cap

Project: Santa Monica Bay Restoration Project
Project Location: North of 23554 PCH, Malibu, CA
Project Number: 49.17691.0033

Log of SMBRP-15

Date(s) Drilled	12/31/02	Logged By	JW	Checked By	CD
Drilling Method	Hollow-Stem Auger	Drill Bit Size/Type	8 inches- O.D.	Total Depth of Borehole	70.0 feet
Drill Rig Type	CME-95	Drilling Contractor	Gregg Drilling and Testing	Approximate Surface Elevation	16 feet
Groundwater Level(s)	15 feet	Sampling Method	Standard Penetration Test (SPT)	Top of Casing Elevation	
Well Details	None installed			Hammer Data	Automatic; 140 lbs, 30 in. drop

Surface Elev., feet	Depth, feet	SAMPLES Type	SAMPLES Number	Penetration Resistance, Blows / 6 in.	Graphic Log	Unified Soil Classification [Geologic Unit]	MATERIAL DESCRIPTION	Well Completion Diagram	WELL CONSTRUCTION DETAILS
16	0						Hand auger used between 0-5'		**WELL NOT INSTALLED** *Installation Stopped Due to Sloughing/Caving in Boring*
11	5	SPT	SPT-1	16 15 14		SM/ML	**ALLUVIUM (Qal)- (0-70')** silty SAND/sandy SILT: dry		
6	10	SPT	SPT-2	11 14 17			@ 10' silty SAND/sandy SILT: dark golden tan brown, moist, loose		pp=0
						SM	silty SAND: wet		
1	15	SPT	SPT-3	8 13 15				▼	
-4	20	SPT	SPT-4	6 7 8			SAND: gray to greenish brown, wet, silty		
						SP			
-9	25	SPT	SPT-5	15 17 22			as above, rounded gravels, coarse grained, wet		
						SM			
-14	30	SPT	SPT-6	20 26 41			silty SAND: medium-grained, gray green brown, wet		
						SM			
-19	35								

BING YEN & ASSOCIATES, INC.
Geotechnical & Environmental Consultants

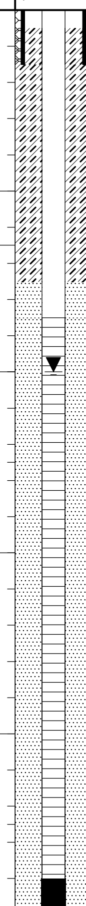
Project: Santa Monica Bay Restoration Project **Project Location:** North of 23554 PCH, Malibu, CA **Project Number:** 49.17691.0033	**Log of SMBRP-15** Sheet 2 of 2

Surface Elev., feet	Depth, feet	Samples: Type	Samples: Number	Penetration Resistance, Blows / 6 in.	Graphic Log	Unified Soil Classification [Geologic Unit]	MATERIAL DESCRIPTION	Well Completion Diagram	WELL CONSTRUCTION DETAILS
-19	35		SPT-7	21 50(4")			as above, gravelly		
-24	40		SPT-8	30 33 34			gravelly silty SAND: very dense		
						CL			
-29	45		SPT-9	7 9 13			CLAY: dark green brown		pp=1.25-2.0
						ML			
-34	50		SPT-10	8 17 17			sandy SILT: wet, trace clay		p=2.0
-39	55		SPT-11	14 13 20			sandy SILT: very fine-grained, gray brown, wet, trace clay		
						SM			
-44	60		SPT-12	46 50(5")			gravelly silty SAND with CLAY: wet, very dense		pp=3.0-3.5
-49	65						No recovery, slough in auger		
							No recovery, slough in auger		
-54	70						**Total Depth Drilled- 70 feet** Total Depth Sampled- 60 feet Groundwater encountered at ~15 feet.		
-59	75								

Project: Santa Monica Bay Restoration Project **Project Location:** 23554 PCH, Malibu, CA **Project Number:** 49.17691.0033	# Log of SMBRP-15b Sheet 1 of 1

Date(s) Drilled	**3/21/03**	Logged By	**JW**	Checked By	**CD**
Drilling Method	**Hollow-Stem Auger**	Drill Bit Size/Type	**8 inches- O.D.**	Total Depth of Borehole	**25.0 feet**
Drill Rig Type	**Track-mounted limited access, D25**	Drilling Contractor	**Gregg Drilling and Testing**	Approximate Surface Elevation	**16.52 feet**
Groundwater Level(s)	**10 feet**	Sampling Method	**Bulk**	Top of Casing Elevation	**16.77 feet**
Well Details	**Monitoring Well Installed; Refer to Right-Hand Column(s) for Details**			Hammer Data	**N/A**

Surface Elev., feet	Depth, feet	SAMPLES Type	SAMPLES Number	SAMPLES Penetration Resistance, Blows / 6 in.	Graphic Log	Unified Soil Classification [Geologic Unit]	MATERIAL DESCRIPTION	Well Completion Diagram	WELL CONSTRUCTION DETAILS
17	0						Hand auger used between 0-6.5 feet; Gravel- to cobble-size rock fragments from 1-3'		**WELL MATERIALS**
		Bulk	B-1						
		Bulk	B-2						**Casing Installed:** *-10 feet of 2-inch diameter blank PVC casing between 0-10' (bgs)* *-15 feet of 2-inch diameter .020 slotted PVC casing between 10-25' (bgs)*
		Bulk	B-3						
		Bulk	B-4						
12	5	Bulk	B-5						
						SM/ML	**ALLUVIUM (Qal)- (6.5-25')** silty SAND/sandy SILT: dry, dense		**Backfill Materials:** *-3 bags of bentonite chips placed around casing between 1.5-7.5' (bgs)* *-3 bags of #3 sand placed around casing between 7.5-25' (bgs)*
7	10						silty SAND/sandy SILT: dark golden tan brown, moist, loose Groundwater @~10'		**Surface Completion (0-1.5' bgs):** *-2 bags ready mix concrete* *-2 bags of Portland quick set cement* *-Well box and locking cap*
						SM			
2	15						silty SAND: wet		
-3	20						SAND: gray to greenish brown, wet, silty		
						SM	as above; rounded gravels, coarse-grained, wet		
-8	25						**Total Depth Drilled- 25 feet** Total Depth Sampled- 5.5 feet Groundwater encountered at ~10 feet.		
-13	30								
-18	35								

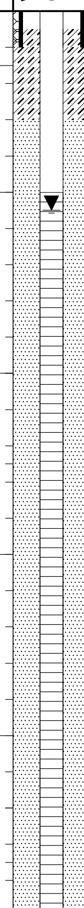


Project: Santa Monica Bay Restoration Project
Project Location: SW of Civic Center Way, Malibu, CA
Project Number: 49.17691.0033

Log of SMBRP-16

Date(s) Drilled	**2/4/03**	Logged By	**AH**	Checked By	**CD**
Drilling Method	**Hollow-Stem Auger**	Drill Bit Size/Type	**8 inches- O.D.**	Total Depth of Borehole	**25.0 feet**
Drill Rig Type	**Track-mounted limited access, D25**	Drilling Contractor	**Gregg Drilling and Testing**	Approximate Surface Elevation	**14.03 feet**
Groundwater Level(s)	**5.5 feet**	Sampling Method	**Standard Penetration Test (SPT)**	Top of Casing Elevation	**14.50 feet**
Well Details	**Monitoring Well Installed; Refer to Right-Hand Column(s) for Details**			Hammer Data	**Automatic; 140 lbs, 30 in. drop**

Surface Elev., feet	Depth, feet	SAMPLES Number	Penetration Resistance, Blows / 6 in.	Unified Soil Classification [Geologic Unit]	MATERIAL DESCRIPTION
14	0	B-1		SM/ML	**FILL (af)- (0-1.5')** sandy SILT/ silty SAND: brown, damp, appears dense, abundant asphalt clasts
		B-2		ML	**ALLUVIUM (Qal)- (1.5'-26.5')** SILT/clayey SILT: black to very dark brown, slightly moist, soft, calcium carbonate blebs observed, low plasticity
		B-3			as above; moist
9	5	B-4		CH	
		SPT-1 pp=1.5	1 2 1		CLAY/ silty CLAY: as above, very moist, soft, medium plasticity
		SPT-2 pp=0	1 1 2		Groundwater at 8' during drilling CLAY: black and strong brown, moist to very moist, soft, high plasticity, massive bedding
4	10	SPT-3 pp=.25	5 1 push	SC/CL	clayey SAND and sandy CLAY: strong brown, moist to wet, very soft, very plastic
				CL-CH	
-1	15	SPT-4 pp=.3	2 2 2		CLAY/silty CLAY: very dark gray, very moist/very wet, medium-plastic
-6	20	SPT-5 pp=.6	1 1 2		as above'; trace gravel and sand
				SP	sandy zone @ ~22'
				CH	CLAY: very dark blue, very moist, medium stiff, very plastic
-11	25	SPT-6 pp=.25	1 2 5		**Total Depth Drilled- 25 feet** Total Depth Sampled- 26.5 feet Groundwater encountered at ~8 feet during drilling, remeasured on 2/4/03 at 11:30 a.m. and static at 5.5 feet.
-16	30				
-21	35				



WELL CONSTRUCTION DETAILS

WELL MATERIALS

Casing Installed:

-5 feet of 2-inch diameter blank PVC casing between 0-5' (bgs)

-20 ft of 2-inch diam., .020 slotted PVC casing between 5-25' (bgs)

Backfill Materials:

-1 bag of bentonite chips placed around casing between 1-3' (bgs)

-5 bags of #3 sand placed around casing between 3-25' (bgs)

Surface Completion (0-1' bgs):

-1.5 bags ready mix concrete
-1.5 bags of Portland quick set cement
-Well box and locking cap

Report: HSA_W_SANTA MONICA BAY; File: 49.17691.0033 SMBRP- REVISED.GPJ; 6/3/04; ID SMBRP-16

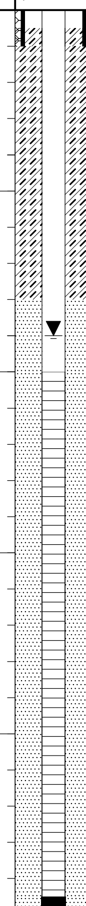
BING YEN & ASSOCIATES, INC.
Geotechnical & Environmental Consultants

Project: Santa Monica Bay Restoration Project **Project Location: 3901 Serra Road, Malibu, CA** **Project Number: 49.17691.0033**	# Log of SMBRP-2 Sheet 1 of 1

Date(s) Drilled	**3/25/03**	Logged By	**JW**	Checked By	**CD**
Drilling Method	**Hollow-Stem Auger**	Drill Bit Size/Type	**8 inches- O.D.**	Total Depth of Borehole	**25.0 feet**
Drill Rig Type	**Track-mounted limited access, D25**	Drilling Contractor	**Gregg Drilling and Testing**	Approximate Surface Elevation	**13.07 feet**
Groundwater Level(s)	**9 feet**	Sampling Method	**Standard Penetration Test (SPT)**	Top of Casing Elevation	**13.13 feet**
Well Details	**Monitoring Well Installed; Refer to Right-Hand Column(s) for Details**			Hammer Data	**Automatic; 140 lbs, 30 in. drop**

Surface Elev., feet	Depth, feet	SAMPLES Type	SAMPLES Number	SAMPLES Penetration Resistance, Blows / 6 in.	Graphic Log	Unified Soil Classification [Geologic Unit]	MATERIAL DESCRIPTION
13	0		B-1 B-2 B-3 B-4 B-5 B-6 B-7			ML	**ALLUVIUM (Qal)- (0-25')** Sandy SILT: dark brown to black, moist, dense, organic rich; color grades lighter, less organics
						SP	Gravelly SAND: dark brown, moist, dense
8	5		SPT-1	6 12 11			
						ML	Groundwater @~9' Clayey SILT: gray, wet, stiff
3	10		SPT-2 pp=1.25	2 5 6			
-2	15		SPT-3 pp=1.25	6 11 10			SILT: gray, wet, stiff, trace clay
-7	20		SPT-4	5 10 11			as above; increasing clay content
							Clayey SILT: dark gray, very stiff
-12	25		SPT-5	6 12 14			**Total Depth Drilled- 25 feet** Total Depth Sampled- 26.5 feet Groundwater encountered at ~9 feet.
-17	30						
-22	35						

Well Completion Diagram



WELL CONSTRUCTION DETAILS

WELL MATERIALS

Casing Installed:

-10 feet of 2-inch diameter blank PVC casing between 0-10' (bgs)

-15 feet of 2-inch diameter .020 slotted PVC casing between 10-25' (bgs)

Backfill Materials:

-3 bags of bentonite chips placed around casing between 1-8' (bgs)

-5 bags of #3 sand placed around casing between 8-25' (bgs)

Surface Completion (0-1' bgs):

-1.5 bags ready mix concrete
-1.5 bags of Portland quick set cement
-Well box and locking cap

BING YEN & ASSOCIATES, INC.
Geotechnical & Environmental Consultants

Project: Santa Monica Bay Restoration Project
Project Location: 3415 Cross Creek Road, Malibu, CA
Project Number: 49.17691.0033

Log of SMBRP-3c

Date(s) Drilled	**2/3/03**	Logged By	**AH**	Checked By	**CD**
Drilling Method	**Hollow-Stem Auger**	Drill Bit Size/Type	**8 inches- O.D.**	Total Depth of Borehole	**30.0 feet**
Drill Rig Type	**Track-mounted limited access, D25**	Drilling Contractor	**Gregg Drilling and Testing**	Approximate Surface Elevation	**36.47 feet**
Groundwater Level(s)	**18 feet**	Sampling Method	**Standard Penetration Test (SPT)**	Top of Casing Elevation	**36.53 feet**
Well Details	**Monitoring Well Installed; Refer to Right-Hand Column(s) for Details**			Hammer Data	**None**

Surface Elev., feet	Depth, feet	SAMPLES Type	SAMPLES Number	Penetration Resistance, Blows / 6 in.	Graphic Log	Unified Soil Classification [Geologic Unit]	MATERIAL DESCRIPTION
36	0		B-1			ML	**ALLUVIUM (Qal)- (0-31.5')** SILT: dark yellowish brown, moist, trace clay
			pp=2.4 B-2				as above; trace SAND
31	5		SPT-1				@3.5' large clast encountered 8" of limey sandstone clast fragments at the bottom of the sampler; SILT: brown, moist, trace gravel
			SPT-2 pp=2.5				as above
							large clast @ 8 to 9.5', sandstone/ limey sandstone, no sample taken
26	10		SPT-3			SP	very gravelly SAND: yellowish brown, slightly moist/ damp, little to some silt
							large clast encountered @ ~13'
21	15		SPT-4				gravelly SAND: dark grayish brown, moist, medium dense to dense, crude bedding observed
							groundwater @ 18'
16	20		SPT-5				as above; dark brown to dark grayish brown, wet
11	25		SPT-6				as above
							large clast encountered @ 26'
							gravelly SAND: dark grayish brown, wet, appears dense, moderately well bedded, 1-inch thick clay layer observed, medium plastic
6	30		SPT-7				**Total Depth Drilled- 30 feet** Total Depth Sampled- 31.5 feet Groundwater encountered at ~18 feet.
1	35						

Well Completion Diagram

WELL CONSTRUCTION DETAILS

WELL MATERIALS

Casing Installed:

-15 feet of 2-inch diameter blank PVC casing between 0-15' (bgs)

-15 feet of 2-inch diameter .020 slotted PVC casing between 15-30' (bgs)

Backfill Materials:

-4 bags of bentonite chips placed around casing between 1-13.5' (bgs)

-3.5 bags of #3 sand placed around casing between 13.5-30' (bgs)

Surface Completion (0-1' bgs):

-2 bags ready mix concrete
-1 bag of Portland quick set cement
-Well box and locking cap

BING YEN & ASSOCIATES, INC.
Geotechnical & Environmental Consultants

Project: Santa Monica Bay Restoration Project
Project Location: 3515 Cross Creek Road, Malibu, CA
Project Number: 49.17691.0033

Log of SMBRP-6

Date(s) Drilled	**1/2/03**	Logged By	**JW**	Checked By	**CD**
Drilling Method	**Hollow-Stem Auger**	Drill Bit Size/Type	**8 inches- O.D.**	Total Depth of Borehole	**25.0 feet**
Drill Rig Type	**MST-D25**	Drilling Contractor	**Gregg Drilling and Testing**	Approximate Surface Elevation	**26.60 feet**
Groundwater Level(s)	**11 feet**	Sampling Method	**Standard Penetration Test (SPT)**	Top of Casing Elevation	**26.88 feet**
Well Details	**Monitoring Well Installed; Refer to Right-Hand Column(s) for Details**			Hammer Data	**Automatic; 140 lbs, 30 in. drop**

Surface Elev., feet	Depth, feet	Samples: Type/Number	Penetration Resistance, Blows / 6 in.	Unified Soil Classification [Geologic Unit]	MATERIAL DESCRIPTION
27	0			SM/ML	**ALLUVIUM (Qal)- (0-25')** sandy SILT and SAND: dark brown, slightly moist, few gravels
				ML	sandy SILT: dark brown, slightly moist, medium dense
22	5	SPT-1 pp=1.0	3 3 4		
17	10	SPT-2 pp=0	29 20 20		groundwater @ 11'
				SP	
12	15	SPT-3	4 4 5		cobble zone @ 15-16' SAND: medium- to coarse-grained, clast fragments in sample, abundant gravels
				SM	
7	20	SPT-4	14 16 14		gravelly silty SAND
					gravel zone @ 22'
					gravelly SAND: light brown
2	25	SPT-5	16 15 22		**Total Depth Drilled- 25 feet** Total Depth Sampled- 26.5 feet Groundwater encountered at ~11 feet.
-3	30				
-8	35				

WELL CONSTRUCTION DETAILS

WELL MATERIALS

Casing Installed:

-10 feet of 2-inch diameter blank PVC casing between 0-10' (bgs)

-15 feet of 2-inch diameter .020 slotted PVC casing between 10-25' (bgs)

Backfill Materials:

-3 bags of bentonite chips placed around casing between 1-8.5' (bgs)

-6 bags of #3 sand placed around casing between 8.5-25' (bgs)

Surface Completion (0-1' bgs):

-1.5 bags ready mix concrete
-1.5 bags of Portland quick set cement
-Well box and locking cap

Project: Santa Monica Bay Restoration Project
Project Location: 23519 Civic Center Way, Malibu, CA
Project Number: 49.17691.0033

Log of SMBRP-7b

Date(s) Drilled	12/27/02	Logged By	JW	Checked By	CD
Drilling Method	Hollow-Stem Auger	Drill Bit Size/Type	8 inches- O.D.	Total Depth of Borehole	45.0 feet
Drill Rig Type	CME-95	Drilling Contractor	Gregg Drilling and Testing	Approximate Surface Elevation	18.71 feet
Groundwater Level(s)	13 feet	Sampling Method	Standard Penetration Test (SPT)	Top of Casing Elevation	18.99 feet
Well Details	Monitoring Well Installed; Refer to Right-Hand Column(s) for Details			Hammer Data	Automatic; 140 lbs, 30 in. drop

Surface Elev., feet	Depth, feet	SAMPLES: Type	SAMPLES: Number	Penetration Resistance, Blows / 6 in.	Graphic Log	Unified Soil Classification [Geologic Unit]	MATERIAL DESCRIPTION	Well Completion Diagram
19	0					ML	**ASPHALT (0-0.1')** **ALLUVIUM (Qal)- (0.1-46.5')** sandy SILT: dark brown, slightly moist	
14	5	SPT	SPT-1 pp= 2.2-2.5	5 6 10			as above	
9	10	SPT	SPT-2 pp= 1.8-2.0	6 8 8			increased clay content	
							groundwater @ 13'	
4	15	SPT	SPT-3 pp= 1.5-1.7	4 5 7				
-1	20	SPT	SPT-4 pp= 1.5-1.8	4 4 6			sandy SILT: moist, very fine-grained, uniform consistency, trace clay	
						SM-ML		
-6	25	SPT	SPT-5	4 5 7			interbedded silty SAND	
						ML		
-11	30	SPT	SPT-6 pp= 1.8-2.25	5 11 12			sandy SILT: gray green, very moist, trace clay	
-16	35							

WELL CONSTRUCTION DETAILS

WELL MATERIALS

Casing Installed:

-15 feet of 2-inch diameter blank PVC casing between 0-15' (bgs)

-15 feet of 2-inch diameter .020 slotted PVC casing between 15-30' (bgs)

Backfill Materials:

-3 bags of bentonite chips placed around casing between 1-8' (bgs)

-7 bags of #3 sand placed around casing between 8-25' (bgs)

**Note: Bentonite chips were placed in boring between 25-45' prior to well casing installation*

Surface Completion (0-1' bgs):

-2 bags ready mix concrete
-1 bag of Portland quick set cement
-Well box and locking cap

Project: Santa Monica Bay Restoration Project	Log of SMBRP-7b
Project Location: 23519 Civic Center Way, Malibu, CA	Sheet 2 of 2
Project Number: 49.17691.0033	

Surface Elev., feet	Depth, feet	SAMPLES Type	SAMPLES Number	Penetration Resistance, Blows / 6 in.	Graphic Log	Unified Soil Classification [Geologic Unit]	MATERIAL DESCRIPTION	Well Completion Diagram	WELL CONSTRUCTION DETAILS
-16	35		SPT-7 pp=1.75	11 15 17			sandy SILT: gray green, very moist, stiff, trace clay		
-21	40		SPT-8 pp= 1.9-2.1	11 18 23			sandy SILT: gray green, trace clay		
							as above		
-26	45		SPT-9 pp=1.8	14 22 29			**Total Depth Drilled- 45 feet** Total Depth Sampled- 46.5 feet Groundwater encountered at ~13 feet.		
-31	50								
-36	55								
-41	60								
-46	65								
-51	70								
-56	75								

Project: Santa Monica Bay Restoration Project **Project Location:** North of 23555 Civic Center Way, Malibu, CA **Project Number:** 49.17691.0033	# Log of SMBRP-8 Sheet 1 of 2

Date(s) Drilled	**12/26/02**	Logged By	**JW**	Checked By	**CD**
Drilling Method	**Hollow-Stem Auger**	Drill Bit Size/Type	**8 inches- O.D.**	Total Depth of Borehole	**40.0 feet**
Drill Rig Type	**MST-D25**	Drilling Contractor	**Gregg Drilling and Testing**	Approximate Surface Elevation	**48.75 feet**
Groundwater Level(s)	**37.5 feet**	Sampling Method	**Standard Penetration Test (SPT)**	Top of Casing Elevation	**48.69 feet**
Well Details	**Monitoring Well Installed; Refer to Right-Hand Column(s) for Details**			Hammer Data	**Automatic; 140 lbs, 30 in. drop**

Surface Elev., feet	Depth, feet	SAMPLES Type	SAMPLES Number	Penetration Resistance, Blows / 6 in.	Graphic Log	Unified Soil Classification [Geologic Unit]	MATERIAL DESCRIPTION	Well Completion Diagram
49	0					ML	**FILL (af)- (0-11')** sandy SILT: light to medium brown, slightly moist to moist Debris laden fill (0-5') Clean fill (5-11')	
44	5		SPT-1 pp=2.65	2 4 5				
			SPT-2	3 5 7				
39	10		SPT-3 pp=1.5	8 18 20		ML	**ALLUVIUM (Qal)- (11-40')** sandy SILT: medium to dark red brown, trace clay and sub angular gravel, hard	
34	15		SPT-4	7 11 10			as above, very stiff	
29	20		SPT-5 pp= 2.2-2.4	8 11 14			as above, very stiff	
24	25		SPT-6 pp= 1.5-1.6	6 7 7			clayey SILT: moist to very moist, increased CLAY content, stiff	
19	30		SPT-7 pp= 1.2-1.5	3 4 4			clayey SILT: yellow brown, increased CLAY content	
14	35							

WELL CONSTRUCTION DETAILS

WELL MATERIALS

Casing Installed:

-25 ft of 2-in diameter blank PVC casing bet. 0-25' (bgs)

-15 feet of 2-inch diameter .020 slotted PVC casing between 25-40' (bgs)

Backfill Materials:

-9 bags of bentonite chips placed around casing between 1-23' (bgs)

-6 bags of #3 sand placed around casing between 23-40' (bgs)

Surface Completion (0-1' bgs):

-2 bags ready mix concrete
-1 bag of Portland quick set cement
-Well box and locking cap

Project: Santa Monica Bay Restoration Project
Project Location: North of 23555 Civic Center Way, Malibu, CA
Project Number: 49.17691.0033

Log of SMBRP-8

Surface Elev., feet	Depth, feet	SAMPLES Type	SAMPLES Number	Penetration Resistance, Blows / 6 in.	Graphic Log	Unified Soil Classification [Geologic Unit]	MATERIAL DESCRIPTION	Well Completion Diagram	WELL CONSTRUCTION DETAILS
14	35		SPT-8 pp= 2.0-3.0	4 4 5			groundwater @ 37.5'		
9	40		SPT-9 pp > 4.5	13 12 35			**Total Depth Drilled- 40 feet** Total Depth Sampled- 41.5 feet Groundwater encountered at 37.5 feet.		
4	45								
-1	50								
-6	55								
-11	60								
-16	65								
-21	70								
-26	75								

Project: Santa Monica Bay Restoration Project **Project Location: 23805 Stuart Ranch Road, Malibu, CA** **Project Number: 49.17691.0033**	**Log of SMBRP-9** Sheet 1 of 2

Date(s) Drilled	**12/27/02**	Logged By	**JW**	Checked By	**CD**
Drilling Method	**Hollow-Stem Auger**	Drill Bit Size/Type	**8 inches- O.D.**	Total Depth of Borehole	**45.0 feet**
Drill Rig Type	**CME-95**	Drilling Contractor	**Gregg Drilling and Testing**	Approximate Surface Elevation	**50.10 feet**
Groundwater Level(s)	**41.5 feet**	Sampling Method	**Standard Penetration Test (SPT)**	Top of Casing Elevation	**50.32 feet**
Well Details	**Monitoring Well Installed; Refer to Right-Hand Column(s) for Details**			Hammer Data	**Automatic; 140 lbs, 30 in. drop**

Surface Elev., feet	Depth, feet	SAMPLES Type	SAMPLES Number	Penetration Resistance, Blows / 6 in.	Graphic Log	Unified Soil Classification [Geologic Unit]	MATERIAL DESCRIPTION	Well Completion Diagram
50	0					ML	**ASPHALT (2")** **FILL (af)- (0-10')**	
45	5	SPT	SPT-1 pp= 1.5-2.5	3 4 6			sandy SILT: dark brown, dry to slightly moist, fine-grained, trace clay and subangular gravel, stiff	
40	10	SPT	SPT-2 pp= 1.25-1.5	4 4 7		ML	**ALLUVIUM (Qal)- (10-45')** sandy SILT: light red brown, slightly moist to moist, very fine-grained, trace clay, stiff	
35	15	SPT	SPT-3 pp=1.5	11 22 27			@ 15' same as described above	
30	20	SPT	SPT-4 pp= 1.5-1.7	11 25 33			@ 20' same as described above	
25	25	SPT	SPT-5 pp= 1.5-1.8	13 16 21			increased sand content, dry to slightly moist, dense	
20	30	SPT	SPT-6 pp= 1.5-1.8	7 8 8			sandy SILT: trace gravel, uniform	
						SW		
15	35							

WELL CONSTRUCTION DETAILS

WELL MATERIALS

Casing Installed:

-30 feet of 2-inch diameter blank PVC casing between 0-30' (bgs)

-15 feet of 2-inch diameter .020 slotted PVC casing between 30-45' (bgs)

Backfill Materials:

-9 bags of bentonite chips placed around casing between 1-28' (bgs)

-6 bags of #3 sand placed around casing between 28-45' (bgs)

Surface Completion (0-1' bgs):

-2 bags ready mix concrete
-1 bag of Portland quick set cement
-Well box and locking cap

Surface Elev., feet	Depth, feet	SAMPLES Type	Number	Penetration Resistance, Blows / 6 in.	Graphic Log	Unified Soil Classification [Geologic Unit]	MATERIAL DESCRIPTION	Well Completion Diagram	WELL CONSTRUCTION DETAILS
15	35		SPT-7	7 13 14			SAND: coarse-grained, moist, dense		
						ML			
10	40		SPT-8 pp= 1.8-2.2	10 14 19			sandy SILT: wet, medium- to coarse- grained	▼	
							@ 45' same as described above		
5	45		SPT-9 pp= 2.0-2.5	14 20 23			**Total Depth Drilled- 45 feet** Total Depth Sampled- 46.5 feet Groundwater encountered at ~41.5 feet.		
0	50								
-5	55								
-10	60								
-15	65								
-20	70								
-25	75								

APPENDIX 2: HYDRAULIC CONDUCTIVITY TESTING RESULTS

Appendix 2 Summary
Saturated Zone Hydraulic Conductivity Estimates - Malibu, CA

Monitoring	**Hydraulic Conductivity**			
Well	**(ft/s)**	**(ft/min)**	**(ft/day)**	**(m/s)**
SMBRP-1*	1.2E-04	7.1E-03	10.3	3.6E-05
SMBRP-2	2.7E-06	1.6E-04	0.231	8.1E-07
SMBRP-3c	3.2E-05	1.9E-03	2.80	9.9E-06
SMBRP-6	6.7E-05	4.0E-03	5.76	2.0E-05
SMBRP-7b*	3.6E-05	2.2E-03	3.11	1.1E-05
SMBRP-8	2.1E-06	1.3E-04	0.181	6.4E-07
SMBRP-9	2.5E-05	1.5E-03	2.17	7.7E-06
SMBRP-10c	9.2E-07	5.5E-05	0.0797	2.8E-07
SMBRP-11	6.7E-05	4.0E-03	5.82	2.1E-05
SMBRP-12	6.9E-05	4.1E-03	5.97	2.1E-05
SMBRP-13*	1.4E-03	8.5E-02	123	4.3E-04
SMBRP-14	1.1E-04	6.5E-03	9.40	3.3E-05
SMBRP-15b	9.0E-05	5.4E-03	7.80	2.8E-05
SMBRP-16	6.7E-06	4.0E-04	0.575	2.0E-06

Source: SEI field notes, 2003

STONE ENVIRONMENTAL, INC.

Note: * = average of two tests, ft/s = feet per second, ft/min = feet per minute, ft/day = feet per day,
m/s = meters per second

Path: O:\Proj-01\1269-W-MalibuCA\Sampling_Slug Tests\HydraulicConductivitySummary.xls

5/19/03 ANM

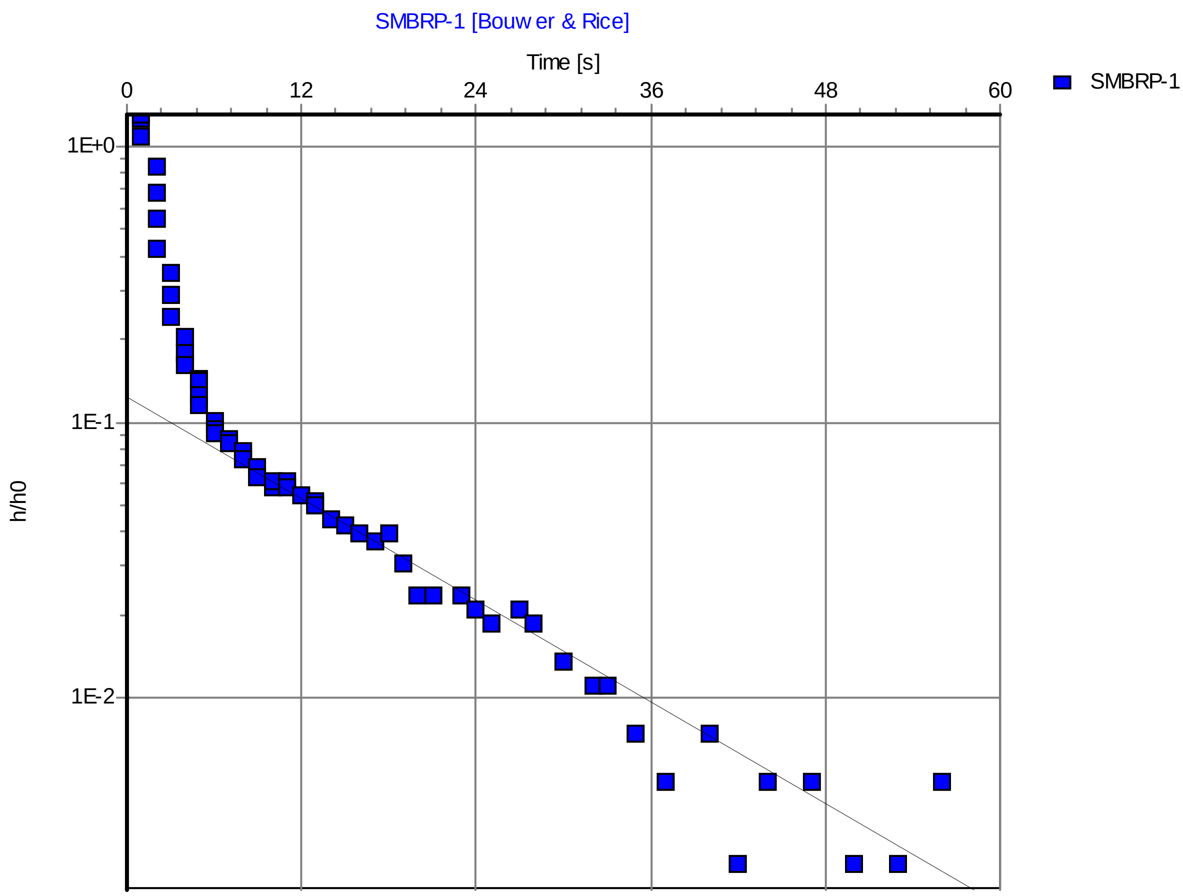
Stone Environmental, Inc.
535 Stone Cutters Way
Montpelier, VT 05602
Phone: +1 802 229 4541

Slug Test Analysis Report

Project: Malibu_CA

Number: 011269-W

Client: City of Malibu, CA



Slug Test: **SMBRP-1**

Analysis Method: **Bouwer & Rice**

Analysis Results: Conductivity: 3.34E+0 [ft/d]

Test parameters:

Test Well:	SMBRP-1	Aquifer Thickness:	50 [ft]
Casing radius:	0.083 [ft]	Gravel Pack Porosity (%)	25
Screen length:	15 [ft]		
Boring radius:	0.33 [ft]		
r(eff):	0.180 [ft]		

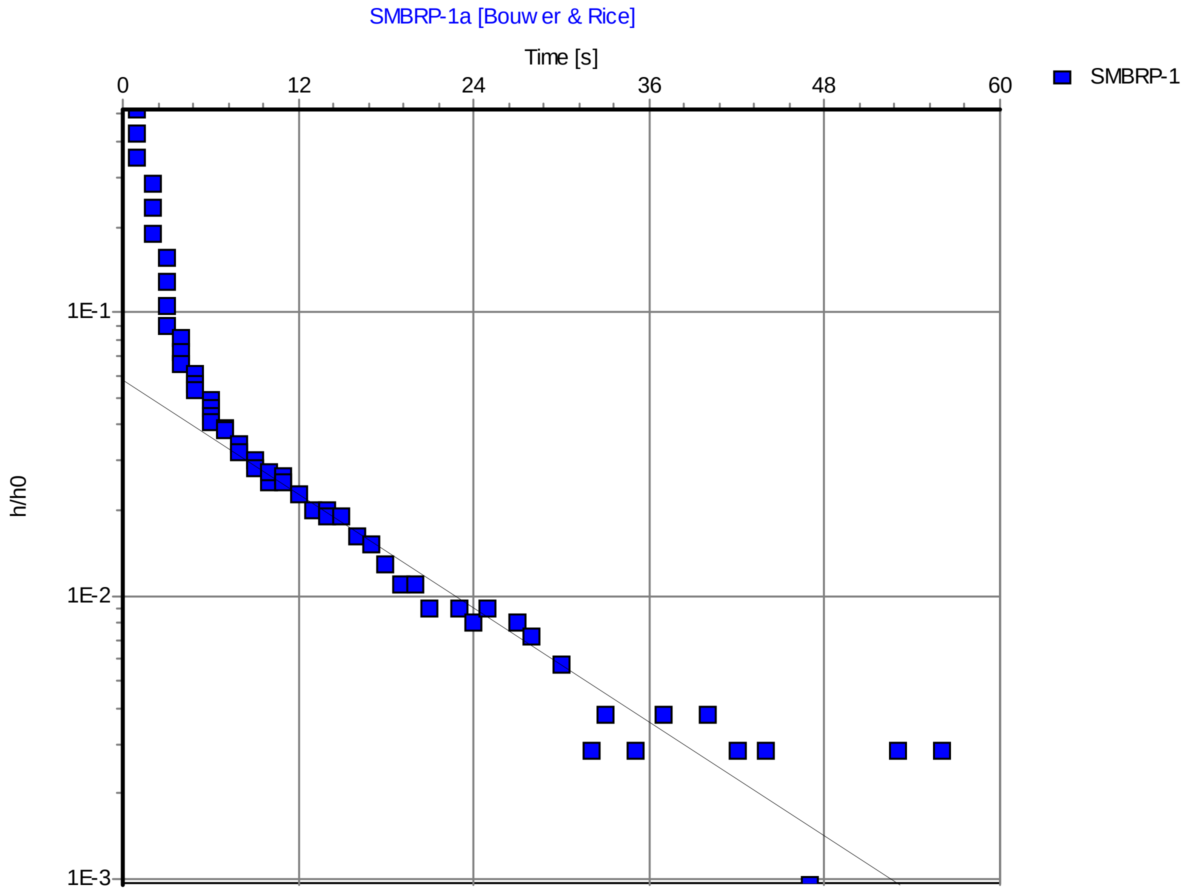
Comments:

Evaluated by: Amy Macrellis

Evaluation Date: 5/12/2003

Stone Environmental, Inc.
535 Stone Cutters Way
Montpelier, VT 05602
Phone: +1 802 229 4541

Slug Test Analysis Report	
Project:	Malibu_CA
Number:	011269-W
Client:	City of Malibu, CA



Slug Test: **SMBRP-1a**

Analysis Method: **Bouwer & Rice**

Analysis Results: Conductivity: 1.72E+1 [ft/d]

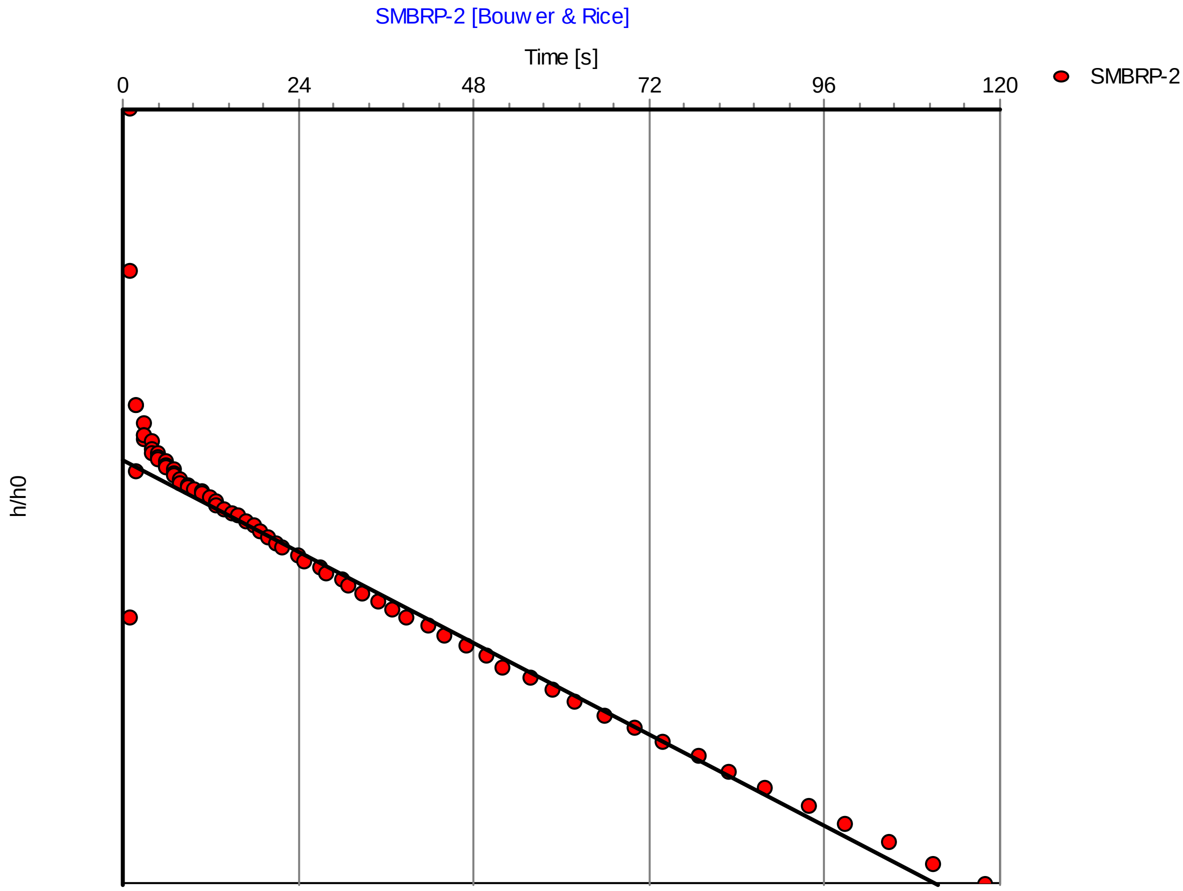
Test parameters:				
	Test Well:	SMBRP-1	Aquifer Thickness:	50 [ft]
	Casing radius:	0.083 [ft]	Gravel Pack Porosity (%)	25
	Screen length:	15 [ft]		
	Boring radius:	0.33 [ft]		
	r(eff):	0.180 [ft]		

Comments:

Evaluated by: Amy Macrellis

Evaluation Date: 5/12/2003

Stone Environmental, Inc. 535 Stone Cutters Way Montpelier, VT 05602 Phone: +1 802 229 4541	**Slug Test Analysis Report** Project: Malibu_CA Number: 011269-W Client: City of Malibu, CA



Slug Test: **SMBRP-2**

Analysis Method: **Bouwer & Rice**

Analysis Results: Conductivity: 2.31E-1 [ft/d]

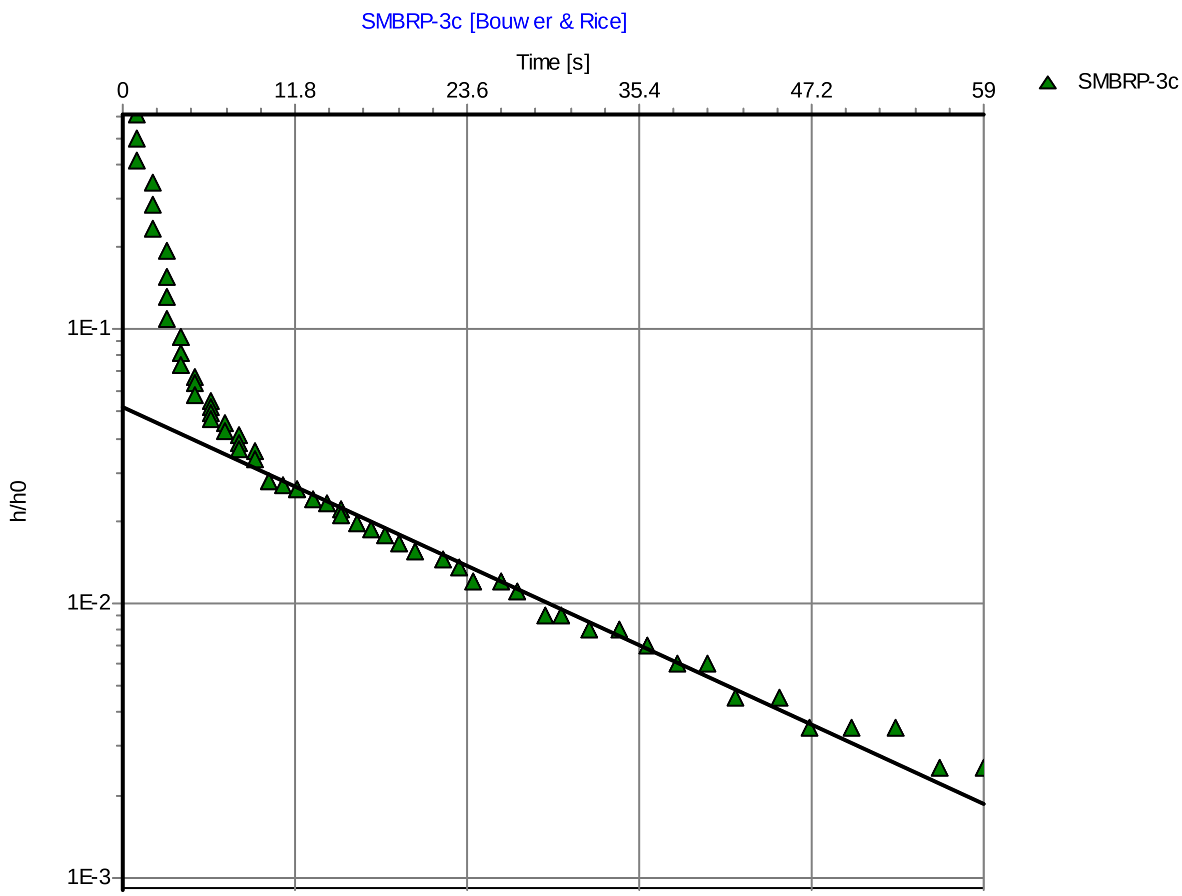
Test parameters:				
	Test Well:	SMBRP-2	Aquifer Thickness:	50 [ft]
	Casing radius:	0.083 [ft]	Gravel Pack Porosity (%)	25
	Screen length:	15 [ft]		
	Boring radius:	0.33 [ft]		
	r(eff):	0.180 [ft]		

Comments:

Evaluated by: Amy Macrellis

Evaluation Date: 5/12/2003

Stone Environmental, Inc.	**Slug Test Analysis Report**	
535 Stone Cutters Way	Project:	Malibu_CA
Montpelier, VT 05602	Number:	011269-W
Phone: +1 802 229 4541	Client:	City of Malibu, CA



Slug Test: **SMBRP-3c**

Analysis Method: **Bouwer & Rice**

Analysis Results: Conductivity: 2.80E+0 [ft/d]

Test parameters:			
Test Well:	SMBRP-3c	Aquifer Thickness:	50 [ft]
Casing radius:	0.083 [ft]	Gravel Pack Porosity (%)	25
Screen length:	15 [ft]		
Boring radius:	0.33 [ft]		
r(eff):	0.180 [ft]		

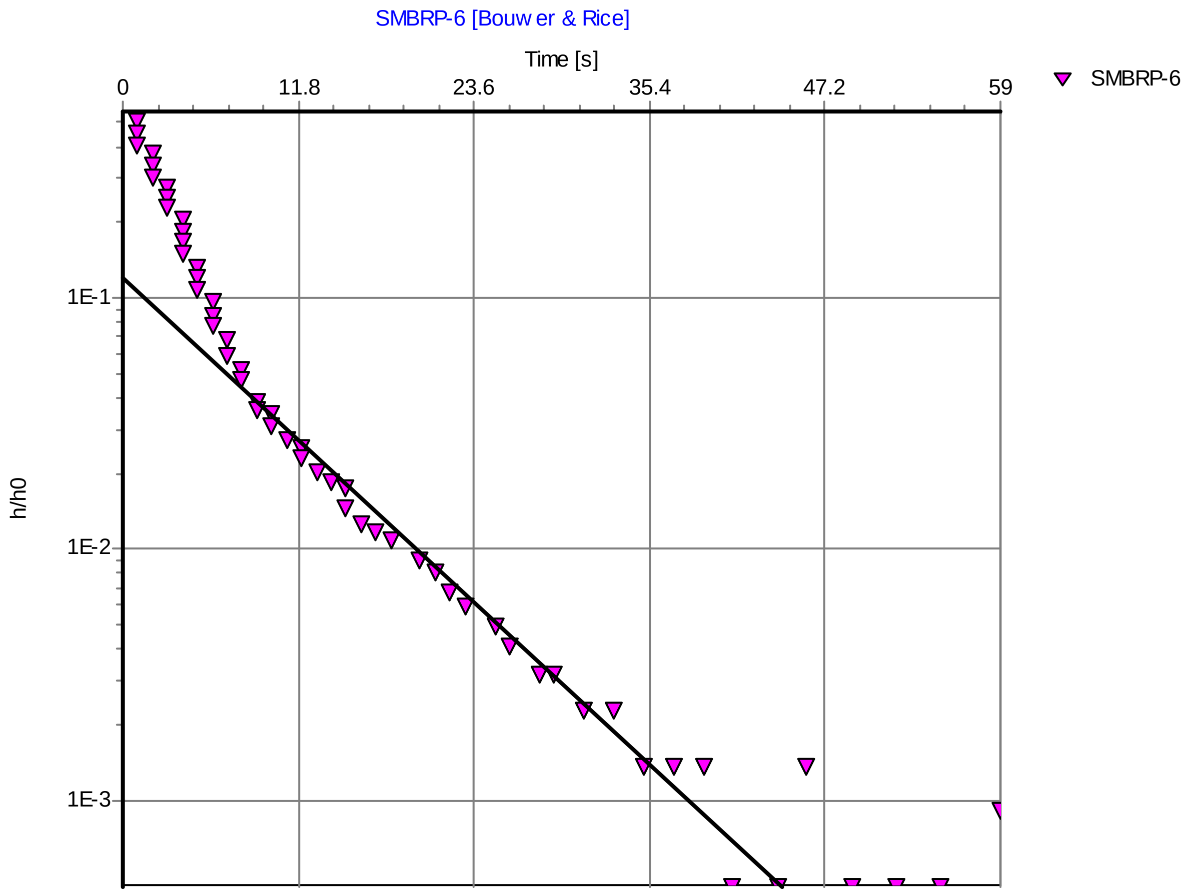
Comments:

Evaluated by: Amy Macrellis

Evaluation Date: 5/12/2003

Stone Environmental, Inc.
535 Stone Cutters Way
Montpelier, VT 05602
Phone: +1 802 229 4541

Slug Test Analysis Report	
Project:	Malibu_CA
Number:	011269-W
Client:	City of Malibu, CA



Slug Test: **SMBRP-6**

Analysis Method: **Bouwer & Rice**

Analysis Results:

Conductivity: 5.76E+0 [ft/d]

Test parameters:

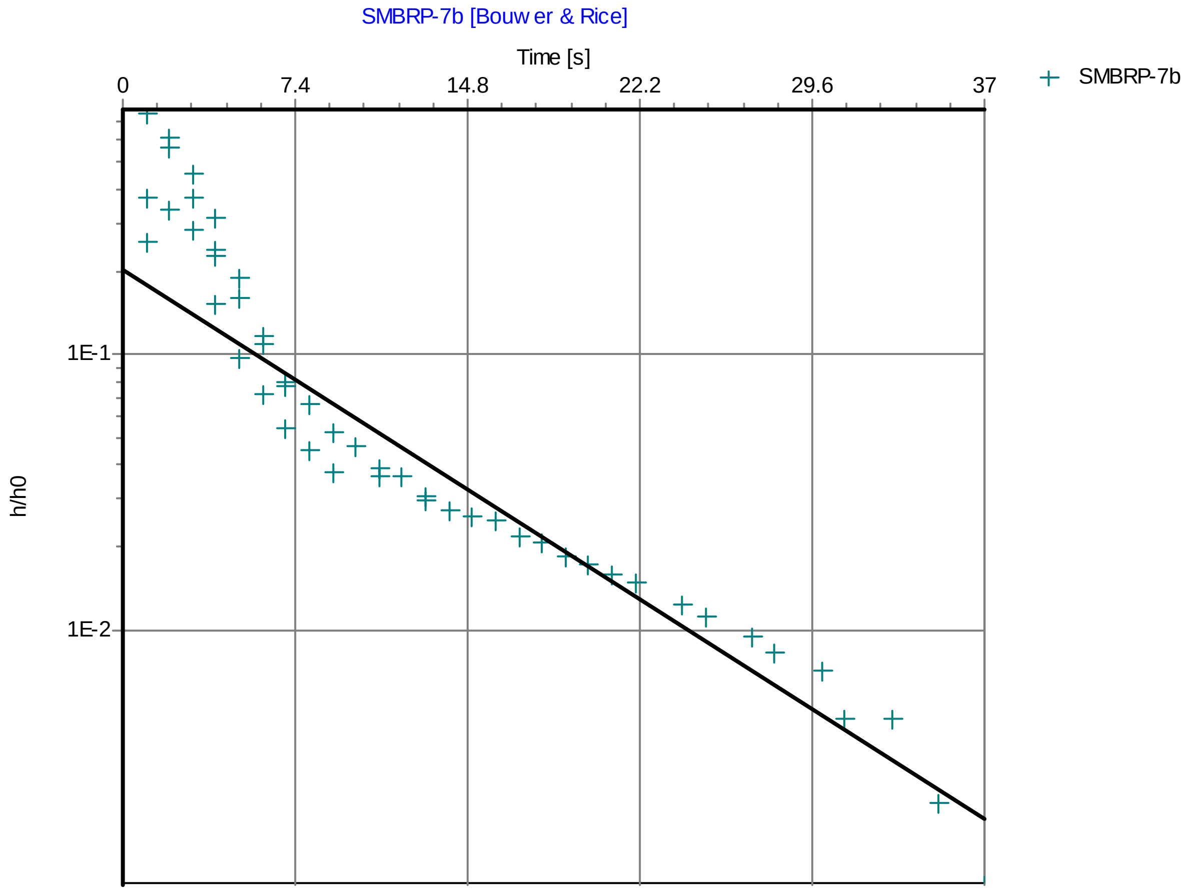
Test Well:	SMBRP-6	Aquifer Thickness:	100 [ft]
Casing radius:	0.083 [ft]	Gravel Pack Porosity (%)	25
Screen length:	15 [ft]		
Boring radius:	0.33 [ft]		
r(eff):	0.180 [ft]		

Comments:

Evaluated by: Amy Macrellis

Evaluation Date: 5/12/2003

Stone Environmental, Inc.	Slug Test Analysis Report
535 Stone Cutters Way	Project: Malibu_CA
Montpelier, VT 05602	Number: 011269-W
Phone: +1 802 229 4541	Client: City of Malibu, CA



Slug Test: **SMBRP-7b**

Analysis Method: **Bouwer & Rice**

Analysis Results: Conductivity: 5.86E+0 [ft/d]

Test parameters:				
	Test Well:	SMBRP-7b	Aquifer Thickness:	200 [ft]
	Casing radius:	0.083 [ft]	Gravel Pack Porosity (%)	25
	Screen length:	15 [ft]		
	Boring radius:	0.33 [ft]		
	r(eff):	0.180 [ft]		

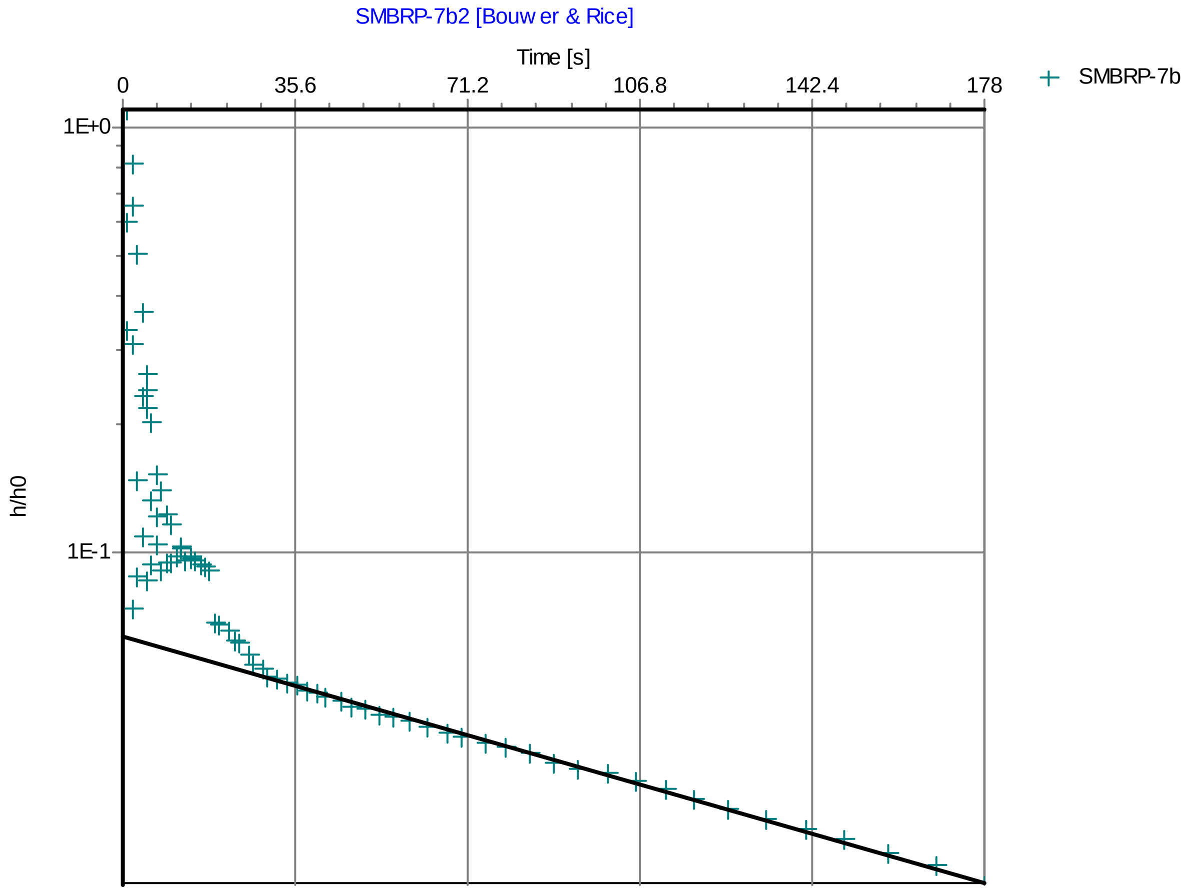
Comments:

Evaluated by: Amy Macrellis

Evaluation Date: 5/12/2003

Stone Environmental, Inc.
535 Stone Cutters Way
Montpelier, VT 05602
Phone: +1 802 229 4541

Slug Test Analysis Report	
Project:	Malibu_CA
Number:	011269-W
Client:	City of Malibu, CA



Slug Test: **SMBRP-7b2**

Analysis Method: **Bouwer & Rice**

Analysis Results:

Conductivity: 3.55E-1 [ft/d]

Test parameters:

Test Well:	SMBRP-7b	Aquifer Thickness:	200 [ft]
Casing radius:	0.083 [ft]	Gravel Pack Porosity (%)	25
Screen length:	15 [ft]		
Boring radius:	0.33 [ft]		
r(eff):	0.180 [ft]		

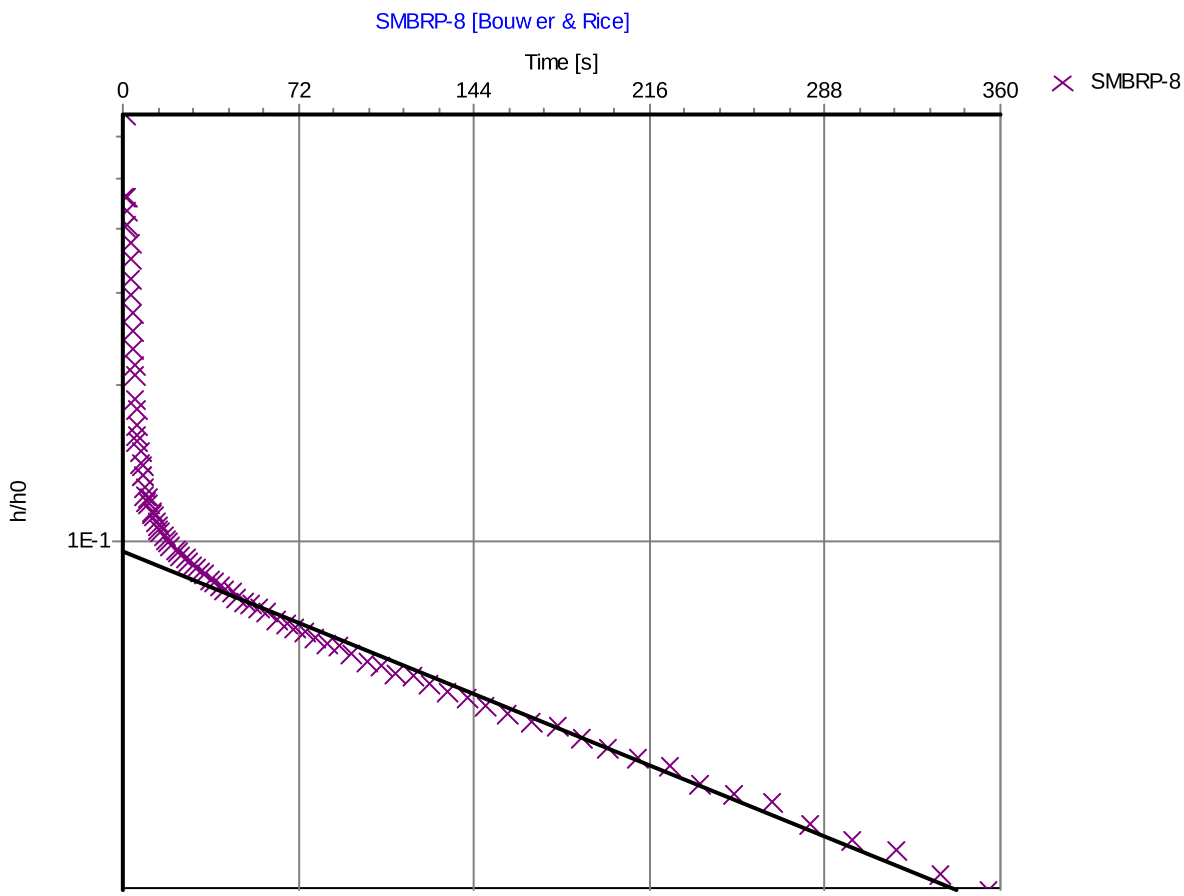
Comments:

Evaluated by: Amy Macrellis

Evaluation Date: 5/8/2003

Stone Environmental, Inc.
535 Stone Cutters Way
Montpelier, VT 05602
Phone: +1 802 229 4541

Slug Test Analysis Report	
Project:	Malibu_CA
Number:	011269-W
Client:	City of Malibu, CA



Slug Test: **SMBRP-8**

Analysis Method: **Bouwer & Rice**

Analysis Results: Conductivity: 1.81E-1 [ft/d]

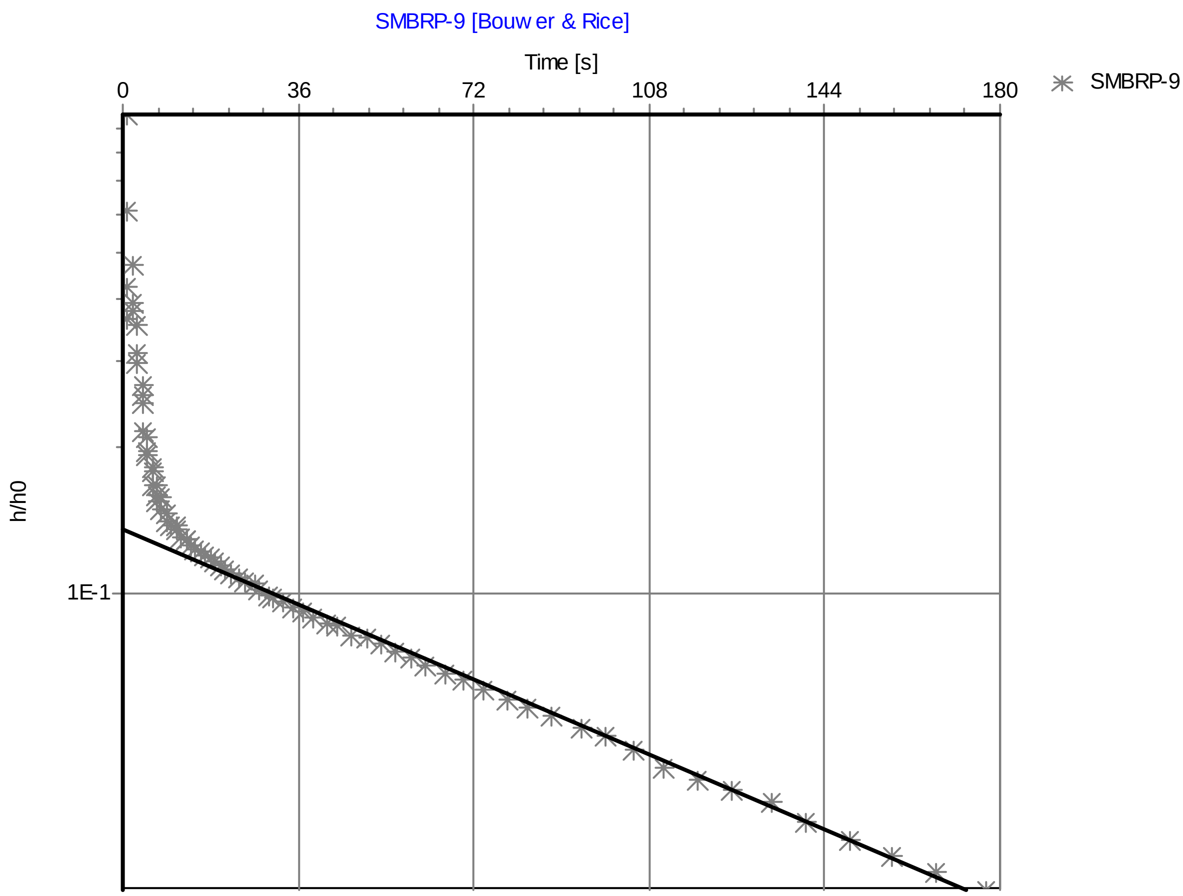
Test parameters:				
Test Well:	SMBRP-8	Aquifer Thickness:	50 [ft]
Casing radius:	0.083 [ft]	Gravel Pack Porosity (%)	25
Screen length:	15 [ft]		
Boring radius:	0.33 [ft]		
r(eff):	0.180 [ft]		

Comments:

Evaluated by: Amy Macrellis

Evaluation Date: 5/12/2003

Stone Environmental, Inc.	**Slug Test Analysis Report**
535 Stone Cutters Way	Project: Malibu_CA
Montpelier, VT 05602	Number: 011269-W
Phone: +1 802 229 4541	Client: City of Malibu, CA



Slug Test: **SMBRP-9**

Analysis Method: **Bouwer & Rice**

Analysis Results: Conductivity: 2.17E+0 [ft/d]

Test parameters:				
	Test Well:	SMBRP-9	Aquifer Thickness:	80 [ft]
	Casing radius:	0.083 [ft]	Gravel Pack Porosity (%)	25
	Screen length:	15 [ft]		
	Boring radius:	0.33 [ft]		
	r(eff):	0.180 [ft]		

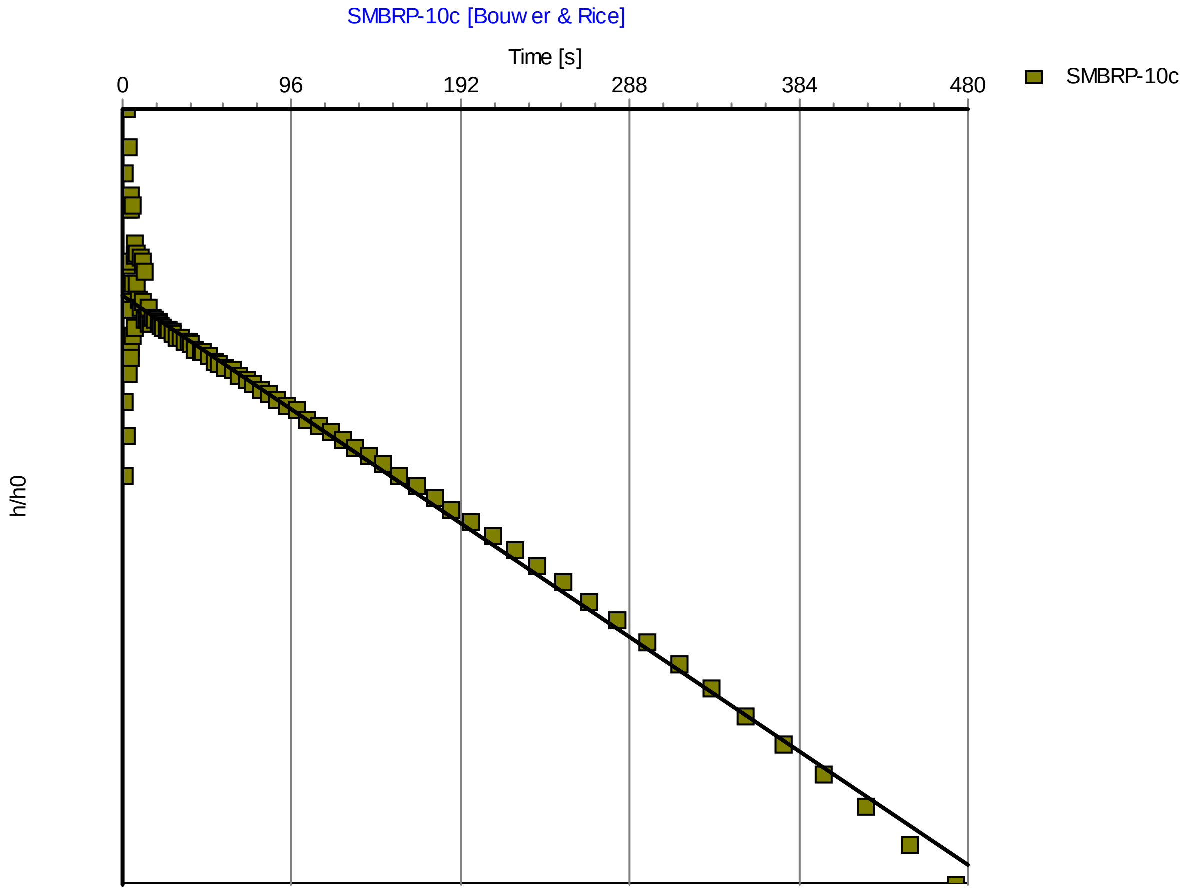
Comments:

Evaluated by: Amy Macrellis

Evaluation Date: 5/12/2003

Stone Environmental, Inc.
535 Stone Cutters Way
Montpelier, VT 05602
Phone: +1 802 229 4541

Slug Test Analysis Report	
Project:	Malibu_CA
Number:	011269-W
Client:	City of Malibu, CA



Slug Test: **SMBRP-10c**

Analysis Method: **Bouwer & Rice**

Analysis Results:

Conductivity:	7.97E-2 [ft/d]

Test parameters:

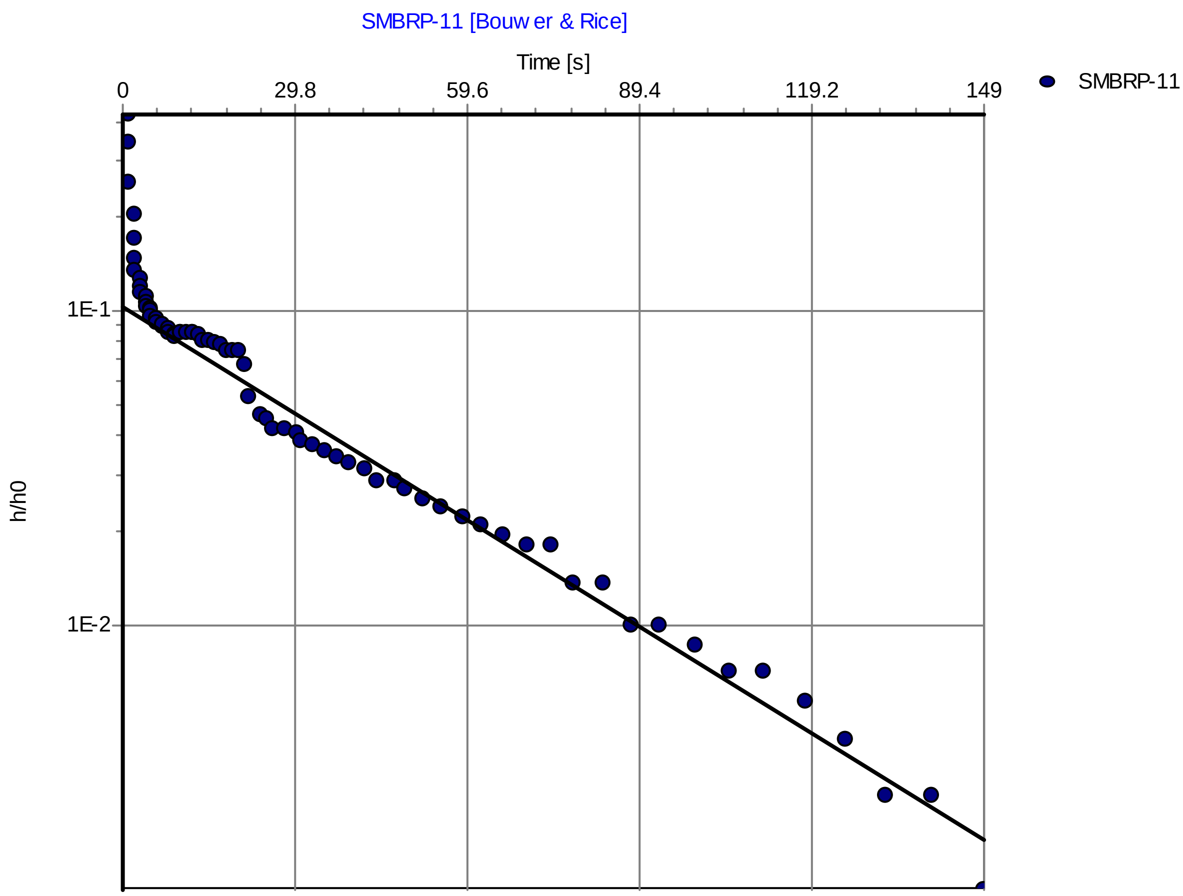
Test Well:	SMBRP-10c	Aquifer Thickness:	200 [ft]
Casing radius:	0.083 [ft]	Gravel Pack Porosity (%)	25
Screen length:	15 [ft]		
Boring radius:	0.33 [ft]		
r(eff):	0.180 [ft]		

Comments:

Evaluated by: Amy Macrellis

Evaluation Date: 5/12/2003

Stone Environmental, Inc.	Slug Test Analysis Report	
535 Stone Cutters Way	Project:	Malibu_CA
Montpelier, VT 05602	Number:	011269-W
Phone: +1 802 229 4541	Client:	City of Malibu, CA



Slug Test: **SMBRP-11**

Analysis Method: **Bouwer & Rice**

Analysis Results:			Conductivity:	5.82E+0 [ft/d]
Test parameters:	Test Well:	SMBRP-11	Aquifer Thickness:	100 [ft]
	Casing radius:	0.083 [ft]	Gravel Pack Porosity (%)	25
	Screen length:	15 [ft]		
	Boring radius:	0.33 [ft]		
	r(eff):	0.180 [ft]		

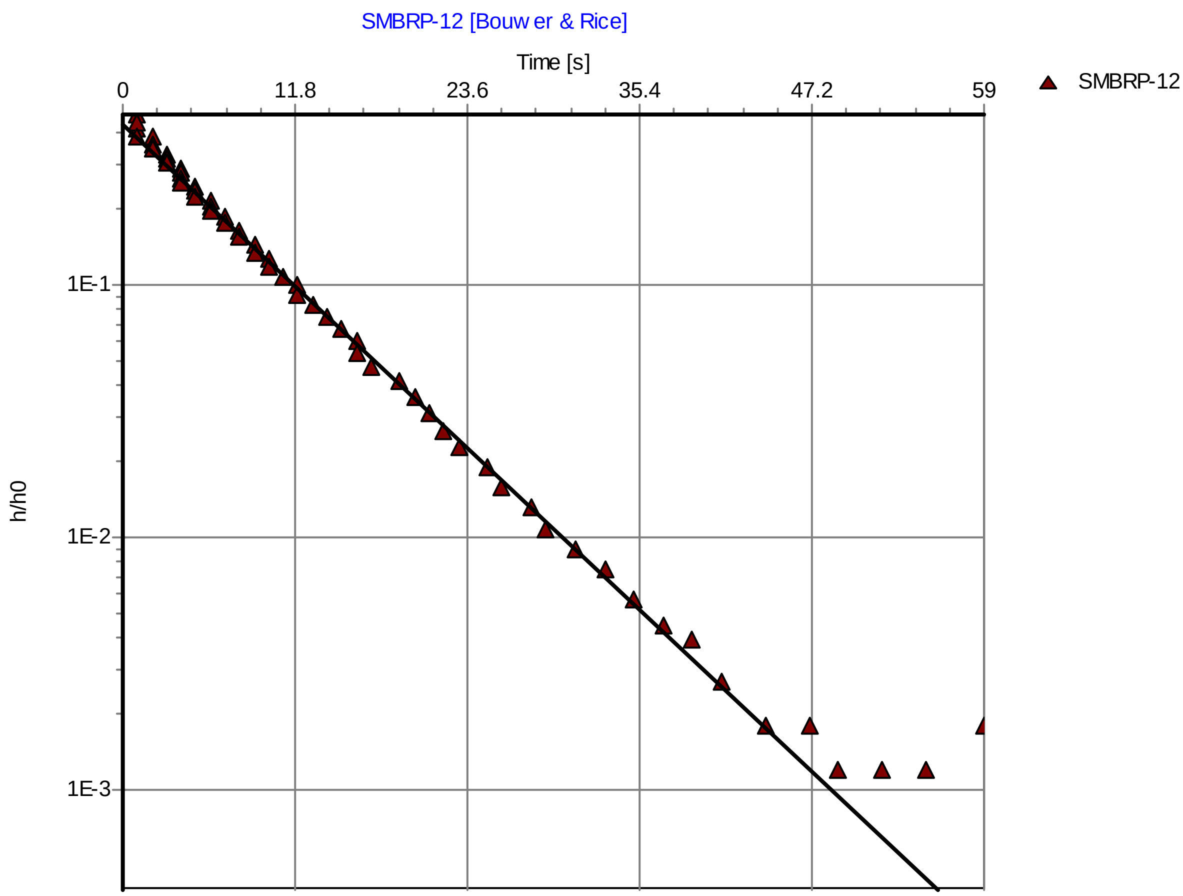
Comments:

Evaluated by: Amy Macrellis

Evaluation Date: 5/12/2003

Stone Environmental, Inc.
535 Stone Cutters Way
Montpelier, VT 05602
Phone: +1 802 229 4541

Slug Test Analysis Report	
Project:	Malibu_CA
Number:	011269-W
Client:	City of Malibu, CA



Slug Test:	**SMBRP-12**
Analysis Method:	**Bouwer & Rice**

Analysis Results:		Conductivity:	5.97E+0 [ft/d]

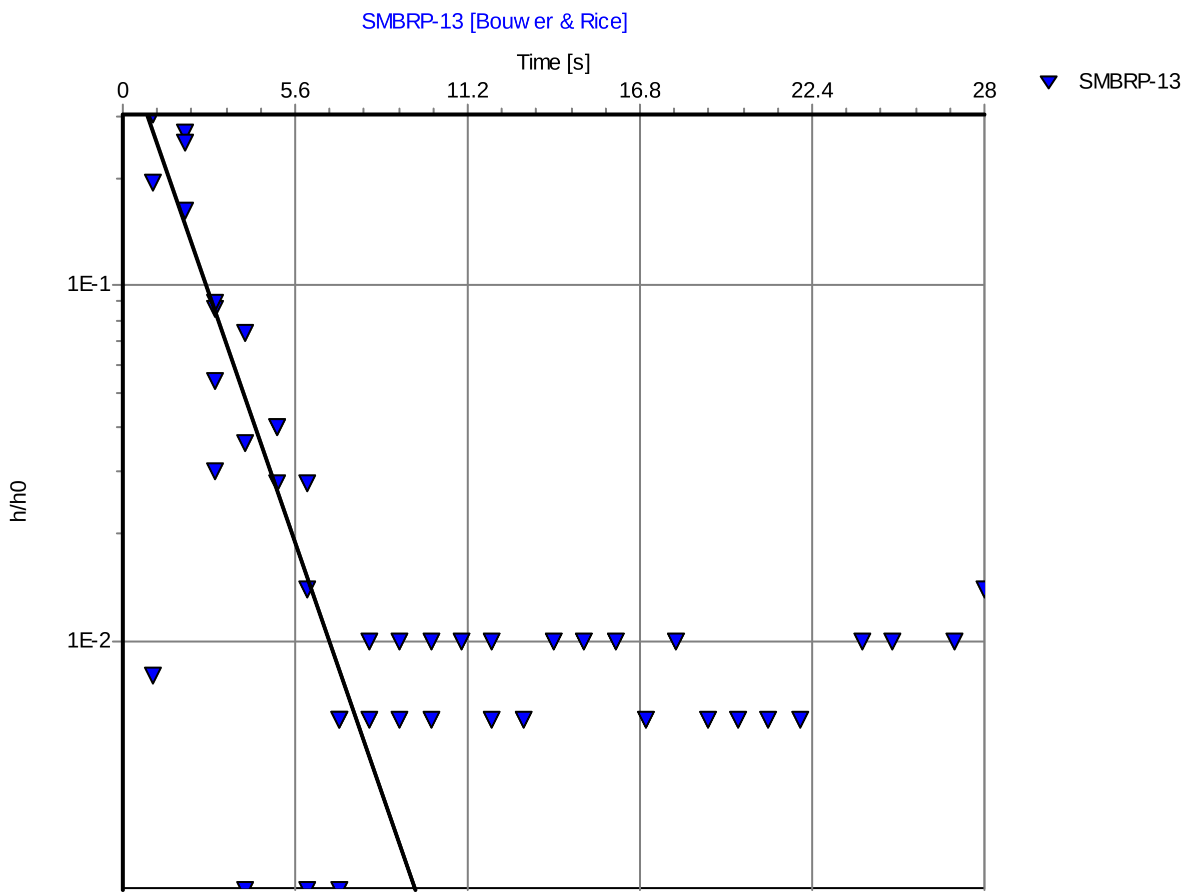
Test parameters:	Test Well:	SMBRP-12	Aquifer Thickness:	100 [ft]
	Casing radius:	0.083 [ft]	Gravel Pack Porosity (%)	25
	Screen length:	15 [ft]		
	Boring radius:	0.33 [ft]		
	r(eff):	0.180 [ft]		

Comments:

Evaluated by:	Amy Macrellis
Evaluation Date:	5/12/2003

Stone Environmental, Inc.
535 Stone Cutters Way
Montpelier, VT 05602
Phone: +1 802 229 4541

Slug Test Analysis Report	
Project:	Malibu_CA
Number:	011269-W
Client:	City of Malibu, CA



Slug Test: **SMBRP-13**

Analysis Method: **Bouwer & Rice**

Analysis Results:

Conductivity: 1.29E+2 [ft/d]

Test parameters:				
	Test Well:	SMBRP-13	Aquifer Thickness:	100 [ft]
	Casing radius:	0.083 [ft]	Gravel Pack Porosity (%)	25
	Screen length:	15 [ft]		
	Boring radius:	0.33 [ft]		
	r(eff):	0.180 [ft]		

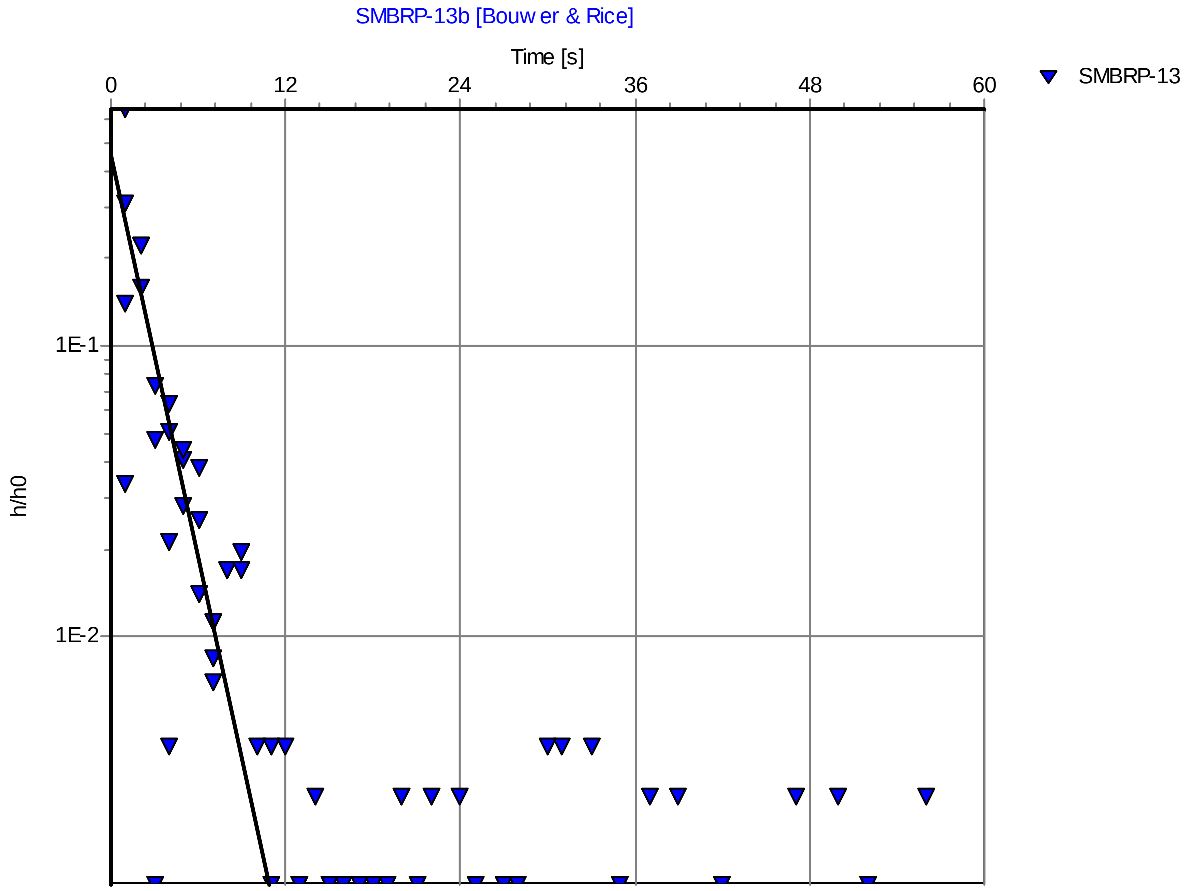
Comments:

Evaluated by: Amy Macrellis

Evaluation Date: 5/12/2003

Stone Environmental, Inc.
535 Stone Cutters Way
Montpelier, VT 05602
Phone: +1 802 229 4541

Slug Test Analysis Report	
Project:	Malibu_CA
Number:	011269-W
Client:	City of Malibu, CA



Slug Test: **SMBRP-13b**

Analysis Method: **Bouwer & Rice**

Analysis Results: Conductivity: 1.16E+2 [ft/d]

Test parameters:

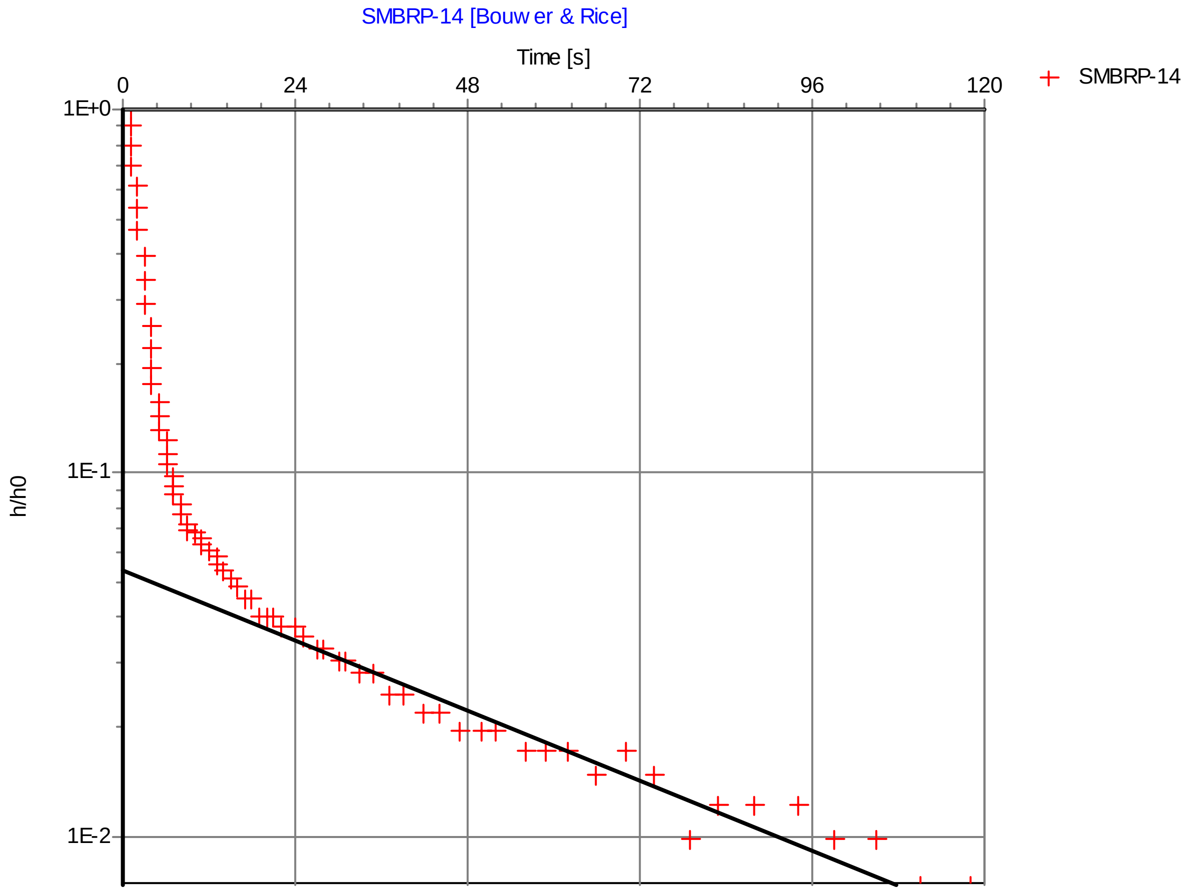
Test Well:	SMBRP-13	Aquifer Thickness:	100 [ft]
Casing radius:	0.083 [ft]	Gravel Pack Porosity (%)	25
Screen length:	15 [ft]		
Boring radius:	0.33 [ft]		
r(eff):	0.180 [ft]		

Comments:

Evaluated by: Amy Macrellis

Evaluation Date: 5/12/2003

Stone Environmental, Inc. 535 Stone Cutters Way Montpelier, VT 05602 Phone: +1 802 229 4541	**Slug Test Analysis Report** Project: Malibu_CA Number: 011269-W Client: City of Malibu, CA



Slug Test: **SMBRP-14**

Analysis Method: **Bouwer & Rice**

Analysis Results:

Conductivity: 9.40E+0 [ft/d]

Test parameters:

Test Well:	SMBRP-14	Aquifer Thickness:	3.54 [ft]
Casing radius:	0.083 [ft]	Gravel Pack Porosity (%)	25
Screen length:	5 [ft]		
Boring radius:	0.33 [ft]		
r(eff):	0.180 [ft]		

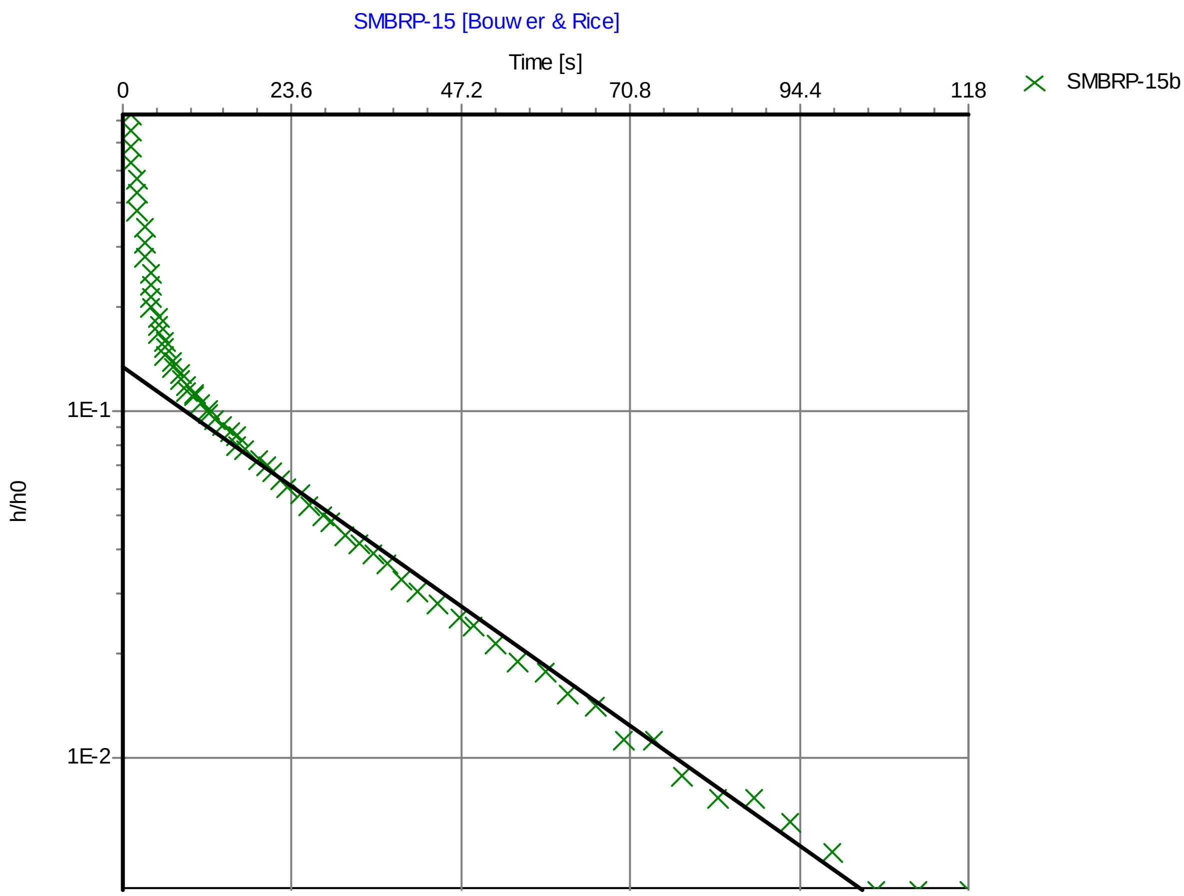
Comments:

Evaluated by: Amy Macrellis

Evaluation Date: 5/12/2003

Stone Environmental, Inc.
535 Stone Cutters Way
Montpelier, VT 05602
Phone: +1 802 229 4541

Slug Test Analysis Report	
Project:	Malibu_CA
Number:	011269-W
Client:	City of Malibu, CA



Slug Test: **SMBRP-15**

Analysis Method: **Bouwer & Rice**

Analysis Results:

Conductivity: 7.80E+0 [ft/d]

Test parameters:

Test Well:	SMBRP-15b	Aquifer Thickness:	100 [ft]
Casing radius:	0.083 [ft]	Gravel Pack Porosity (%)	25
Screen length:	15 [ft]		
Boring radius:	0.33 [ft]		
r(eff):	0.180 [ft]		

Comments:

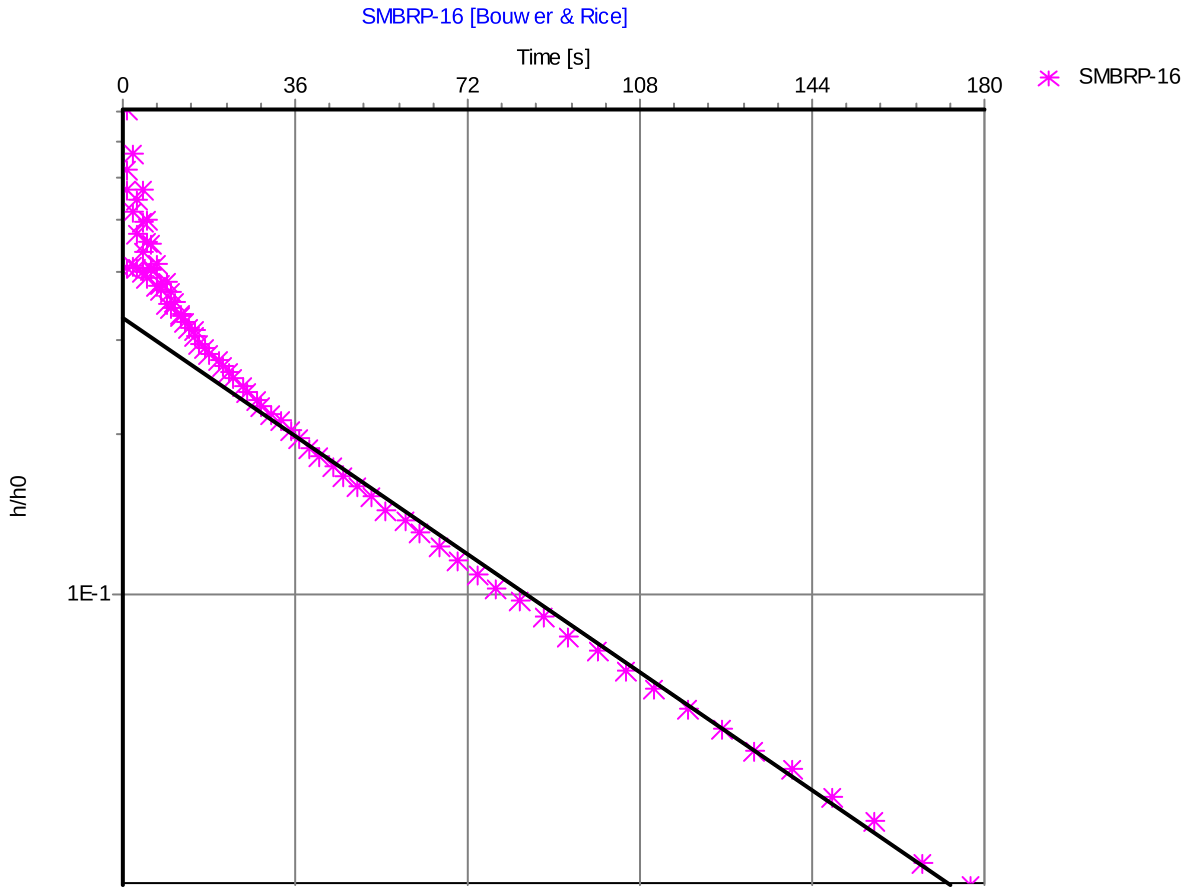
Evaluated by: Amy Macrellis

Evaluation Date: 5/12/2003

Stone Environmental, Inc.
535 Stone Cutters Way
Montpelier, VT 05602
Phone: +1 802 229 4541

Slug Test Analysis Report

Project:	Malibu_CA
Number:	011269-W
Client:	City of Malibu, CA



Slug Test: **SMBRP-16**

Analysis Method: **Bouwer & Rice**

Analysis Results:

Conductivity: 5.75E-1 [ft/d]

Test parameters:

Test Well:	SMBRP-16	Aquifer Thickness:	100 [ft]
Casing radius:	0.083 [ft]	Gravel Pack Porosity (%)	25
Screen length:	20 [ft]		
Boring radius:	0.33 [ft]		
r(eff):	0.180 [ft]		

Comments:

Evaluated by: Amy Macrellis

Evaluation Date: 5/12/2003

APPENDIX 3: HYDROGEOLOGY MODEL REPORT

Ground-Water Flow
and Solute Transport Modeling
Malibu, California

prepared for

Santa Monica Bay Restoration Project

by

McDonald Morrissey Associates, Inc.

Concord, New Hampshire

July 28, 2004

Table of Contents:

Figures:

Malibu Figures (cont.):

Figures (cont.):

Malibu Figures (cont.):

Figure 32 – Nitrate loading rates to the ocean and lagoon under flooded conditions, with no degradation, five-year half life, and two-year half life, if nitrate concentrations are reduced to 10 mg/l in 2004.

Figure 33 – Nitrate loading rates to the ocean and lagoon under breached conditions, with no degradation, five-year half life, and two-year half life, if nitrate concentrations are reduced to 10 mg/l in 2004.

Tables:

Introduction

A numerical model was constructed to simulate ground-water flow in the alluvial deposits along Malibu Creek and Malibu Lagoon near the Malibu Civic Center area (figure 1). The objectives of the modeling are as follows: develop a quantitative water budget for the flow system; delineate directions of ground-water flow; identify contributing areas for the surf zone and the lagoon; estimate ground-water travel times and estimate nitrate loading to the lagoon and the ocean.

Conceptual Model

Hydrogeologic Setting

There are two primary hydrostratigraphic units within the study area: bedrock and alluvium. Bedrock is at or near land surface in the upland areas and beneath the unconsolidated sediments (alluvium) that are present in the Civic Center area along Malibu Creek and Lagoon. These units are briefly described below.

Bedrock

Bedrock immediately adjacent to the alluvium includes the Sespe and Lower Topanga Formations, that are described as relatively resistant sandstones and conglomerates; and the Conejo Volcanics, that are described as andesitic and basaltic breccias and basaltic flow (Ambrose and Orme, 2000). At some locations these rocks are fractured and faulted and, as a result, have some permeability.

A contour map showing the elevation of the top of bedrock in the alluvium is shown in figure 2. Bedrock elevations were determined using information from drill holes that were done for geotechnical analyses, from water supply wells that were drilled for the now defunct Malibu Water Company and from CPT data presented by Leighton Associates (1994). Information presented by Ambrose and Orme (2000) and the position of the exposed bedrock, offshore of Malibu Point at the eastern end of Malibu Colony, were also used in developing the bedrock surface shown in figure 2.

In general, the bedrock elevation varies from approximately 120 ft NGVD or higher along the edges of the alluvium in the northern part of the study area to -126 ft NGVD in the vicinity of Cross Creek Plaza at the location of an abandoned water supply well. The thalweg is conceptualized as extending from the present course of Malibu Creek toward the south west. This interpretation differs from that of Ambose and Orme (2000, figure 1-9) who had mapped a bedrock high beneath Malibu Colony approximately 1600 feet west of the exposed bedrock knob at Malibu Point.

According to Orme (verbal communication, Jan. 9, 2003) the evidence for these bedrock highs comes from geotechnical test information collected at 23544 Malibu Colony Road (middle bedrock high) and 23318 Malibu Colony Drive (east bedrock high) respectively. Geotechnical data for these locations is on file at the City of Malibu.

Close examination of information from 23544 Malibu Colony Road revealed that there is no actual observation of bedrock but rather that it was assumed to be 8-10 feet below land surface. The stratigraphic log from a nearby property (23556 Malibu Colony Road) has a drilling log, which shows no refusal at 50 feet below land surface. Based upon this observation, the existence of the middle bedrock knob is questioned. The eastern BR high is based upon a test pit at 23318 Malibu Colony Road, which clearly describes bedrock at 8.5 feet below land surface. Bedrock was also encountered near this location in a test well drilled for this study (well SMBRP-14) and a bedrock outcrop is observable at low tide just offshore from this general location.

A geotechnical study of the Civic Center area (Leighton and Associates, Inc., 1994) states that "subsurface data, as well as the geomorphic expression, appear to indicate that the predominant course of the Malibu Creek during the latest Pleistocene and throughout much of Holocene time, was through the center of the Civic Center, emptying into the Ocean south of the Hughes Market shopping Center. Other lines of evidence for this interpretation include shallow bedrock in the vicinity of the modern Malibu Creek, and a now abandoned large meander east of Serra Retreat that would direct flow southwestward across the central portion of the Civic Center area."

Although there are no definitive data to either prove or disprove the location of the thalweg, all of the information cited above appears to indicate that it would exist to the west of the bedrock knob exposed at Malibu Point. This interpretation was used to guide development of the bedrock surface map for this study.

Alluvium

The drainage area for Malibu Creek covers approximately 109 square miles (mi^2) and is shown on the map in figure 3. Malibu Creek deposited alluvial materials along the coast as it flowed from its upland drainage to the sea. The alluvial deposits cover an area of approximately 1.3 square miles (Yerkes and Cambell 1980), as shown in figure 4.

The alluvium is described as having "spatial and temporal patterns of great complexity involving frequent lateral and vertical facies changes attributable to the conflict between fluvial, estuarine, lagoonal, beach, nearshore, and colluvial conditions" (Ambrose and Orme, 2000). The sediments underlie the relatively flat area of the City of Malibu Civic Center and along Malibu Creek and Lagoon, and they are bordered by the foothills of the Santa Monica Mountains to the north and Santa Monica Bay to the south.

The thickness of the saturated alluvium varies from a featheredge near the contact with upland areas to approximately 120 feet or more near the ocean. A north-south geologic cross section, extending from bedrock uplands to the sea, is shown in figure 5a (Ambrose and Orme, 2000). The upper 40 feet consists of alternating layers of fine- to medium-grained alluvial sands and finer-grained estuarine sands and silt. On the landward side, these strata are underlain by a thick section of coarse-grained alluvial gravel. The elevation of the top of the alluvial gravels (Civic Center gravels) is at approximately -30 ft NGVD and is relatively flat lying. On the seaward side, the fluvial gravels pinch out and are replaced by lagoonal muds, beach sands, and beach gravel. Bedrock is shown in figure 5a in the upland area where drill holes have intersected bedrock.

Examination of detailed cross-sections included in the report by Leighton and Asssociates, Inc. (1994) show the sand layers above the Civic Center gravel are relatively continuous and flat lying throughout the area north of the Pacific Coast Highway. These sand beds range in thickness from about 5 to 10 feet and, at any given location, it appears that 2 or 3 distinct sandy layers, separated by fine grained silts and clays, exist above the gravels.

An east-west geologic cross section, extending from Malibu Point to Amarillo Beach, is shown in figure 5b (Ambrose and Orme, 2000). This section shows alternating layers of beach and estuarine deposits in the top 40-50 feet, between land surface and deeper, fine-grained lagoonal deposits. Bedrock is delineated near each end of the section shown in figure 5b where alluvium is pinched out by bedrock outcrops immediately along the coast.

Hydraulic Properties of the Alluvium

Hydraulic properties of the saturated alluvium have been estimated by a variety of techniques at several different locations. Slug tests conducted on three wells completed in alluvium in Winter Canyon yielded hydraulic conductivities that ranged from 13-53 feet per day (ft/d) (Earth Consultants International, 2000a). A ground-water model of the Winter Canyon alluvium used hydraulic conductivities ranging from 22 to 66 ft/d (Earth Consultants International, 2000).

Laboratory testing of clay samples collected from borings near the City of Malibu offices along Civic Center Way reported hydraulic conductivity estimates of 0.00014 and 0.00076 ft/d (Earth Consultants International, June, 2000b). Slug tests conducted on five shallow wells, located near a waste-water disposal system in Cross Creek Plaza gave hydraulic conductivity estimates that range from 0.6 to 4 ft/d (URS Greiner Woodward Clyde, 1999). The same study estimated hydraulic conductivities of 200-400 ft/d in the Cross Creek Plaza area based upon results of bromide tracer and coliphage seeding tests.

Slug tests conducted on observation wells completed for this study are summarized in table 1. The values range from less than 1 ft/d to 123 ft/d with an average value of 13 ft/d. These wells are generally less than 50 feet deep and are screened near the water table. None of the observation wells drilled for this study intersect the coarse gravels that underlie the Civic Center area. The highest hydraulic conductivity (123 ft/d), estimated from slug testing done for this study, was at well SMBRP-3c which is located in the coarse deposits along upper Malibu Creek.

Water supply in the Malibu Civic Center was originally provided by the Marblehead Land Company, and then by the Malibu Water Company, from wells drilled into alluvial deposits and shallow bedrock along Malibu Creek. The first of these wells was drilled in 1902 and the final well was installed in about 1959. Several of these original supply wells were abandoned due to salt water intrusion and ultimately the water supply for Malibu was obtained, via pipeline, from Los Angeles County Water Works District No. 29 (Brown and Caldwell, 1962). Records for the old Malibu Bay Company wells were obtained from Grant Adamson during research for this project.

Locations of the Malibu Water Company wells are shown in figure 6 and a summary of well construction and operation information is included in table 2. Specific capacity data from the wells was used to estimate transmissivity with a method described by Driscoll (1986). Estimated transmissivities for the old production wells range from approximately 10,000 ft^2/d to 23,000 ft^2/d, which translates to hydraulic conductivities of 200-500 ft/d.

Sources of Ground Water

Recharge from Upland Runoff

Upland areas adjacent to the alluvium provide recharge to the ground-water flow system. This recharge includes two components; ground-water in the upland that travels downgradient to recharge the alluvium, and surface-water runoff from the upland that infiltrates as it passes from less permeable bedrock in the uplands onto the more permeable alluvium. Estimates of the amount of recharge from uplands are made by delineating the drainage areas of contributing uplands along with an estimate of available ground and surface water runoff.

A map showing the upland areas that contribute recharge to ground water in the alluvium is shown in figure 7. The size of each contributing area and estimated average annual runoff is summarized in table 3. The areas were delineated using land surface topography (U.S. Geological Survey 1995).

The Winter Canyon sub drainage includes a thin strand of alluvium that is separated from the main body of alluvium by a low bedrock ridge that extends to a point just south of the Pacific Coast Highway. The total drainage area for Winter Creek is 252 acres, of which 37 acres are underlain by alluvium. Although the ground-water flow system in Winter Canyon is somewhat isolated from the main body of alluvium, it is included in this analysis because two wastewater treatment and discharge systems are located there.

The West Alluvial sub-drainage contributes runoff to the north and west sides of the main body of alluvium from an area covering 198 acres. On the east side of Malibu Creek, there are four sub-drainages: the North Alluvium, Malibu Tributary, Serra Retreat, and East Alluvium areas. The North Alluvium sub-drainage has an area of 48 acres and contributes runoff to alluvium along Malibu Creek and north of the Serra Retreat. The Malibu Tributary sub-drainage covers 228 acres and includes an unnamed intermittent stream that flows westward along the alluvium north of the Serra Retreat. The East Alluvium sub-drainage covers 127 acres and delivers runoff to the alluvium along the east side of Serra Retreat and Malibu Creek. The upland area at Serra Retreat covers 21 acres and contributes runoff in a radial direction to surrounding alluvium.

Two additional sub-drainages were delineated along the shoreline east and west of the main body of alluvium and are referred to as the East Shore and West Shore sub-drainages. These sub-drainages contribute recharge to a thin strip of alluvium that exists between the mountain front and the bay. The extent of these areas are shown on figure 7 and summarized in table 3.

The average annual precipitation in Malibu is approximately 14 inches per year based upon 35 years of data collected at the Los Angeles County Department of Public Works Malibu Beach-Dunne precipitation station (LawGibb Group, 2001). Only a small fraction of the total precipitation in upland areas can become recharge to the alluvium because of runoff and evapotranspiration. A small amount of precipitation will infiltrate in upland areas, flow through shallow bedrock and recharge the alluvium. In addition, some of the surface runoff from upland areas may infiltrate the alluvium near the contact with alluvium and bedrock. The exact amount of this recharge is difficult to determine.

Pepperdine has been monitoring precipitation, soil moisture, ground-water levels, and runoff from irrigated areas of their campus since 1997. Based upon these observations they have estimated that approximately 65% of precipitation and irrigation water are lost to evapotranspiration, 20% becomes deep percolation (ground-water recharge), and 13% is surface runoff (Law/Crandall, 2001). Because these estimates have been developed for irrigated areas, they are probably somewhat high for non-irrigated and developed areas. For the sake of this investigation it was assumed recharge to alluvium from upland areas is 2 inches per year, or approximately 14% of the average annual precipitation. Table 3 summarizes the estimated total average annual runoff from each of the sub-drainage areas.

Soil Absorption System Recharge

Information on total water use in the study area was obtained from metered flow data collected by the Los Angeles County Department of Public Works. The County provided total use data for several sub-areas within the study area for the period from May 1, 2002 through May 1, 2003. These data were used to estimate the amount of ground-water recharge from waste-water disposal systems.

Analysis of total water use data for the Malibu Colony area showed that the average annual household water use was approximately 500 gal/day. This area does not appear to include extensive irrigated areas because the lot sizes are small relative to house size. Based upon this observation it is assumed that the total water use is equivalent to the amount of water that is returned to ground water via subsurface waste disposal.

In other parts of the study area total annual water use was much higher than was observed in the Colony. Much of this water use is attributed to irrigation, especially in areas with large lots that have extensive landscaping. Such areas exist near Serra Retreat along Malibu Creek and in the uplands adjacent to the main body of alluvium including residences along Coastview, Malibu Knolls, Harbor Vista, and Malibu Crest Roads on the west side, and Cross Creek, Mariposa de Oro, Palm Canyon and Sweetwater Canyon Roads on the east side. In these locations it was assumed that the amount of waste-water that recharges ground water is 500 gal/day and the remainder is attributed to irrigation. It is further assumed that one-half of water used for irrigation recharges the ground-water system.

A summary of waste-water disposal that is assumed to recharge the ground-water system is included in table 4. The total amount of waste-water disposal in Winter Canyon is approximately 88,000 gallons per day. Most of this waste-water is disposed of at the treatment facilities run by the County of Los Angeles and the Malibu Bay Company.

Total waste-water disposal in the main body of the alluvium and the associated bedrock upland is estimated to be approximately 244,000 gallons per day as shown in table 4. Commercial waste-water disposal in the main body of alluvium is approximately 62,000 gallons per day and residential waste-water disposal is about 126,000 gallons per day. Waste-water disposal in upland areas adjacent to the main body of alluvium is almost entirely residential and totals 56,000 gallons per day.

Infiltration of Precipitation

Some of the precipitation that falls directly on the alluvium becomes ground-water recharge. This recharge is assumed to be small because most rain comes as intense winter storms with considerable runoff and much of the runoff is diverted to surface water via storm sewers. There are several areas atop the alluvium that are paved, through which there is no infiltration. In unpaved areas some of the precipitation will run off and some will be lost to evapotranspiration. For the purpose of this study, it is estimated that 1 inch of the average annual precipitation (14 inches/year) on unpaved alluvial areas becomes ground-water recharge.

Malibu Creek Infiltration

Infiltration of stream flow is a common source of recharge to alluvial aquifers (Morrissey et al., 1988). Recharge occurs as streams flow from steep upland areas, which are predominantly bedrock, onto more permeable, relatively flat alluvial deposits. The rate of recharge is controlled by the difference in head between the stream and the underlying ground water and the permeability of the streambed and underlying alluvial deposits.

Malibu Creek streamflow data are collected at the Los Angeles County Flood Control District continuous recording gage F130R, (formerly USGS gaging station 111055500), located 0.3 mi downstream of Cold Creek and approximately 3.5 miles upstream from Arizona Crossing. The gaging station was installed in 1931 and operated cooperatively by the USGS and Los Angeles County until 1978. From 1979 until the present the gage has been operated by Los Angeles County. Flows recorded at the gage include any releases from the Las Virgenes Municipal Water District Tapia Water Treatment Facility which was constructed in 1965.

Entrix, Inc. (1999) summarized flow conditions in Malibu Creek as part of a study to evaluate habitat for steelhead trout and tidewater goby. Table 5, which was adapted from the report by Entrix report, shows a summary of average monthly streamflows at the gaging station for three different time periods starting in 1931. There is a general trend toward increasing stream flow during the time periods shown in table 5 especially for the months of April, May, June, July and October. This increase in stream flow is attributed to increased urbanization in the watershed which causes increased runoff.

Infiltration of stream flow has been observed as Malibu Creek exits the canyon and crosses onto the alluvial deposits along the coastal plain. On August 23, 1999 flow at the gaging station was measured at 1.4 cfs, 2,300 feet downstream flow had decreased to about 1 cfs and 3,300 further downstream, just below Cross Creek Road, the stream was dry (Entrix, Inc., 1999). On September 10, 1998 a similar pattern was noticed. Flow near the mouth of the canyon was 8.2 cfs and 600 feet downstream of Cross Creek Road it was 6.4 cfs, a 1.8 cfs depletion (Entrix, Inc., 1999).

On September 24, 2003 Malibu Creek had an average daily flow of 3.0 cfs at the LA County gage (written comm., LA County DPW, April 2, 2004). Stream flow in the Creek was measured at 0.6 cfs 3,200 feet above Cross Creek Road/Arizona Crossing and the stream channel was dry just above the Cross Creek Road bridge (written comm., McDonald Morrissey Associates, Inc., 2003)

Entrix (1999) also states that LVMWD staff observed that "the stream is almost always dry below Cross Creek Road in the late summer months." Examination of streamflow records show that average daily flows during the late summer months are typically 2-4 cfs. Some of this water is lost to evapotranspiration and to infiltration along the stream channel above the main body of alluvium but, based upon available gaging data, a significant amount recharges the alluvial deposits in the Civic Center area. These recharge rates are estimated to be on the order of 0.5 to 2 cfs during low flows and may be higher during flood conditions.

Excess Irrigation

Recharge to ground water from infiltration of excess irrigation is likely to occur at locations where turf and landscaping are maintained such as the golf course near Malibu Colony, at the nursery near the west side of the study area and at and private residences that maintain lawns and other landscapes that require irrigation.

In the northern part of the study area, along Malibu Creek and near Serra Retreat, the amount of recharge from excess irrigation was estimated by subtracting waste water disposal (500 gallons per day per residence) from the total reported water use for the area and applying one-half of the remainder as recharge. The same approach was used in each of the upland areas that are adjacent to the alluvium and at the nursery located on the west side of the study area. At the golf course it is estimated that total irrigation is approximately 3 feet per year and that approximately one-third becomes ground-water recharge. Estimated rates of ground water recharge from excess irrigation through alluvium are shown on the map in figure 8.

Sinks for Ground Water

Ground-water sinks are areas where ground water discharges out of the alluvial ground-water flow system. Potential ground-water sinks include natural discharge to surface waters and the ocean, evapotranspiration from riparian vegetation, and pumping wells used for irrigation or other water uses in the study area.

Discharge to Ocean and Malibu Lagoon

Water table maps were constructed in order to determine general directions of ground-water flow in the alluvium and to differentiate between ground-water flow to the ocean and lagoon. Data used to construct the water table maps were collected on September 25, 2003 and on March 9, 2004 from a network of monitoring wells that were surveyed to the nearest 0.01 ft. The data were collected within a relatively short time frame (approximately 2 hours) in order to avoid effects of transient water level changes. During these measurement runs, observations of surface water stage were also made on Malibu Creek at the PCH highway bridge and at Arizona Crossing at surveyed reference points.

During the September 2003 measurement the barrier beach was intact and the lagoon was flooded. Malibu Creek channel was dry from a point just above Arizona Crossing about 3,000 feet downstream to northernmost extent of the flooded lagoon. A contour map of observed water levels for the September 2003 measurement is shown in figure 9.

During the March 2004 measurement the barrier beach was breached and flow in Malibu Creek was discharging to the ocean. On this date the lagoon was not flooded and flow was continuous from Malibu Canyon to the ocean. The lagoon stage on March 9, 2004 was approximately 3 feet lower than stage measured during the September 25, 2003 measurement. Malibu Creek stage above Cross Creek Road was about 1 foot higher in September 2003 than it was on the March 2003 measurement. A contour map of ground -water elevations for the March 2003 measurement is shown in figure 10.

Figures 9 and 10 show that ground water flows toward the Pacific Ocean and Malibu Lagoon. During both the flooded and breached lagoon condition it appears that ground-water from Winter Canyon, the western side of the alluvial flow system, and the area south of the Pacific Coast Highway discharges to the ocean. Ground water on the eastern side of the alluvial flow system, including the Cross Creek Plaza area, discharges to Malibu Lagoon and Creek. The effect of lagoon flooding on ground-water levels is apparent when figures 9 and 10 are compared. During the flooded condition ground-water levels in the Cross Creek Plaza area are approximately 2-3 feet higher than when the lagoon is breached.

Evapotranspiration

Evapotranspiration from ground water can occur where the root zone of vegetation is at or below the water table. The most likely place for this to occur in the study area is along Malibu Creek and lagoon where there is riparian vegetation and shallow depths to water. The Las Virgenes Water District estimated the water demand of riparian vegetation along Malibu Creek downstream of the Tapia Water Reclamation Facility (Letter from Las Virgenes Water District to National Marine Fisheries Service, September 2, 1998) using a method that takes into account vegetation species type and density along with microclimatic characteristics. Results of this study estimate that riparian vegetation consumes approximately 1.2 cfs of water in the reach below the treatment plant and Cross Creek Road, a distance of about 4 miles, which is approximately 0.3 cfs per mile.

Pumping

The Los Angeles County Department of Health Services – Environmental Health Division regulates water supply wells in Malibu. All water wells are required to be permitted by Environmental Health. At present there is no documentation of any pumping wells in the study area. However, a cursory examination done during field work for this study suggests that there are several private wells in use in the study area. It appears that the wells are being used for irrigation of landscaped areas.
It is assumed that the net effect of pumping from these wells on the ground-water system is minimal.

Summary of Sources and Sinks for the Ground-Water Flow System

A generalized diagram summarizing estimated average annual rates for each of the sources and sinks described above is included in figure 11. The estimated total average annual inflow to the alluvial ground-water flow system is approximately 1.93 cfs (cubic feet per second) or 1.25 million gallons per day. The sources of recharge to the system are infiltration from Malibu Creek (0.89 cfs), infiltration from waste-water infiltration (0.52 cfs), irrigation return (0.26 cfs), upland runoff (0.23 cfs), and infiltration of precipitation (0.03 cfs). Approximately 42% of the recharge to the ground- water flow system is from infiltration of waste-water.

If it is assumed that the system is in a quasi-steady-state condition, that is, there is no long-term change in storage, the total average annual outflow is also 1.93 cfs. The sinks for ground-water flow are discharge to Malibu Lagoon (1.18 cfs), the Pacific Ocean (0.60 cfs) and to evapotranspiration (0.15 cfs). Approximately 61% of ground water in the system discharges to Malibu Lagoon, 31 % to the Ocean and 8% to evapotranspiration.

Numerical Ground-Water Flow Model

The purposes for constructing a ground-water flow model of the Malibu site were to develop a quantitative water budget for the flow system, delineate directions of ground-water flow, identify contributing areas for the surf zone and the lagoon, estimate ground-water travel times and estimate nitrate loading to the lagoon and the ocean.

Construction

The ground-water model used for this investigation is MODFLOW, which was developed by the U.S. Geological Survey (McDonald and Harbaugh, 1988). MODFLOW requires that the ground-water flow domain be subdivided into blocks. Specifications describing aquifer hydraulic properties, recharge, discharge, and other factors that can affect the ground-water flow system are required for each block in the model grid. Specifications must also be made to describe flow conditions along each boundary of the model domain (boundary conditions), and for transient simulations, initial ground-water elevation must be specified for each block at the start of the simulation (initial conditions). The ground-water model calculates a ground-water elevation for each block in the model grid at each discrete time interval.

Model Grid

The model developed for this study covers an area that is approximately 1 square mile as shown in figure 12. The extent of the model was designed to simulate ground-water flow in alluvial deposits that underlie the Malibu Civic Center area along Malibu Creek and Lagoon (Yerkes and Campbell, 1980). The model domain also includes the alluvial deposits in Winter Canyon and sections of shore line east and west of the main body of the alluvium.

The model grid has 50 foot uniform spacing for rows and columns and is subdivided into 4 layers. The total number of active cells in the model domain is 42,422. Layer thickness varies from a few feet or less near the edges of the model to a maximum of about 50 feet where the alluvial deposits are thickest. Layers 1 and 2 are designed to represent the sands and silts that exist atop the Civic Center gravels that were described by Leighton (1994). The top of model layer 3 was set at an elevation of -30 feet in the Civic Center area in order to correspond to the top surface of the Civic Center gravels. The bottom of the model was designed to be at the contact between alluvium and the underlying bedrock.

Boundary Conditions

Conditions that affect the movement of ground water across all model boundaries were specified as follows: the lower boundary, which is at the contact between alluvium and underlying bedrock was assumed to be impermeable. The top boundary, represented by the water table, receives flow from infiltration of precipitation, excess irrigation, stream leakage and from waste-water discharge. Flux boundaries were used in the model to simulate recharge from upland areas adjacent to the alluvium. Recharge from the uplands includes contributions from ground water and surface water runoff as well as waste-water disposal.

A constant head boundary condition was assigned to the contact between the alluvial deposits and the Pacific Ocean in model layer 1. Beneath this, in model layers 2-4, the boundary was simulated as no-flow. The elevation of the constant head that represents the ocean was set based upon average tide elevation.

Malibu Creek and Lagoon were represented as head dependent boundaries in the model using the RIVER package in MODFLOW. Leakage to or from the ground-water system is based upon stage difference and the hydraulic conductivity of the streambed materials. Stage was determined from measuring points, located on Malibu Creek near Arizona Crossing and at the PCH (Pacific Coast Highway) bridge over Malibu Lagoon, and supplemented with topographic data. Initial estimates of streambed conductance were made using streambed area and a hydraulic conductivity of 1 ft/day.

Hydraulic Parameters

Hydraulic parameters represent the characteristics of the subsurface that permit it to transmit and store water. They include hydraulic conductivity, storage coefficient and specific yield. The parameters may vary greatly from point to point within a model domain. Although they cannot be measured everywhere, estimates of parameters can be made by several methods including evaluation of drillers logs, geologic mapping, grain-size analyses of subsurface samples, pump testing of water supply wells and slug testing of observations wells.

Initial estimates of hydraulic conductivity were guided by observations that were detailed in the 'Conceptual Model' section of this report and were refined during model calibration. Values of hydraulic conductivity used in the model for layers 1-4 are shown in figures 13-16. The highest values of hydraulic conductivity are used to represent the coarse grained sands and gravel along the present course of Malibu Creek and where the Civic Center Gravels were mapped (Leighton and Associates, 1994).

Recharge and Discharge

Recharge from infiltration of precipitation on the alluvial deposits is assumed average 1 inch per year in areas where the land surface is not covered with an impervious surface. Where there is recharge from excess irrigation it is added to the recharge from precipitation. Alluvial areas where recharge from irrigation was simulated include the nursery, golf course and residential areas along Cross Creek Road and Mariposa de Oro in the vicinity of Serra Retreat. The RECHARGE package in MODFLOW was used to implement recharge from precipitation and excess irrigation and the modeled rates are shown in figure 17.

Recharge from upland runoff is implemented in the model using the WELL package. Recharge from upland areas is assumed to average 2 inches per year and the total volume is determined based upon the size of the contributing upland areas as described in the "Conceptual Model' section of this report. Locations where recharge from upland runoff is applied in the model are shown in figure 18 and the modeled rates are shown in table 3.

Recharge directly to alluvium from waste-water disposal was simulated with the WELL and RECHARGE packages in MODFLOW. Recharge from waste-water disposal in upland areas was simulated with the RECHARGE package along the edge of the model domain, downgradient from upland disposal areas (fig. 18). The RECHARGE package was also used to simulate recharge from the two waste-water treatment facilities located in Winter Canyon as shown in figure 18.

Residential and commercial waste-water disposal to the main body of alluvium, and to alluvium in Winter Canyon, was simulated with the WELL package as a series of recharge wells. In general, the waste-water recharge was applied to the model cell that corresponds with the centroid of each residential parcel. In the Cross Creek Plaza area, where locations of specific commercial waste-water disposal systems were known, waste-water recharge was applied at the corresponding model location. The modeled waste-water recharge rates are summarized in table 4.

Evapotranspiration from ground water was simulated with the ET package in MODFLOW in the model area where phreatophytes exist along the riparian zone adjacent to Malibu Creek and Lagoon. The maximum evapotranspiration rate was set at 46 inches per year and the extinction depth was set at 15 feet below land surface.

Calibration

Model calibration was accomplished with two steady-state simulations based upon water levels and streamflow data collected on September 25, 2003 for a flooded lagoon condition, and on March 9, 2004 for a breached lagoon condition. During model calibration average annual rates of recharge for all sources were specified in the model and adjustments were made to conductivity values in order to match measured water levels.

Flooded Lagoon Condition

A plot of water levels is shown in figure 19 for each of the wells in the monthly monitoring network established for this study. Examination of figure 19 shows that water levels near the lagoon during September 2003 were near the seasonal high associated with a flooded lagoon condition. Furthermore, water levels away from the lagoon, especially those wells located near the contact between bedrock and alluvium and along the upper reaches of Malibu Creek, are lower than levels observed in early spring.

A steady-state simulation of this hydrologic condition was run by assigning average annual values of recharge for upland runoff, infiltration from precipitation and waste water recharge. In addition, recharge from Malibu Creek was specified to be 0.6 cfs in the reach above Cross Creek Road which is the amount of infiltration that was observed during the September 2003 water level measurement run. The RIVER package was used to simulate Malibu Lagoon, in the area that was observed to be flooded and at the stage measured during the September 2003 measuring run.

During calibration, model hydraulic conductivity values were adjusted to improve the model calculated match between computed water levels and those observed on September 25, 2003. Final values of horizontal hydraulic conductivity obtained from this calibration are shown in figures 13-16. The resulting ratios of horizontal to vertical hydraulic conductivity vary from about 10:1 in the coarse grained alluvial materials to about 1000:1 in areas where there are significant amount of silt and clay above the Civic Center Gravels which cause steep vertical hydraulic gradients.

A comparison of model calculated water levels with those observed on September 25, 2003 is shown in the scatter plot presented in figure 20 and a map showing model calculated water levels and distribution of residuals is shown in figure 21. The residual mean value is 0.16 ft and the absolute residual mean is 0.52 ft. The minimum and maximum residuals are -1.66 ft and 2.08 ft respectively. The range of observed water levels in the main body of alluvium is approximately 20 ft.

The model calibration resulted in model calculated water levels that reasonably represent measured water levels. There is no significant areal bias in residuals and the model does a good job of reproducing the vertical head differences observed at the multi-level piezometers located in the Civic Center area.

A summary of the model calculated water budget for the flooded lagoon condition is shown in table 6. Total recharge to the ground-water flow system is 145,946 ft^3/day (1.092 million gallons per day). In this model run 30.4 % of the total recharge to the system is from waste water disposal, 34.3 % is from Malibu Creek infiltration above Cross Creek Road, 15.5 % from upland runoff and infiltration of precipitation, 15.2 % from excess irrigation and precipitation recharge in irrigated areas and 4.6 % leaks from the lagoon to ground water.

Because this is a steady-state simulation, total modeled discharge from the system is the same as recharge. The model calculated discharge from the ground-water flow system is as follows: 8.5 % to evapotranspiration, 37.7 % to the Pacific Ocean and 53.8 % to Malibu Lagoon.

Breached Lagoon

Additional calibration was accomplished with a steady-state simulation of conditions observed during the March 9, 2004 water level measurement run. On this date the lagoon was breached and flow in Malibu Creek was continuous across the alluvial deposits from Malibu Canyon to the Ocean. Ground-water levels near the lagoon were lower than those observed when the lagoon was flooded and water levels away from the lagoon had started to rise in response to winter precipitation and the associated increase in flow in Malibu Creek (fig. 19).

In this simulation the same long term annual average recharge rates used in the flooded lagoon condition were assigned in the model. The only change to the model was to modify the RIVER package to represent Malibu Creek across the entire model area rather than just at the lagoon as in the previous simulation. Stage in the RIVER package was set to elevations observed at Arizona Crossing and the lagoon and conductance was adjusted to improve the match between calculated and observed heads.

A comparison of model calculated water levels with those observed on March 9, 2004 is shown in the scatter plot presented in figure 22 and a map showing model calculated water levels and distribution of residuals is shown in figure 23. The residual mean value is 0.12 ft and the absolute residual mean is 0.86 ft. The minimum and maximum residuals are -2.30 ft and 2.60 ft respectively. Although this match is not quite as good as that obtained for the flooded lagoon condition it is still a reasonable representation of observed ground-water elevations.

A summary of the model calculated water budget for the breached lagoon condition is shown in table 7. Total recharge to the ground-water flow system is 185, 503 ft^3/day (1.39 million gallons per day). The major difference in recharge between this run and the previous simulation is an increase in leakage from Malibu Creek by a factor of about 2. In this simulation 23.9 % of the total recharge to the system is from waste water disposal, 51.9 % is from Malibu Creek infiltration above Cross Creek

Road, 12.2 % from upland runoff and infiltration of precipitation, and 11.9 % from excess irrigation and precipitation recharge in irrigated areas.

Again, because this is a steady-state simulation, total modeled discharge from the system is the same as recharge. The model calculated discharge from the ground-water flow system is as follows: 7.7 % to evapotranspiration, 23.9 % to the Pacific Ocean and 68.4 % to Malibu Lagoon.

Application

Results from the flow modeling were used as a basis to evaluate directions of ground-water flow, ground-water travel times in the flow system and the capture zones for the lagoon and ocean. In order to accomplish these specific objectives the particle tracking model MODPATH was used. MODPATH is a particle-tracking post processing package that was developed to compute three-dimensional flow paths using output from steady-state or transient ground-water flow simulations by MODFLOW.

MODPATH uses a semi-analytical particle tracking scheme that allows an analytical expression of the particle's flow path to be obtained within each finite-difference grid cell. Particle paths are computed by tracking particles from one cell to the next until the particle reaches a boundary, an internal sink/source, or satisfies some other termination criterion (Pollock, 1994).

Contributing Areas for the Ocean and Lagoon

Particle tracking was done to determine the contributing areas to the lagoon and ocean for both the flooded and breached lagoon conditions. The steady-state flow fields calculated with MODFLOW formed the basis for the particle tracking runs. In these analyses particles were placed at the water table in each active cell in the model grid and tracked forward. The starting locations of each particle that ultimately travels to either the ocean or to Malibu Creek and Lagoon are then plotted. All particle tracking runs assume a uniform porosity of 0.3 in all model layers.

The contributing areas for the ocean and lagoon are shown in figures 24 and 25 respectively, for the flooded lagoon condition. The contributing area for the ocean includes the entire shoreline area including Malibu Colony, Winter Canyon and the west side of the main body of alluvium. The divide between flow to the ocean and the lagoon runs along the west side of the Cross Creek Plaza area, includes the southeastern part of the Chili Cookoff Parcel, and extends across the southern part of the lagoon. The western divide is caused in part by mounding at waste water disposal sites in the western part of Cross Creek Plaza.

The contributing area of the ocean and lagoon are shown in figure 26 and 27 respectively, for the breached lagoon condition. Under this hydrologic condition the capture zone for Malibu Creek and Lagoon extend more to the west than when the lagoon is flooded. The western extent of the creek/lagoon contributing area extends almost as far west as the Malibu City office, includes most of the Chili Cookoff Parcel, and residences in the northeastern part of Malibu Colony.

Model results show that conditions in the lagoon have an effect on its contributing area. Conditions at the lagoon vary seasonally between a flooded and breached condition so the actual contributing area is probably somewhere between those presented here. If either of the two conditions tends to be predominant in time the contributing area would be more like that caused by such a condition.

Time of travel

Groundwater travel times are shown for the ocean and lagoon, under flooded lagoon conditions in figures 24 and 25. Time of travel to the ocean is 0.5 years or less in a strip that extends along the ocean, and about 50 to 100 feet back, across the model area. Travel times for ground water within Malibu Colony and residential areas to the west of the Colony are generally 3 years or less. Travel times from locations of waste-water disposal plants in Winter Canyon are calculated to be approximately 3 years. The longest calculated travel times to the ocean are approximately 50 years or greater. These locations are near the valley wall and include the City and County offices, and parts of the Ioki and Chili cookoff properties.

Travel times to the lagoon are generally must faster than those to the ocean as shown in figure 25. This is caused by sub-surface materials near the lagoon and creek that have a much higher hydraulic conductivity than elsewhere in the flow system. Travel times from the Cross Creek Plaza area to the lagoon under flooded conditions range from about one year or less in the eastern part of the plaza to 10 years on the western side. Residential areas around Serra retreat in the northern part of the alluvium have travel times to the flooded lagoon of 3 to 10 years.

Model calculated ground-water travel times to the ocean and creek, under the breached lagoon condition, are shown in figures 26 and 27 respectively. In this simulation the creek is assumed to be flowing across the entire modeled area. The fastest travel times to the ocean are from areas immediately along the ocean similar to those observed in the flooded lagoon condition. A comparison of figures 24 and 26 shows that ground water flow in the northeastern part of the colony is to the lagoon when it is breached. Travel times from Winter Canyon are identical under both conditions.

Under the breached lagoon condition the area contributing ground-water flow to the lagoon and the creek is larger than when the lagoon is flooded (figs. 26 and 27). In general, travel times are faster to the lagoon under the breached condition because of steeper ground-water gradients. The longest travel times to the lagoon under the breached condition (fig. 27) are from the western most part of the contributing area. Flow from this area is on a longer and deeper flow path than the shallow flow near the lagoon.

Model results show that the location of waste-water disposal can have a profound effect on the time-of-travel to the nearby surface water bodies. Longer, deeper flow paths, with associated longer travel times to receiving waters, allow for greater dilution, dispersion and degradation of waste-water. Longer travel times also allow for greater die off of pathogens before they reach nearby surface waters. The longest ground-water flow paths and travel times occur from the western body of alluvium, near the valley wall, where ground-water flows downward and then south to the Ocean.

Solute Transport Model

The purpose of the solute transport modeling analyses was to estimate loading of nutrients to the ocean and lagoon/creek. Transport modeling was done with the program MT3DMS. MT3DMS can be used to simulate changes in concentrations of miscible contaminants in groundwater considering advection, dispersion, diffusion and some basic chemical reactions, with various types of boundary conditions and external sources or sinks. The chemical reactions included in the model are equilibrium-controlled or rate-limited linear or non-linear sorption, and first-order irreversible or reversible kinetic reactions (Zheng and Wang, 1999).

<u>Model Construction</u>

MT3DMS calculations are based upon the ground-water flows calculated with the MODFLOW model described previously in this report. The same grid system that was used for the flow calculations is utilized in MT3DMS along with all the same hydraulic properties and stresses. In addition to the flow data, the solute transport model requires assignment of values to parameters that control transport. These include diffusion, dispersion, porosity, source concentrations, retardation and any chemical reactions that can act to vary concentrations of chemical constituents as they move through the flow system.

The transport simulation was run for the period from 1930 through 2090, a total of 160 years. The hydraulic stresses assigned to the model are the same throughout time and are identical to those specified for the steady-state simulations of flooded and breached lagoon conditions. The stress periods were designed to represent general changes in source loading to the system as follows:

-*Stress period 1 (1930 to 1964)*. Source loading during this period is from Malibu Colony only.

-*Stress period 2 (1965 to 1974)*. During this stress period source loading is simulated from the Colony, from residential areas in uplands adjacent to the alluvium, residences in Winter Canyon, residences in the northern part of the alluvium near Serra Retreat, Malibu Pier and from the LA county waste water treatment Plant in Winter Canyon.

-*Stress period 3 (1975 to 1989)*. Includes all sources active in stress period 2 plus, commercial systems in the main body of alluvium.

-*Stress Period 4 (1990 to 2090)*. Includes all sources active in stress period 3 plus loading from waste-water disposal at the Malibu Bay Colony plant. This run assumes all stress remain the same into the future. Because of the lag effect caused by ground water travel times, this simulation was run until 2090 in order to see the maximum impacts of loading.

This model set up is an approximation of actual conditions because the start dates of each waste-water system is not modeled precisely. Furthermore, this simulation assumes that hydraulic stresses are consistent throughout the time period. In actuality, Malibu Bay Water Company wells were active during the early stress periods and may have affected the flow system. Because there are no records of timing and amount of pumping at these wells they have not been included. However, for the purposes of estimating gross loading rates to the lagoon and ocean these assumptions are considered to be reasonable.

Sensitivity analyses of denitrification were simulated in the transport model by using a first-order non- reversible decay rate. Based upon information supplied by Questa Engineering (Bruce Douglas, written communication, 2004) these rates were simulated as nitrate half-lives of two and five years.

Transport Parameters and Source Concentrations

Values of dispersivity are dependent upon the scale of observation or testing but this dependence is not well quantified. Estimates of dispersivity for this study were based upon information provided by Gelhar (1992). Longitudinal dispersivity was assumed to be 50 feet, transverse dispersivity 5 feet and vertical dispersivity 0.5 feet. The effect of diffusion was assumed to be negligible. Porosity was assumed to be 0.3.

Concentrations of nitrate were assumed to be 20 mg/l from domestic waste-water disposal systems and 50 mg/l from commercial systems based upon information provided by Questa Engineering (Bruce Douglas, written communication, 2004).

Application

Transport model simulations were run with the steady-state hydraulic stresses, for flooded and breached lagoon conditions, in order to estimate nitrate loading to the ocean and lagoon from waste-water disposal. Although no attempt has been made to do a rigorous calibration of transport model results, the calculated nitrate levels were compared with average nitrate levels observed at each of the project wells in the monthly monitoring network. A comparison of calculated and observed nitrate concentrations is shown in figure 28 for three different scenarios.

In the base run it is assumed that there is no degredation of nitrate in the flow system. Under this condition the model over-predicts nitrate levels observed at observation wells during the project monitoring period. There are many possible reasons for this discrepancy including errors in modeled hydraulic stresses and errors in the assumed transport parameters, especially those involving source strengths, location and timing. Furthermore, there are other possible sources of nitrate loading that have not been modeled. The "no nitrate degradation" simulation is considered to represent the "maximum" loading caused by waste-water disposal.

Sensitivity analyses were run to investigate the effect of chemical degredation on model predicted nitrate levels. Results of model simulations that specify half-lives of five and two for nitrate are shown in figure 28. The degradation reaction has the effect of reducing model predicted nitrate concentrations and causes better, but clearly not perfect, agreement with observed average nitrate concentrations. Although this is not definitive proof, this model result suggests that some degradation of nitrate may be occurring in the flow system.

Model Calculated Loading Rates

Model calculated loading rates to the ocean and lagoon are shown in figure 29 for the flooded lagoon condition with no nitrate degredation, five-year, and two-year nitrate half-lives. Model calculated loading rates to the ocean and lagoon are shown in figure 30 for the breached lagoon condition with no nitrate degredation, five-year, and two-year nitrate half-lives.

A comparison of figures 29 and 30 shows that the model calculated loading rate for both the flooded and breached condition is very similar. However, because capture zones for the ocean and lagoon are different for each condition, the proportion of loading to the ocean and lagoon are different. Under the flooded condition the capture zone for the lagoon (fig. 25) is smaller than for the breached condition (fig.27) and the calculated loading rate is also smaller. Differences in the loading rate to the ocean also occur for the two different conditions.

Inflection points on the model calculated loading rates can observed in figures 29 and 30 at the start of each stress period when nitrate loading changes. For the period from 1930 until 1964 loading occurs from Malibu County and results in loading to the ocean. From 1965 until 1974 additional loading from residential areas in the alluvium, uplands and in Winter Canyon occur causing increases in loading to the lagoon and ocean. In 1975 commercial systems in the alluvium are added and loading to the lagoon increases and finally in 1990 additional waste-water disposal in Winter Canyon causes increased loading to the ocean.

For the simulations in which degradation of nitrate is assumed, either five or two-year half live, the loading appears to reach a maximum steady-state level in about 2010. For the simulation in which no degradation is assumed it appears that maximum steady-state loading rates are not realized until about 2030 at the lagoon and 2090 for the ocean. These lags in loading rate are caused by the ground water travel times that are shown in figures 24-27.

Depending upon the assumption involving degradation of nitrate, the maximum model calculated nitrate loading to the ocean, resulting from waste-water disposal, ranges from 60 lbs/day (flooded lagoon with no degradation) to 21 lbs/day (flooded lagoon with two-year half life). Maximum model calculated loading to the lagoon varies from 31 lbs/day (breached lagoon with no degradation) to 11 lbs/day (breached lagoon with two-year half life). The true answer probably lies somewhere within these ranges. Depending upon the degradation, the maximum loading rate caused by present activities may not be realized until 2010 or much later.

Management Alternatives Analyses

A simulation was run in which nitrate concentrations were reduced to zero in 2004, assuming that all hydraulic stresses remain the same into the future and that there is no degradation of nitrate. The purpose of this simulation was to evaluate the amount of time it would take for nitrate mass that has accumulated in the flow system to “flush out” to the ocean and lagoon. Results of the simulation are shown in figure 31.

Examination of figure 31 shows that, for the flooded condition with no degradation, it would take about twenty years for loading rates to the lagoon and ocean to be less than 10 lbs/day each. The relatively steep drop in loading rate to the ocean in the period from 2004 to 2024 is caused by relatively fast travel times, and resultant flushing, of loading from beachside residences and at commercial plants in Winter Canyon. The illustration also shows that complete flushing of the ground water system occurs slowly because of slow ground water travel times from some parts of the flow system. When denitrification is included the model predicted nitrate loads to the Lagoon and Ocean approach zero by the year 2024.

Another series of simulations was run to evaluate the effect of decreasing nitrate loading from all disposal systems to 10 mg/l. The original assumption was that loading from commercial systems is 50 mg/l and 20 mg/l from residential systems. The effect of reducing nitrate concentrations to 10 mg/l in 2004 is shown in figures 32 and 33 for the flooded and breached lagoon conditions respectively.

Examination of figures 32 and 33 shows that it would take about 20 years to realize the full reduction in nitrate loading to the ocean and lagoon if nitrate levels were instantly reduced to 10 mg/l in 2004. Loading to the ocean, with a 10 mg/l nitrate source concentration, would be reduced from about 50 lbs/day to 20 lbs/day and loading to the lagoon would be reduced from about 30 lbs/day to 10 lbs/day, if no degradation is assumed. Under conditions of no degradation the model predicts that the reduction in loading to the ocean has not reached a steady-state condition after 100 years.

If nitrate degradation is assumed to occur in the system, with a five-year half life, loading to the ocean would be reduced from about 30 lbs/day to 10 lbs/day and loading to the lagoon would be reduced from about 15 lbs/day to about 5 lbs/day. These changes in loading would occur over a twenty year period as shown in figures 32 and 33. In these simulations the model predicts that a change in source concentration to 10 mg/l would cause a 66% decrease in nitrate loading to both the ocean and lagoon over a twenty year period.

If nitrate degradation is assumed to occur in the system, with a two-year half life, loading to the ocean would be reduced from about 20 lbs/day to 7 lbs/day and loading to the lagoon would be reduced from about 10 lbs/day to 3 lbs/day. The time frame for change and the proportionate reduction in loading are very similar to those predicted for the five-year half life simulation.

Summary and Conclusions

Ground-water flow and solute transport models were constructed in order to develop a quantitative water budget for the Malibu alluvial ground-water flow system, delineate directions of ground-water flow, identify contributing areas for the surf zone and the lagoon, estimate ground-water travel times and estimate nitrate loading to the lagoon and the ocean.

The estimated total average annual inflow to the alluvial ground-water flow system is approximately1.93 cfs (cubic feet per second) or 1.25 million gallons per day. The sources of recharge to the system are infiltration from Malibu Creek (0.89 cfs), infiltration from waste-water infiltration (0.52 cfs), irrigation return (0.26 cfs), upland runoff (0.23 cfs), and infiltration of precipitation (0.03 cfs). Approximately 42% of the recharge to the ground- water flow system is from infiltration of waste-water.

If it is assumed that the system is in a quasi-steady-state condition, that is, there is no long-term change in storage, the total average annual outflow is also 1.93 cfs. The sinks for ground-water flow are discharge to Malibu Lagoon (1.18 cfs), the Pacific Ocean (0.60 cfs) and to evapotranspiration (0.15 cfs). Approximately 61% of ground water in the system discharges to Malibu Lagoon, 31 % to the Ocean and 8% to evapotranspiration.

Directions of ground water flow in the alluvial aquifer are generally to the south and southeast toward the Pacific Ocean and Malibu Lagoon. The contributing area for the ocean includes the entire shoreline area, Winter Canyon and the west side of the main body of alluvium. The divide between flow to the ocean and the lagoon in the main body of alluvium runs along the west side of the Cross Creek Plaza area and extends across the southern part of the lagoon. Model results show that conditions in the lagoon have an effect on its contributing area. When the lagoon is breached it has a slightly larger contributing area than when it is flooded.

Ground-water travel times to the ocean and lagoon vary from less than 180 days, at locations immediately adjacent to these features, to more than 50 years at locations near the valley wall in the main body of alluvium. Average ground-water travel times to the lagoon and creek are generally faster than to the ocean because of the high hydraulic conductivity of sub-surface materials near the lagoon and creek. Travel times from locations of waste-water disposal plants in Winter Canyon are calculated to be approximately 3 years.

Depending upon the assumption involving degradation of nitrate, the maximum model calculated nitrate loading to the ocean, resulting from waste-water disposal, ranges from 60 lbs/day (flooded lagoon with no degradation) to 21 lbs/day (flooded lagoon with two-year half life). Maximum model calculated loading to the lagoon varies from 31 lbs/day (breached lagoon with no degradation) to 11 lbs/day (breached lagoon with two-year half life). The true answer probably lies somewhere within these ranges. Depending upon the degradation, the maximum loading rate caused by present activities may not be realized until 2010 or much later.

Model simulations were run to evaluate the effect of reducing nitrate concentrations in waste water to 10 mg/l in all disposal systems. Original values were assumed to be 50 mg/l for commercial systems and 20 mg/l for domestic systems. In these simulations the model predicts that a change in source concentration to 10 mg/l would cause a 66% decrease in nitrate loading to both the ocean and lagoon over a twenty year period.

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FIGURE 1: STUDY AREA
Risk Assessment of Decentralized Wastewater Treatment Systems in High Priority Areas
City of Malibu, California

Source: Roads & Political Boundaries, TIGER FILES, U.S. Bureau of the Census;
Streams, Digitized by SEI from Aerial Imagery, AirPhoto USA, November 2000;
Study Area Boundary, SEI.

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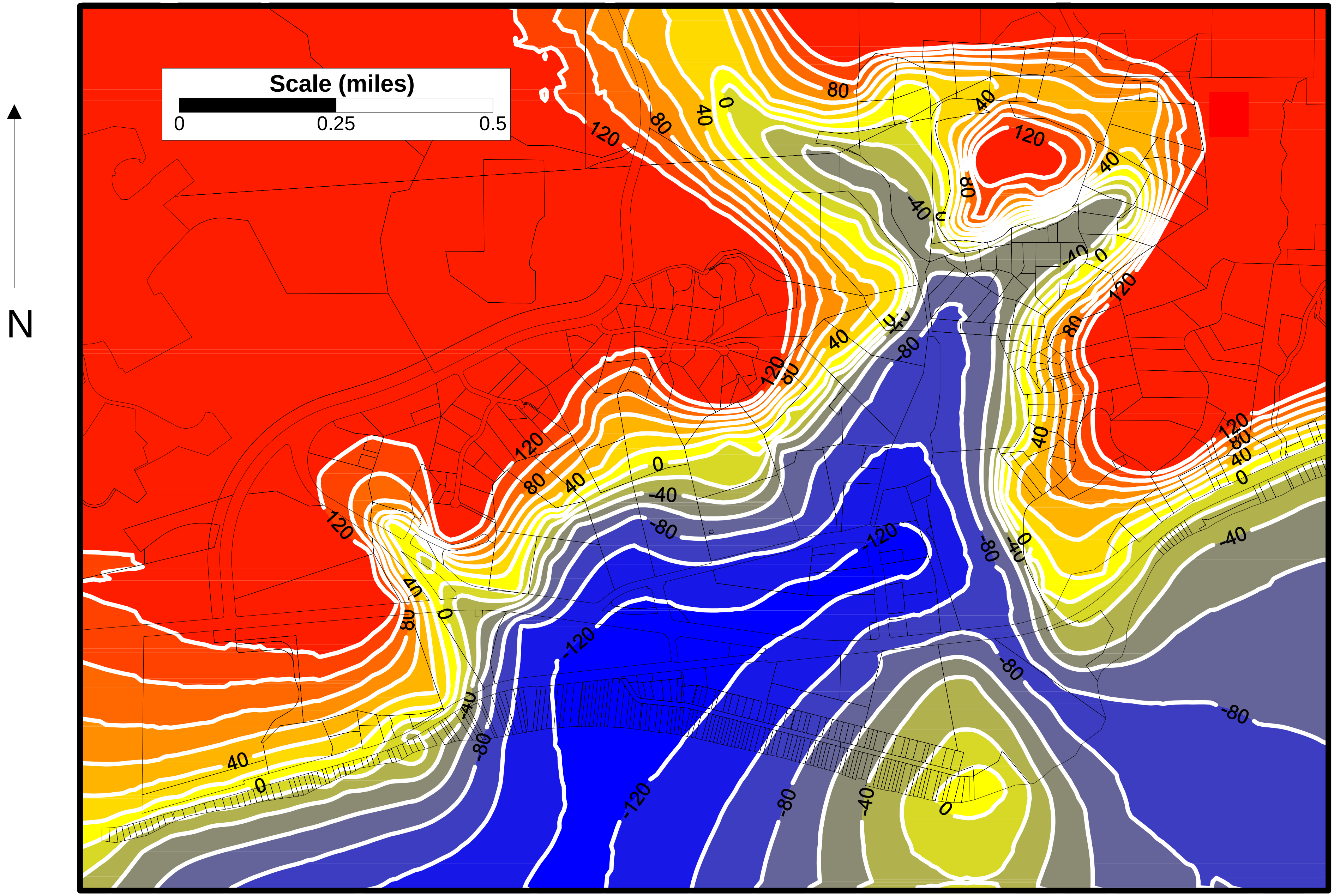
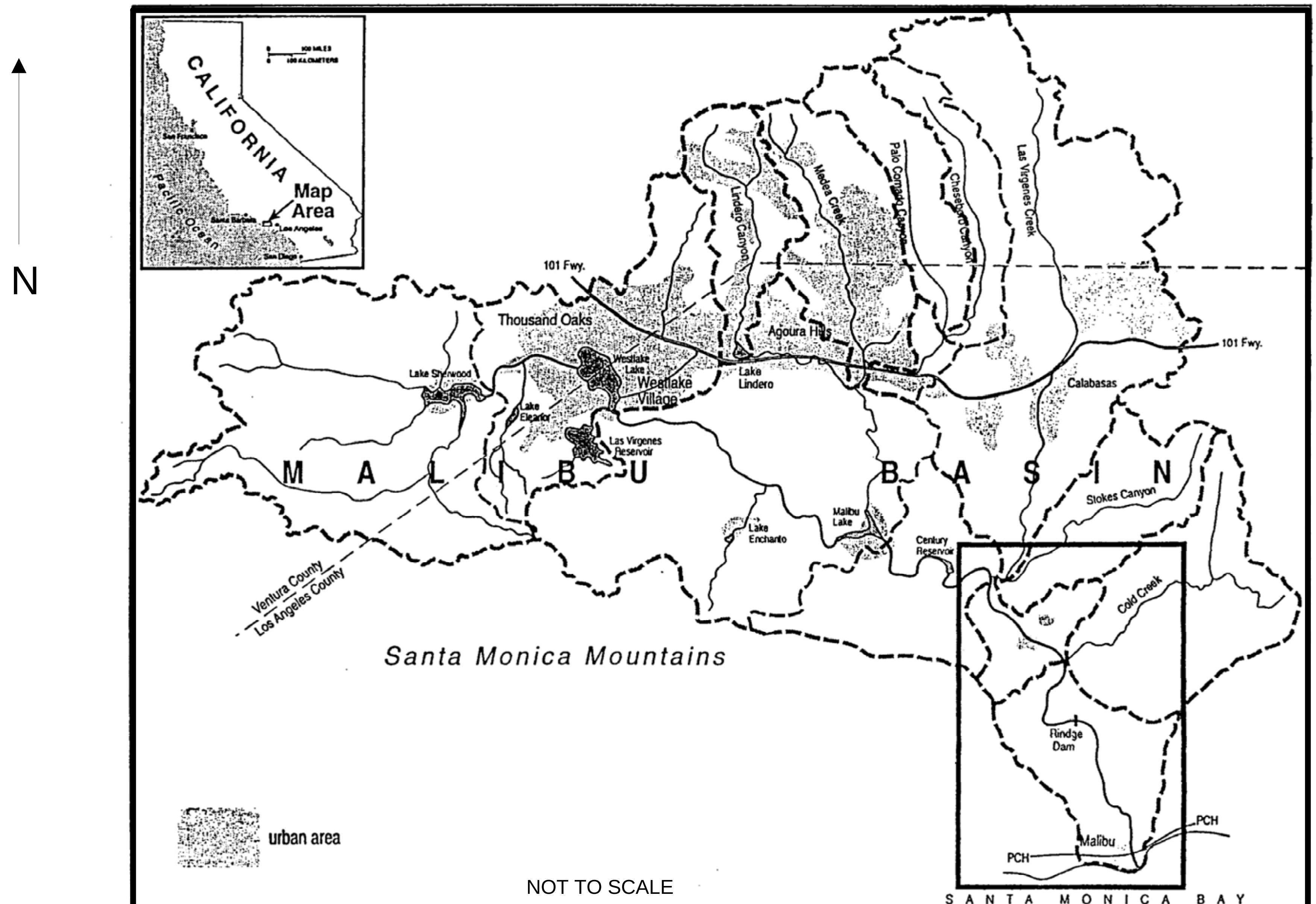


Figure 2 - Map showing top of bedrock elevations.

McDonald Morrissey ASSOCIATES, Inc.



Modified from Ambrose and Orme, 2000

Figure 3 - Map showing drainage area for Malibu Creek.

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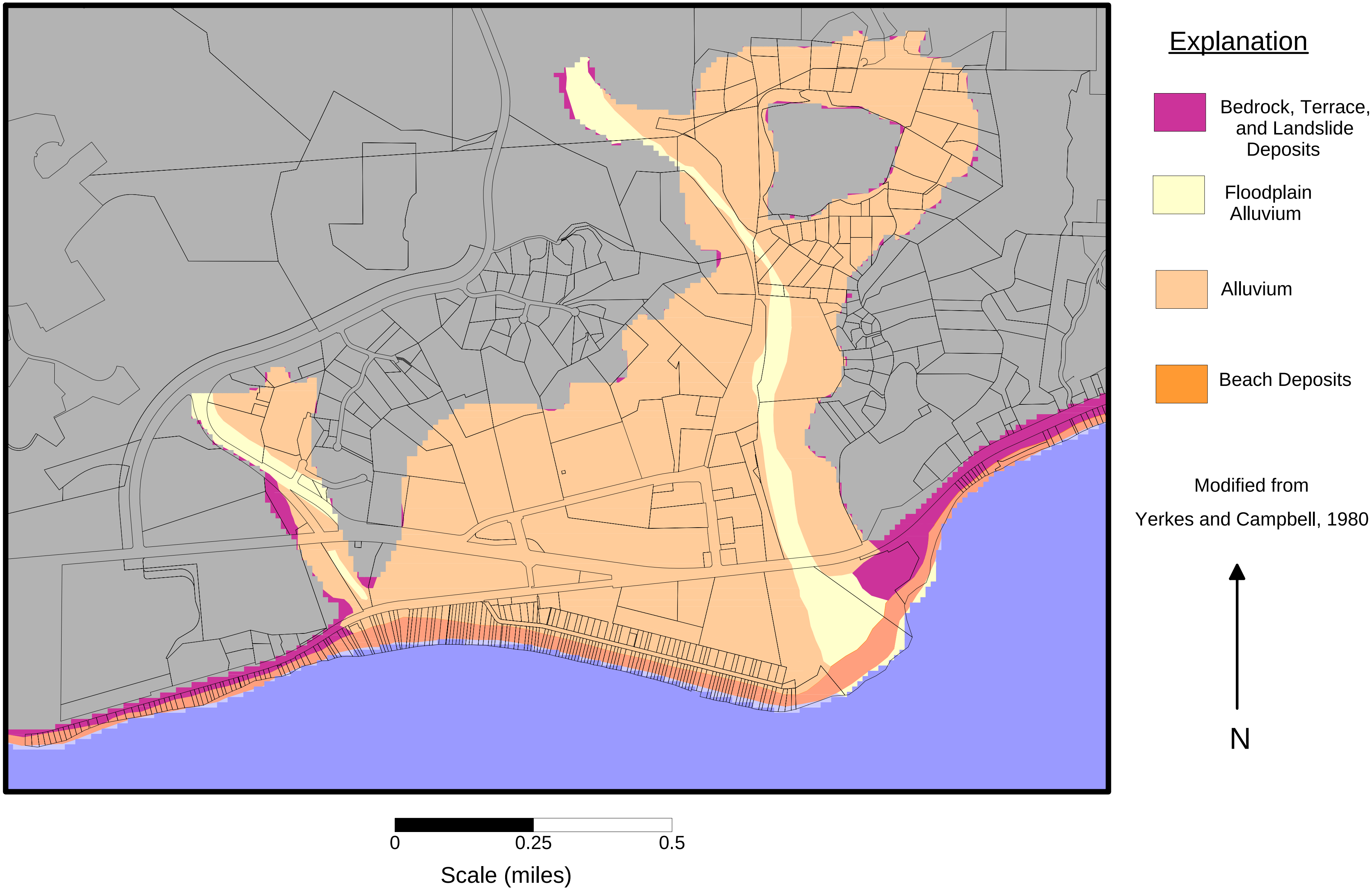

Figure 4 - Map showing the extent of alluvium along Malibu Creek near the Malibu Civic Center area.

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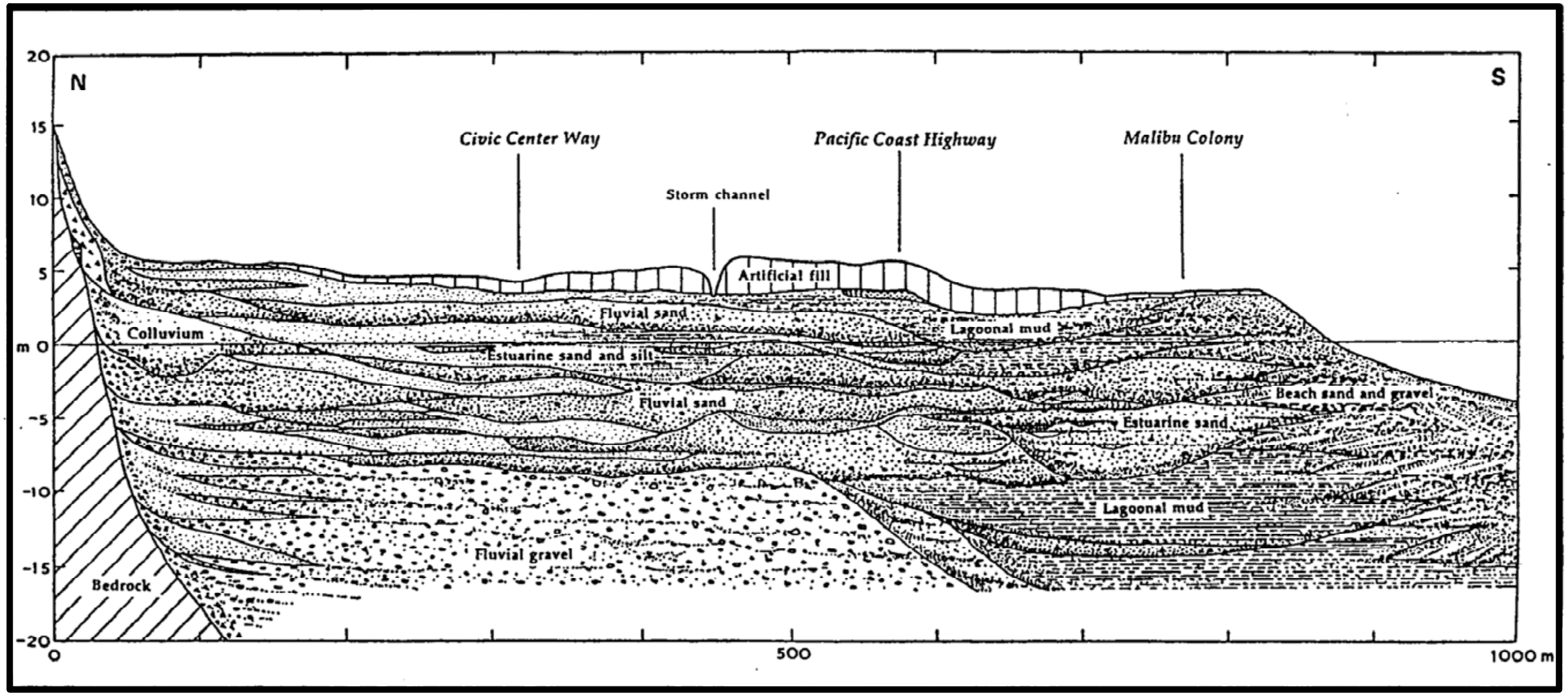

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Figure 5a - North-South cross-section showing sub-surface stratigraphy of Malibu alluvium.

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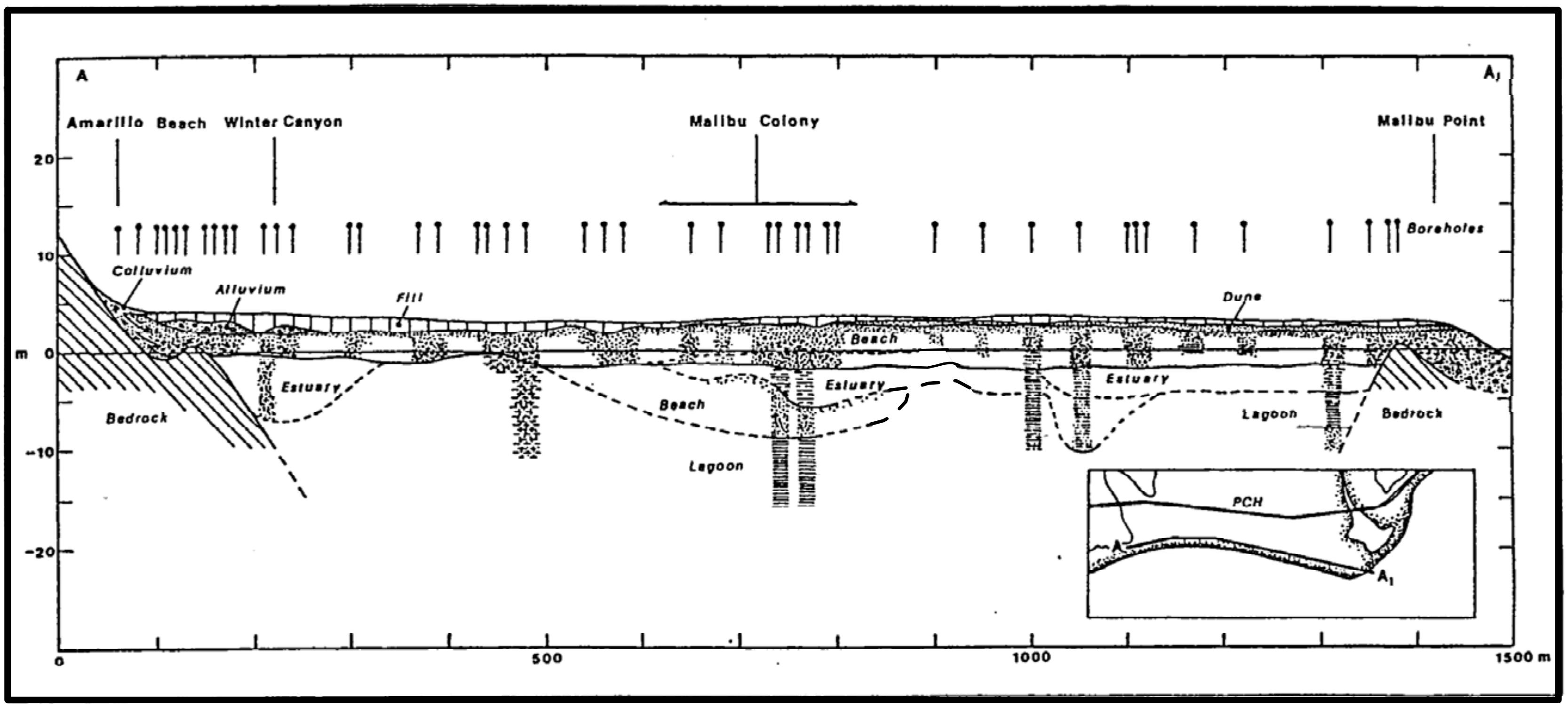

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Figure 5b - East-West cross-section showing sub-surface stratigraphy of Malibu alluvium.

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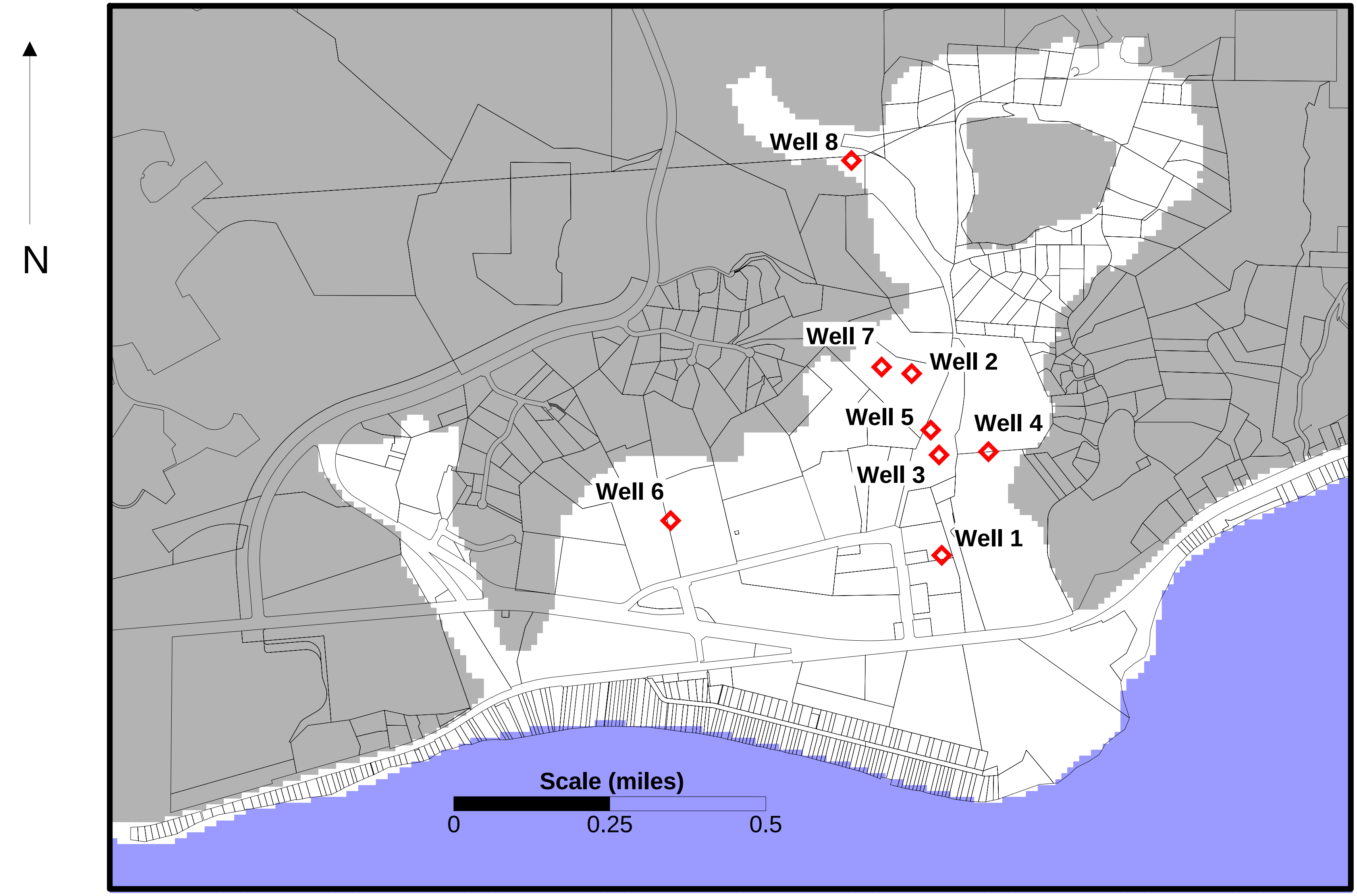

Figure 6 - Map showing locations of former Malibu Bay Water Company supply wells in Malibu alluvium.

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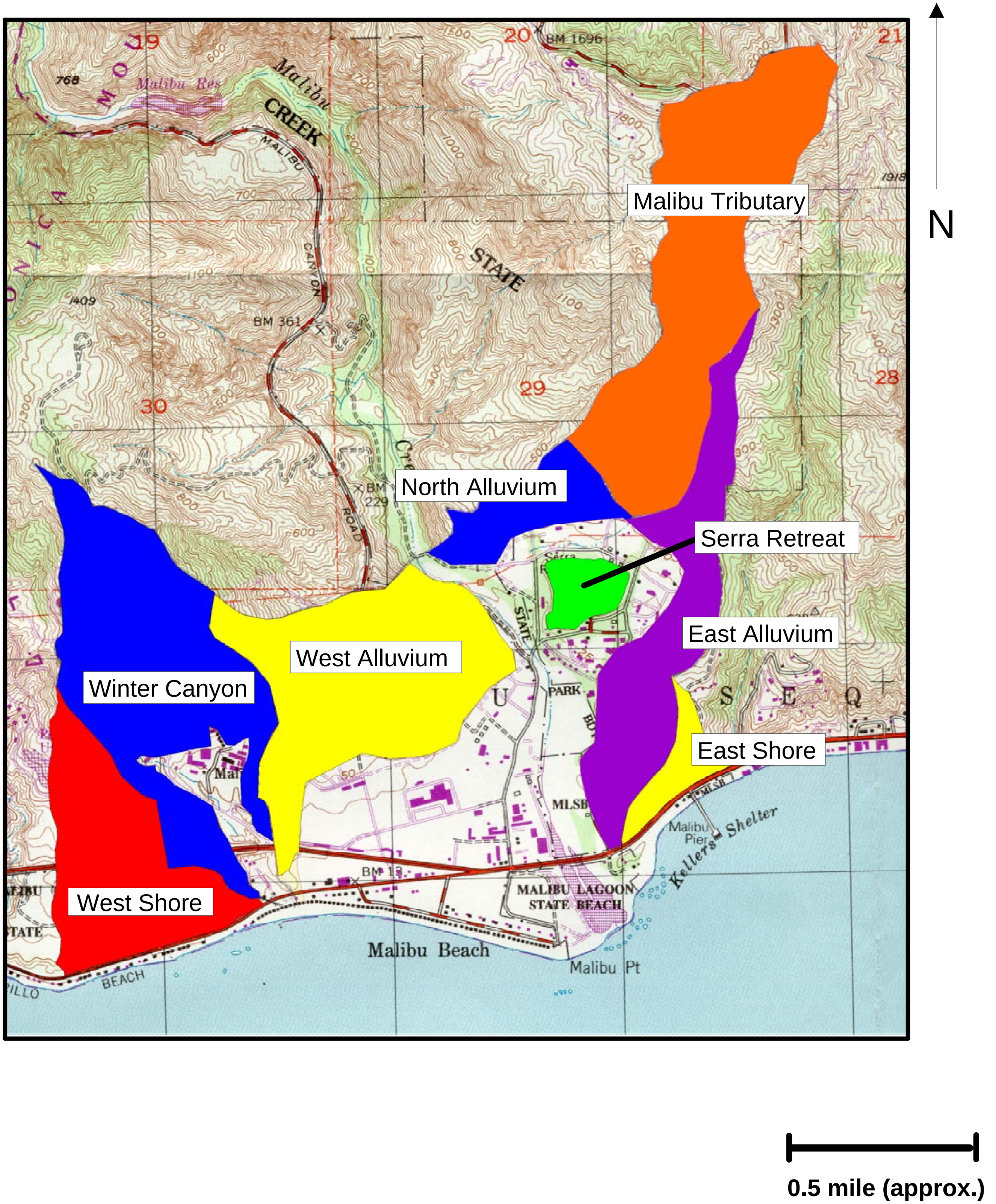

Figure 7 - Map showing upland areas contributing recharge to Malibu alluvium

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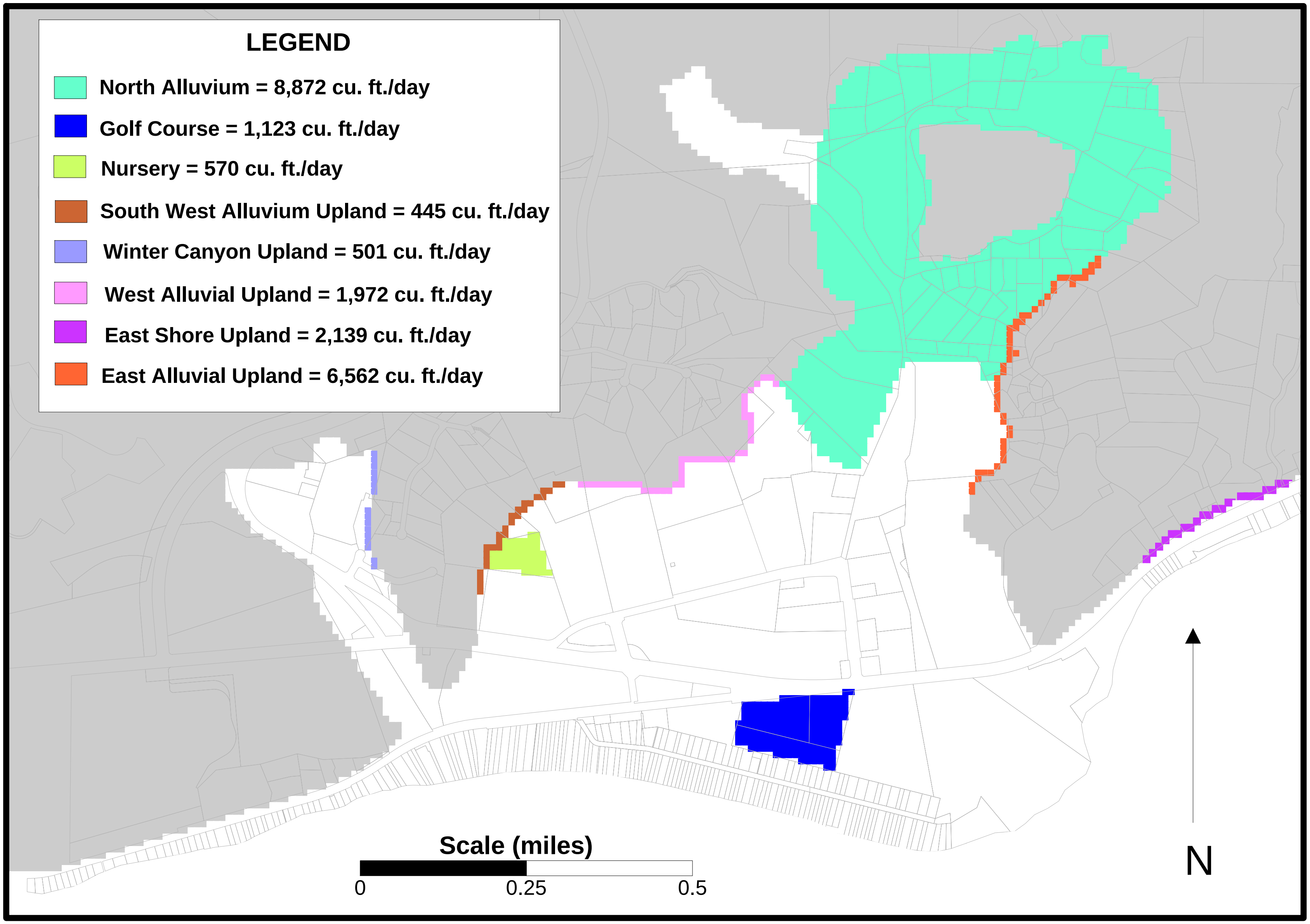

Figure 8 - Map showing estimated rates of ground water recharge from irrigation return.

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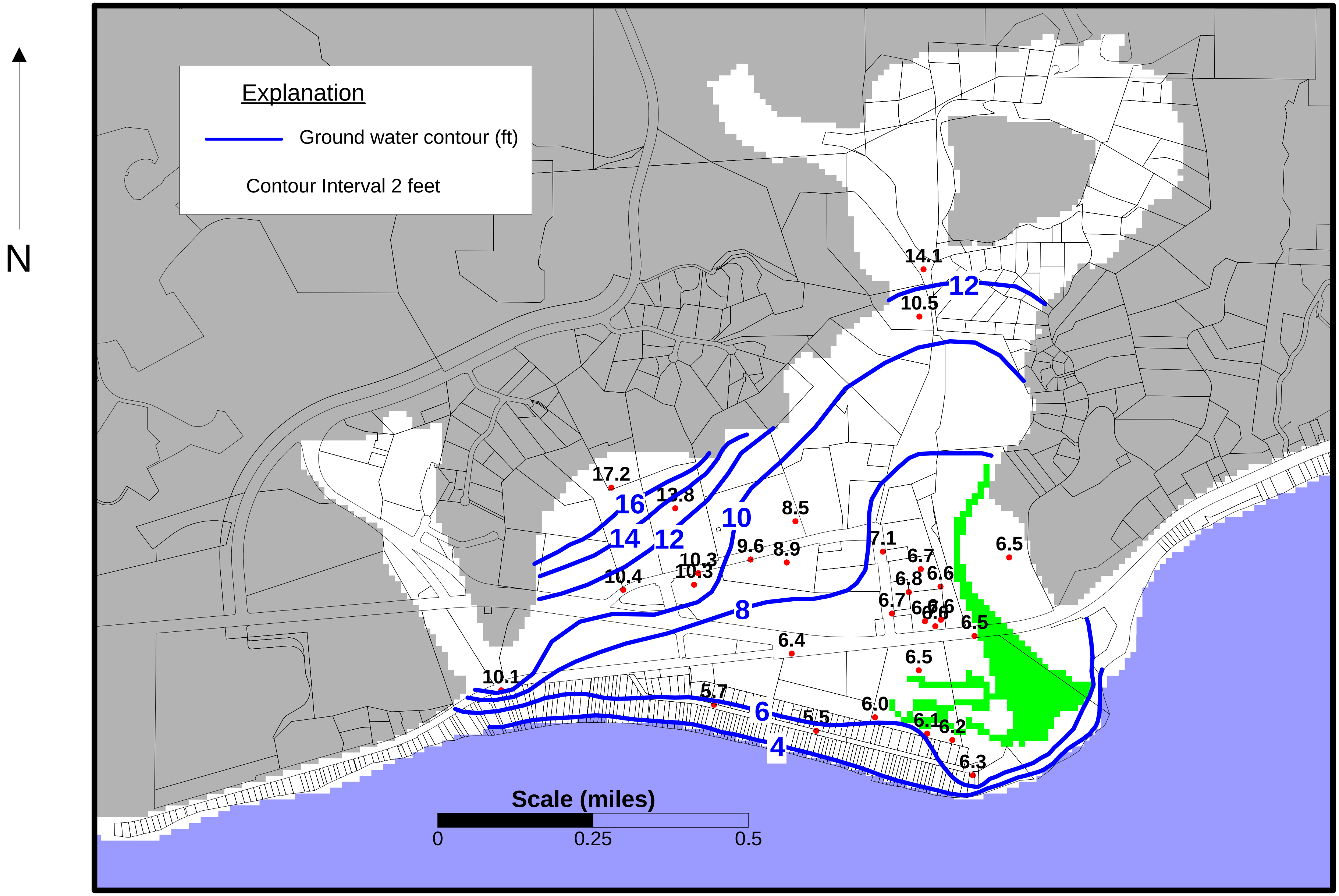

Figure 9 - Map showing water levels measured on September 25, 2003 during flooded lagoon condition.

McDonald Morrissey Associates, Inc.

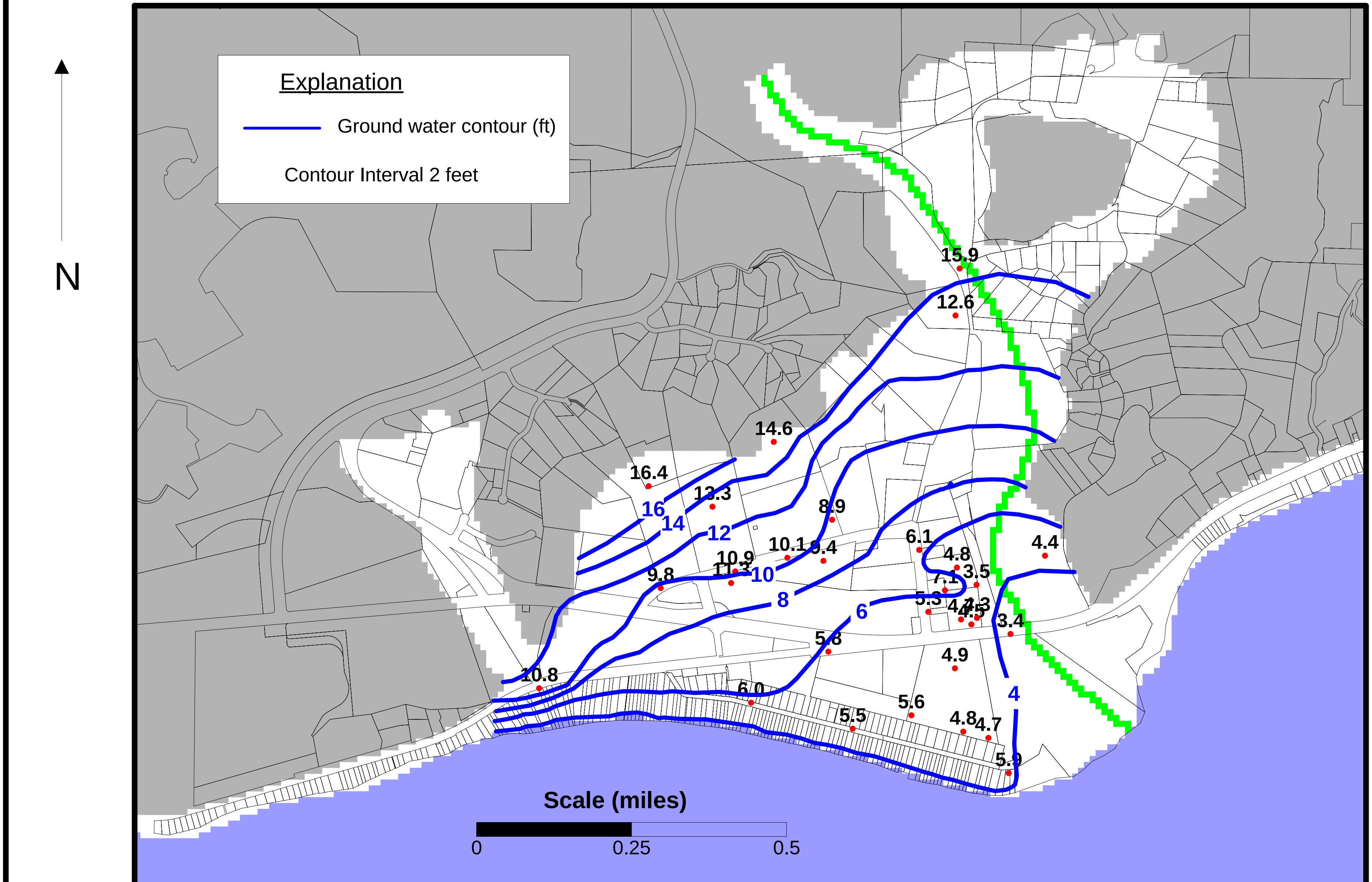

Figure 10 - Map showing water levels measured on March 9, 2004 during breached lagoon condition.

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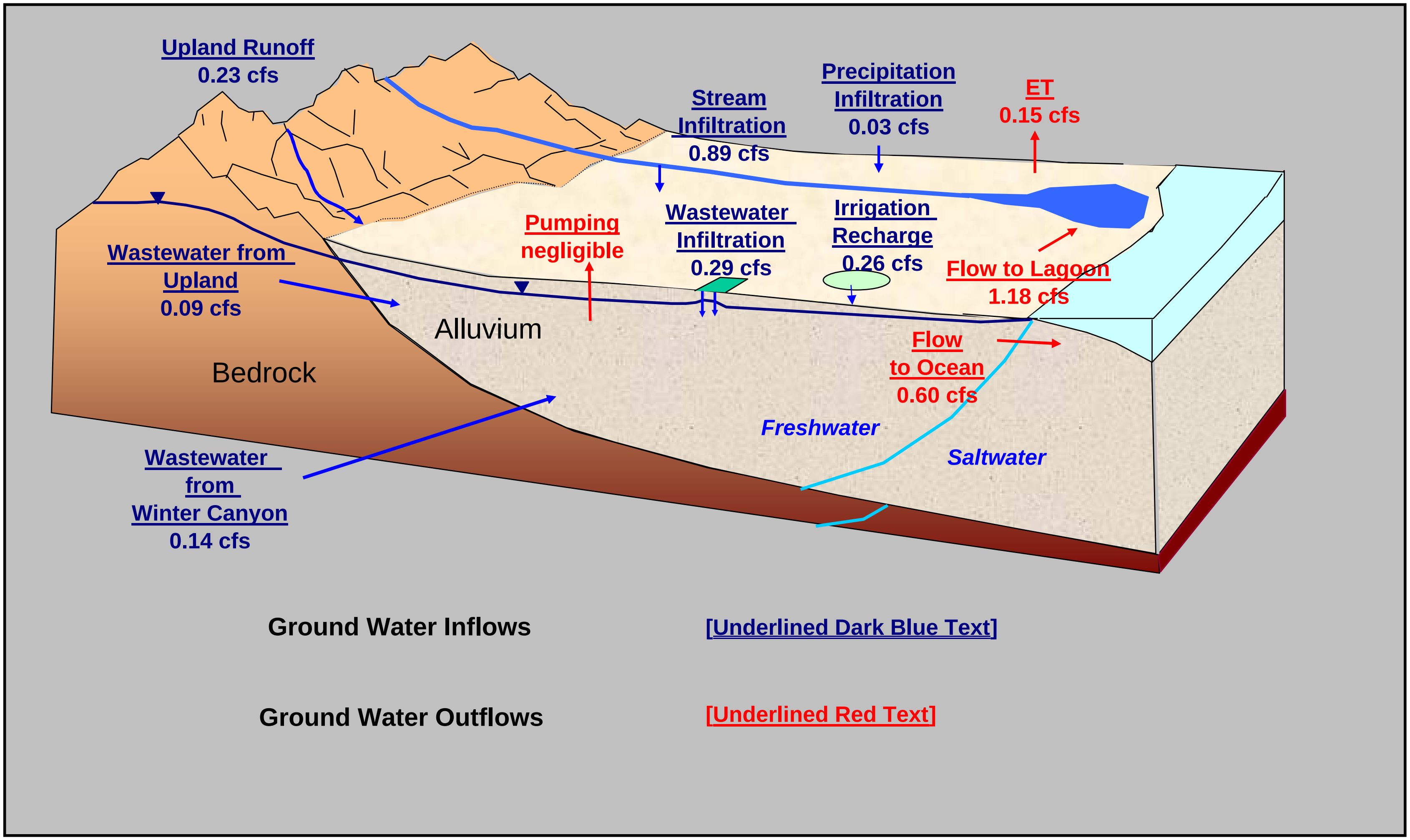

Figure 11 - Generalized block diagram summarizing estimated average annual ground-water budget for the Malibu alluvium.

McDonald Morrissey ASSOCIATES, Inc.

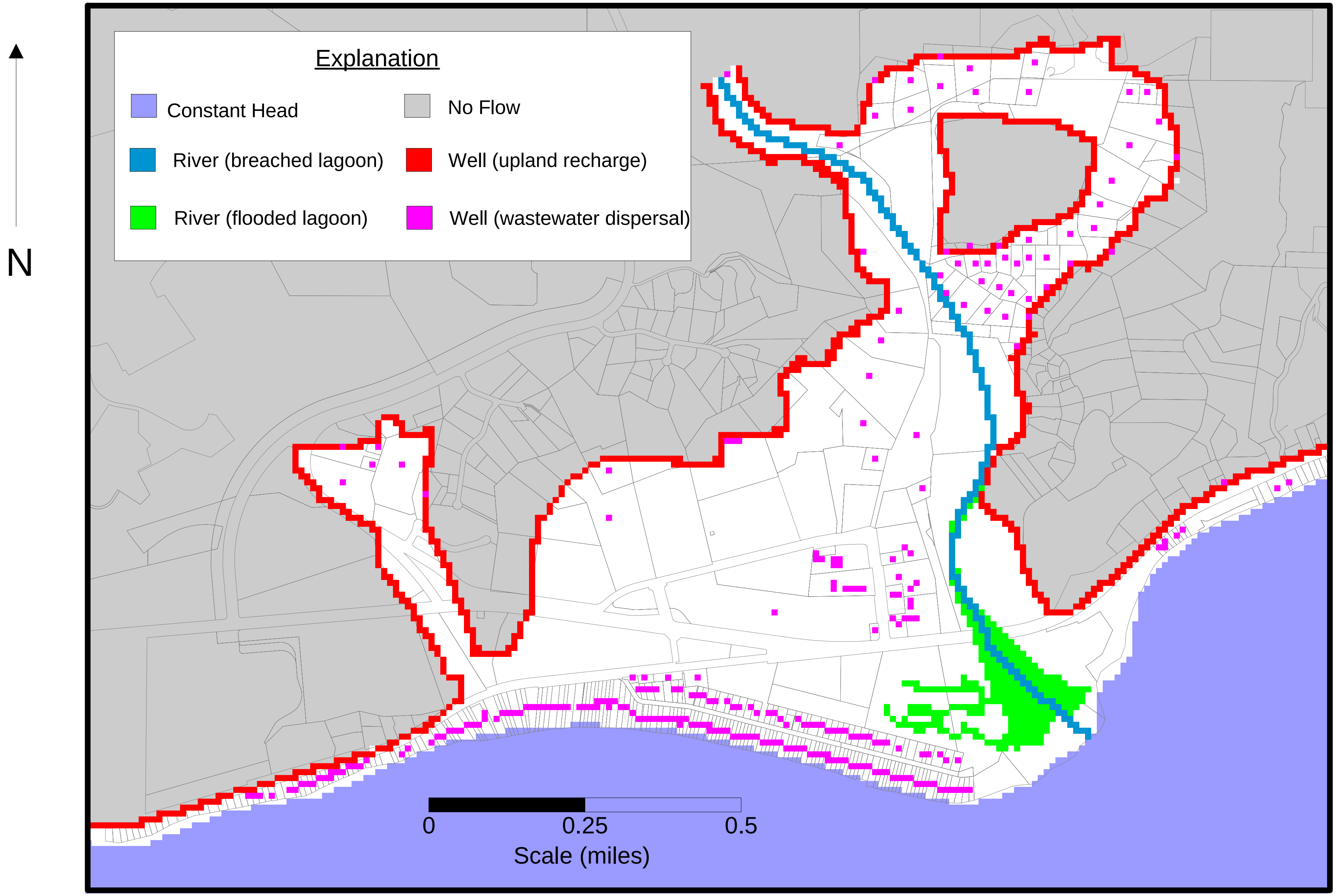

Figure 12 - Map showing boundary conditions for model layer 1

McDonald Morrissey ASSOCIATES, Inc.

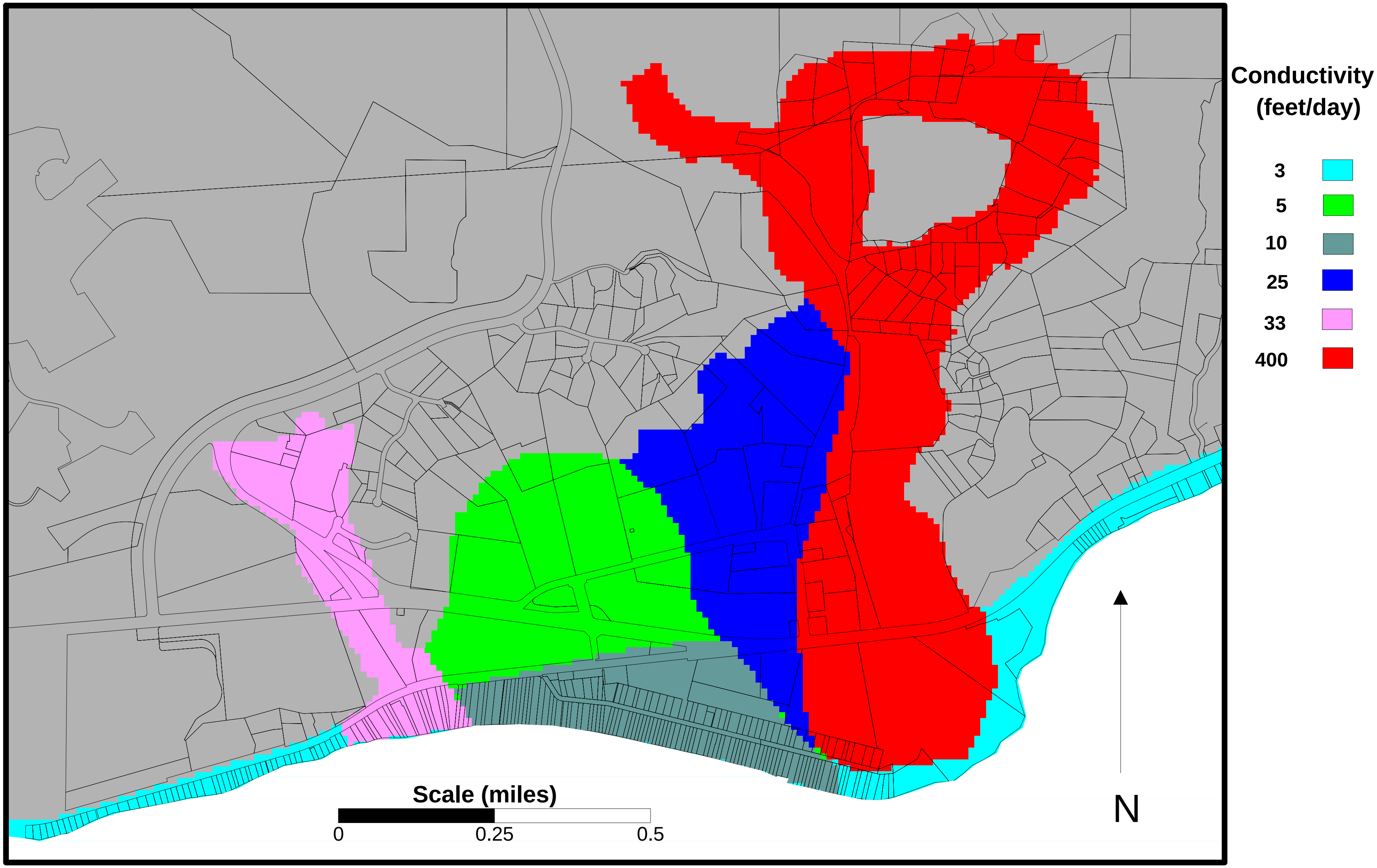

Figure 13 - Map showing hydraulic conductivity values for model layer 1

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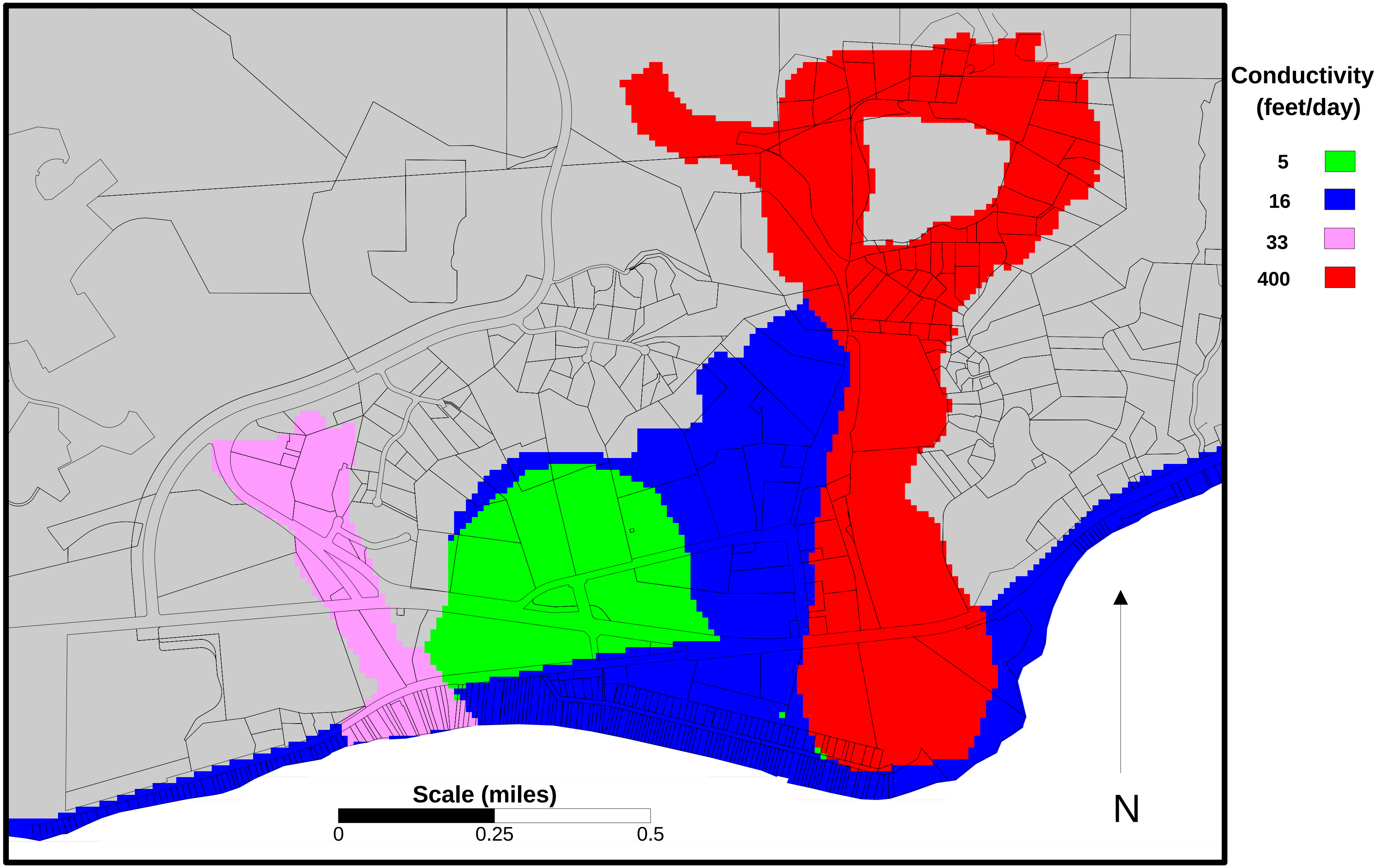

Figure 14 - Map showing hydraulic conductivity values for model layer 2

McDonald Morrissey ASSOCIATES, Inc.

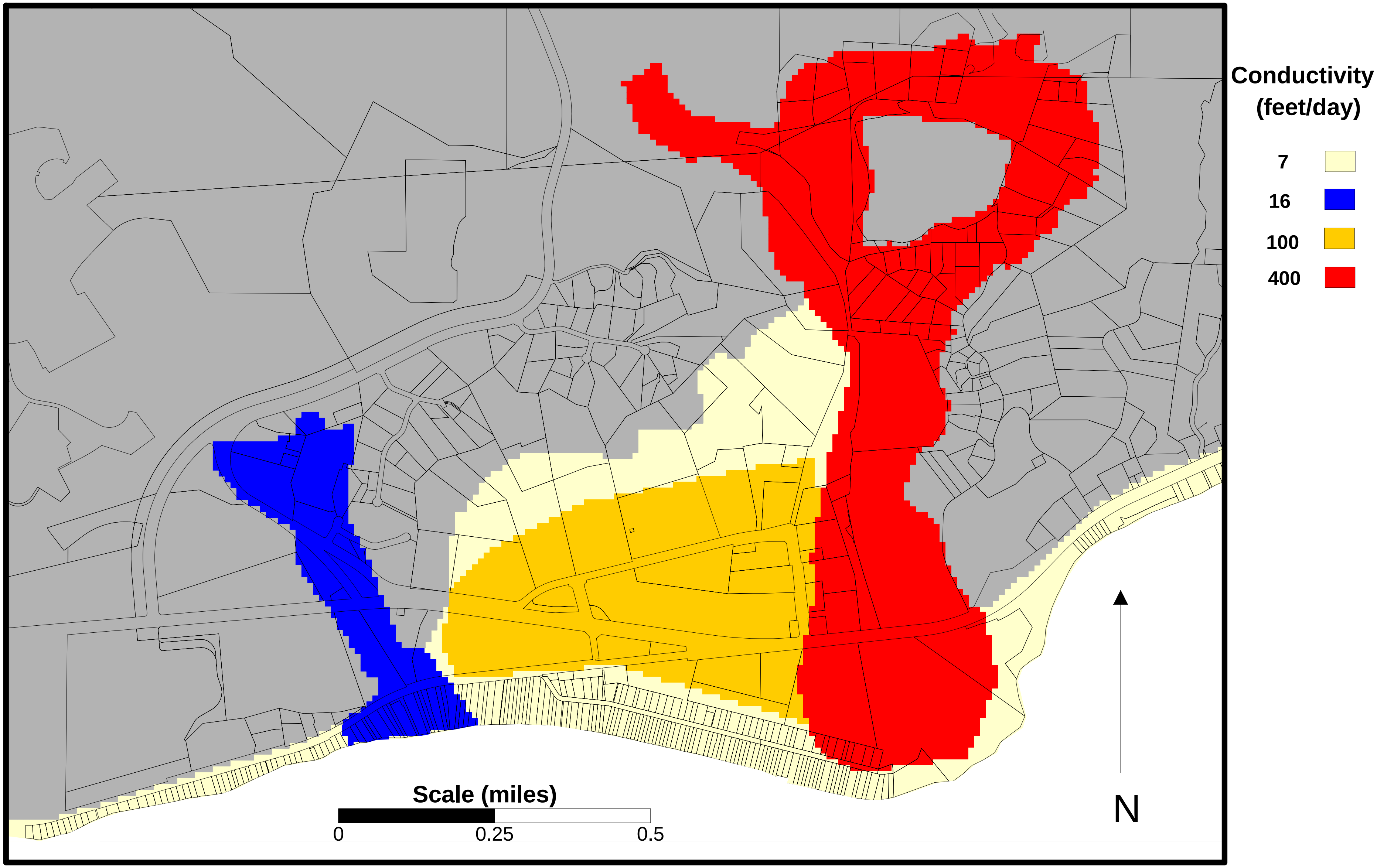

Figure 15 - Map showing hydraulic conductivity values for model layer 3

McDonald Morrissey ASSOCIATES, Inc.

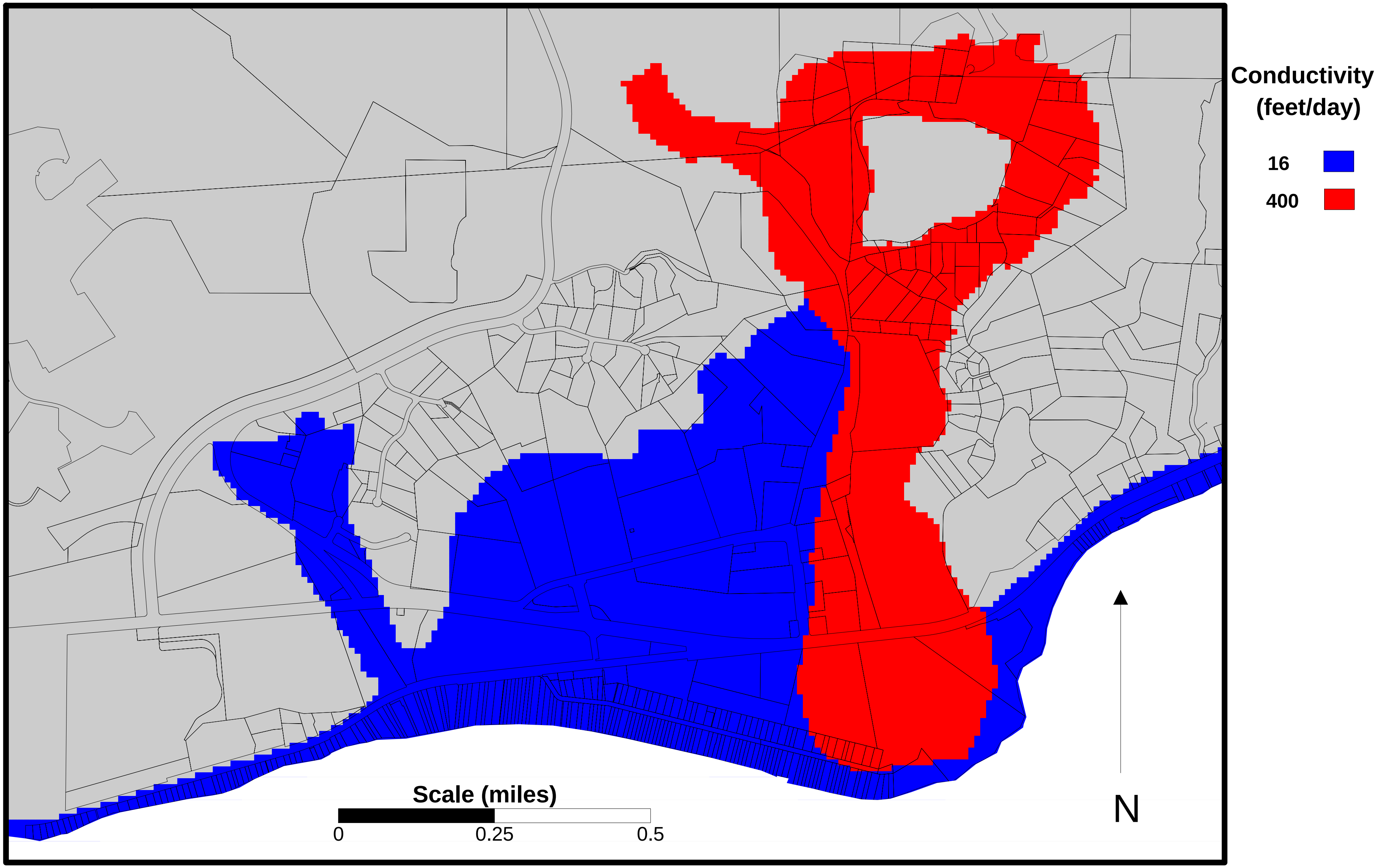

Figure 16 - Map showing hydraulic conductivity values for model layer 4

McDonald Morrissey ASSOCIATES, Inc.

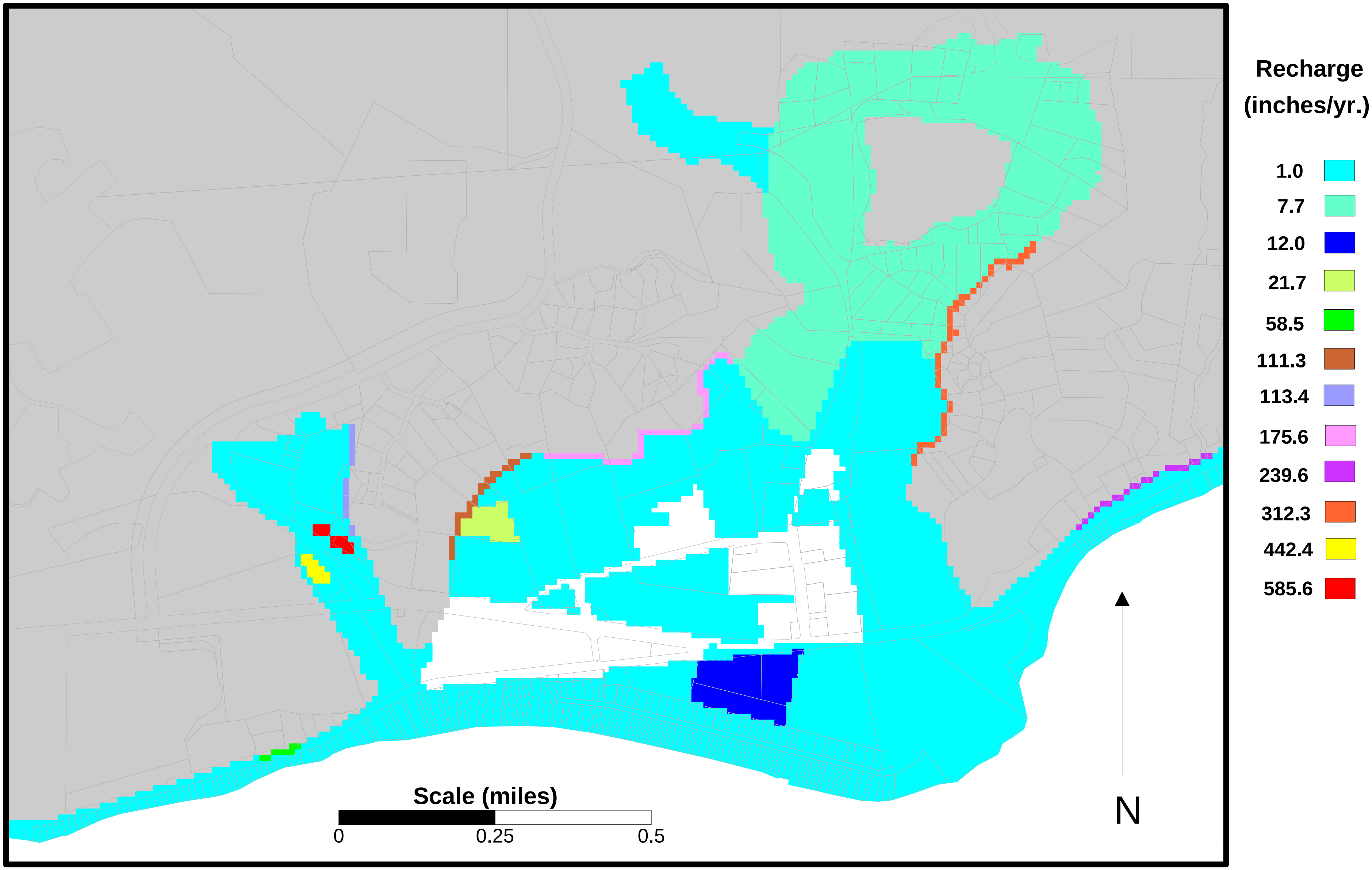

Figure 17 - Map showing locations and modeled rates of recharge

McDonald Morrissey ASSOCIATES, Inc.

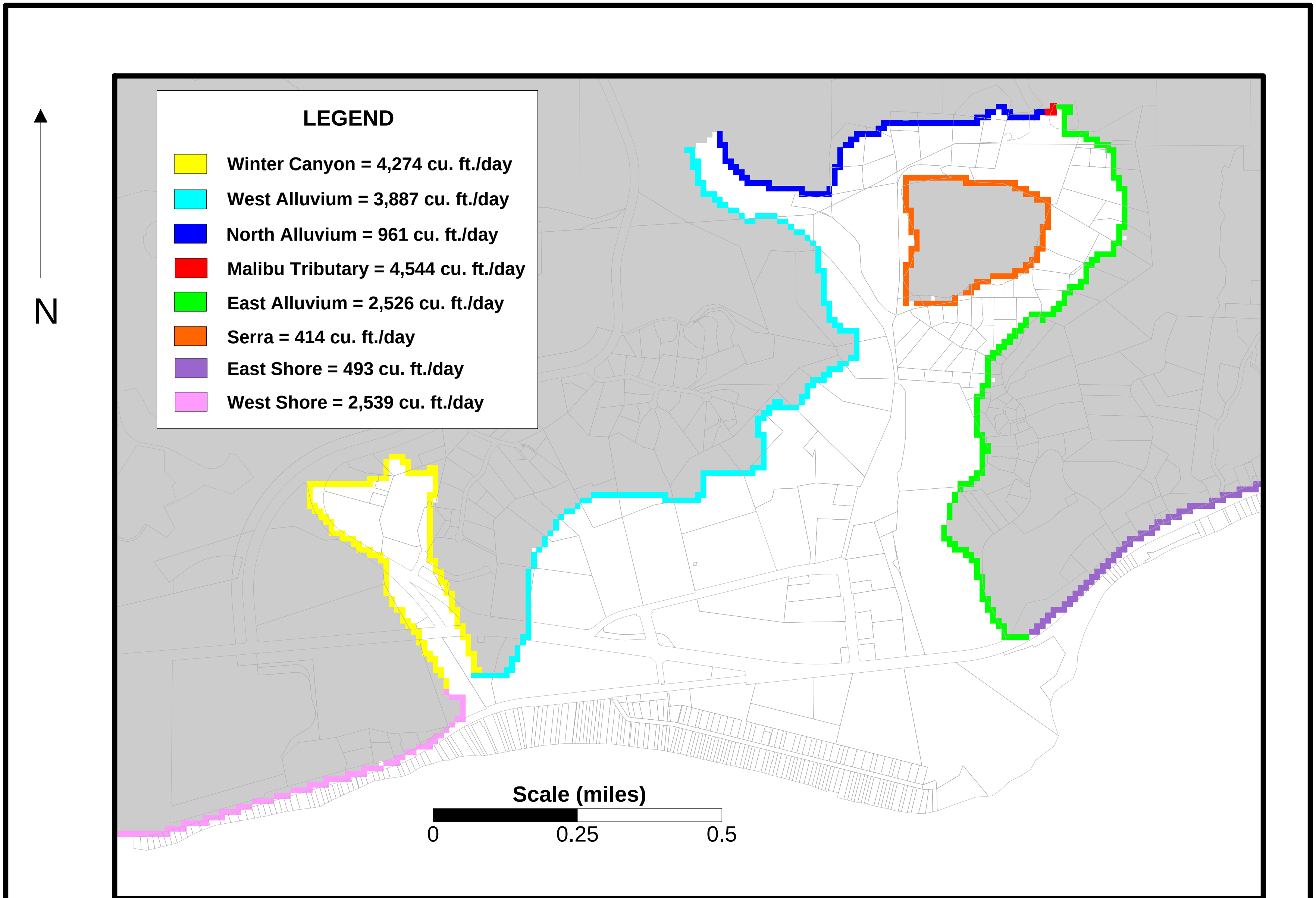

Figure 18 - Map showing locations and modeled rates of recharge from upland runoff.

McDonald Morrissey ASSOCIATES, Inc.

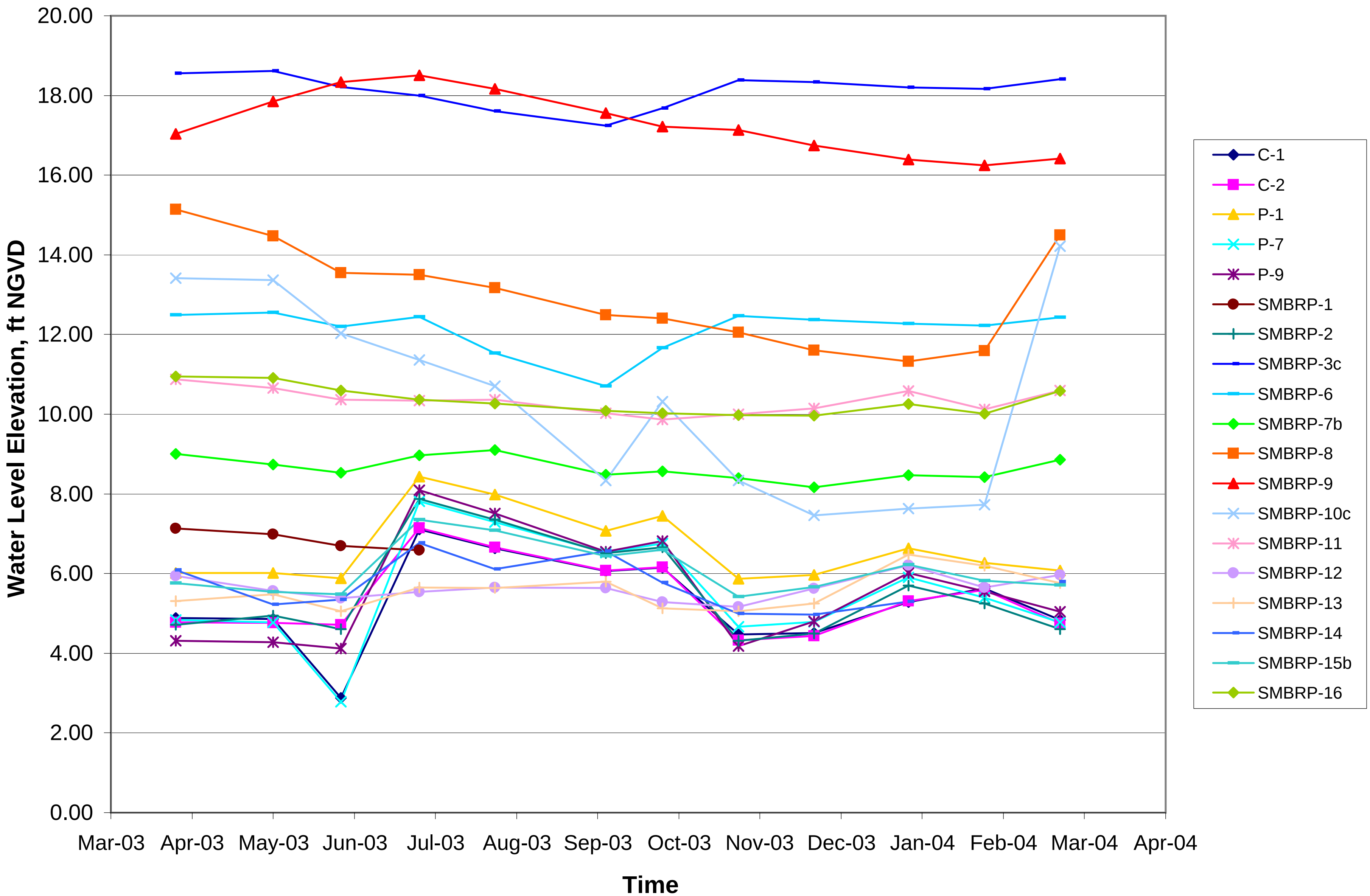

Figure 19 - Graph showing water level hydrographs collected from wells in the monthly monitoring network for the period April, 2003 to April 2004.

McDonald Morrissey ASSOCIATES, Inc.

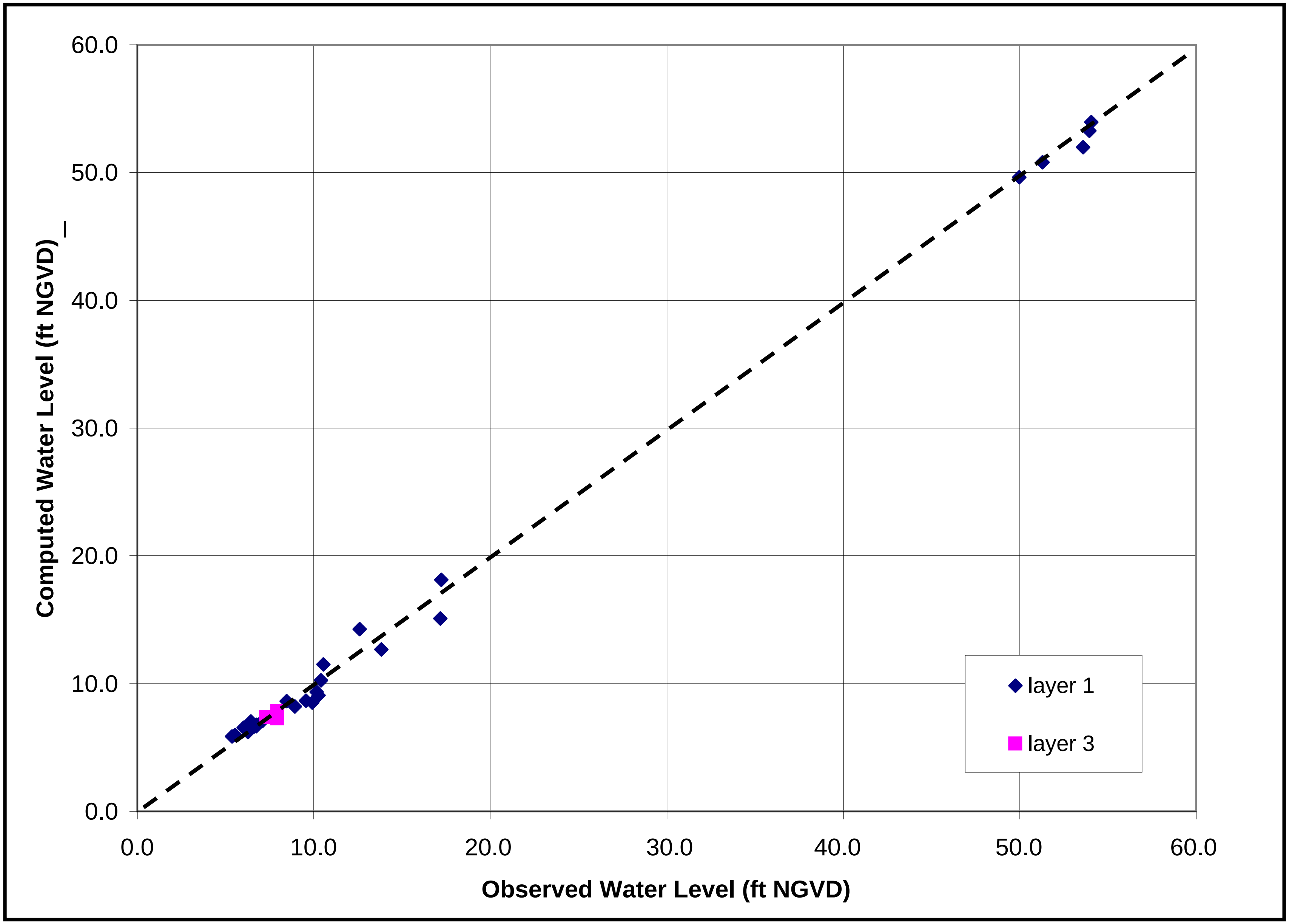

Figure 20 - Scatter plot showing comparison of model calculated water levels with those observed on September 25, 2003 with flooded lagoon

McDonald Morrissey ASSOCIATES, Inc.

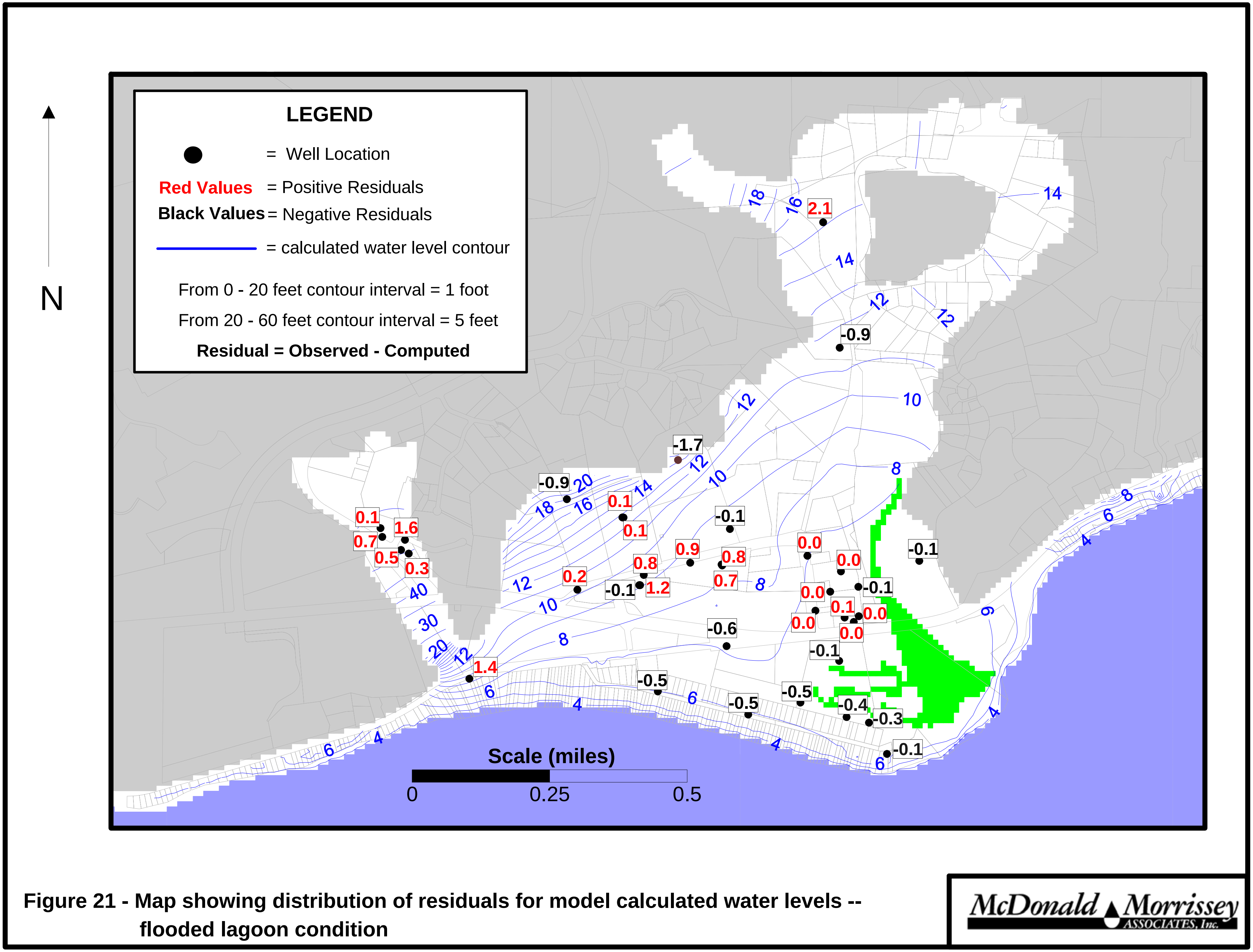

Figure 21 - Map showing distribution of residuals for model calculated water levels -- flooded lagoon condition

McDonald Morrissey ASSOCIATES, Inc.

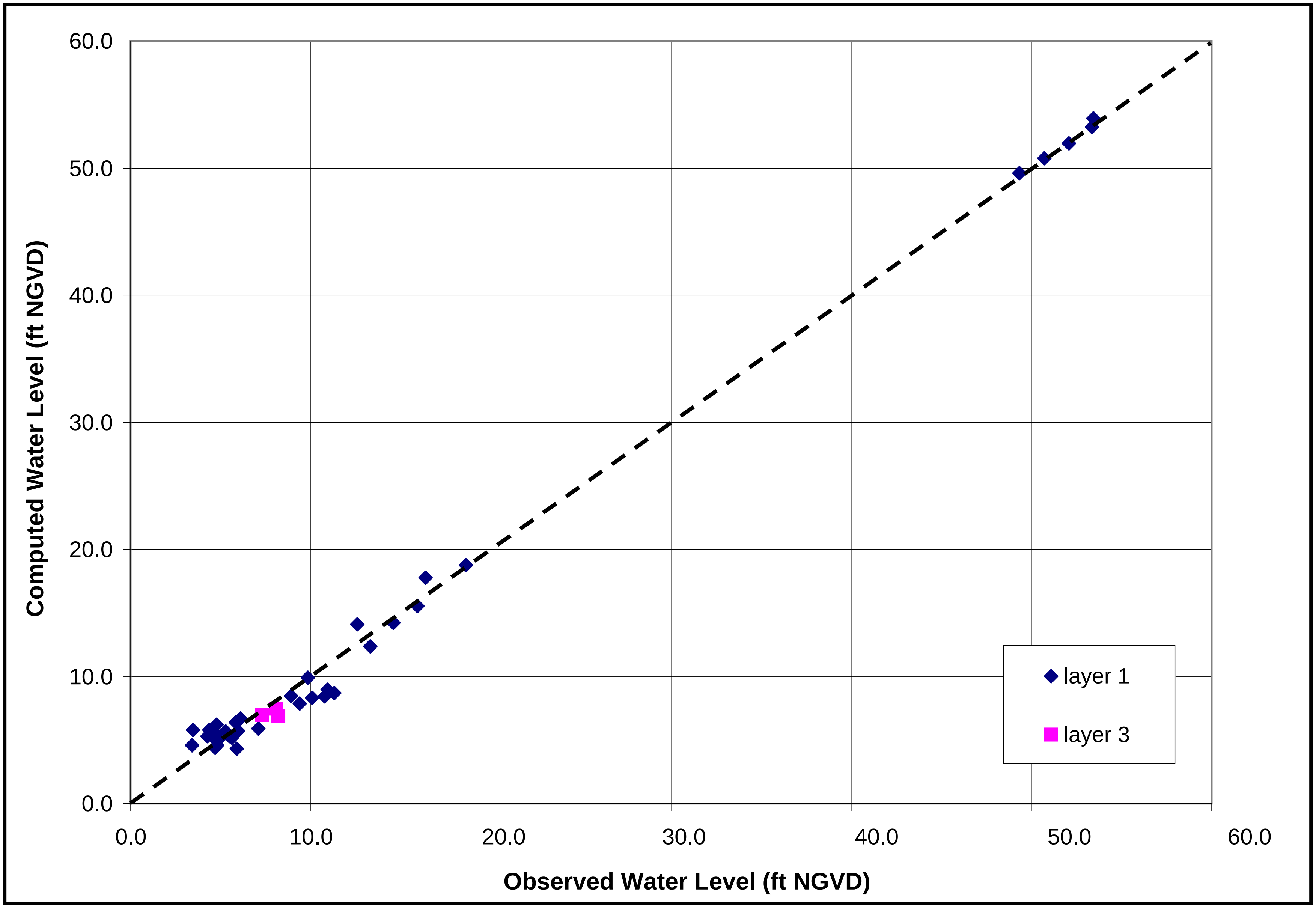

Figure 22 - Scatter plot showing comparison of model calculated water levels with those observed on March 9, 2004 with breached lagoon

McDonald Morrissey ASSOCIATES, Inc.

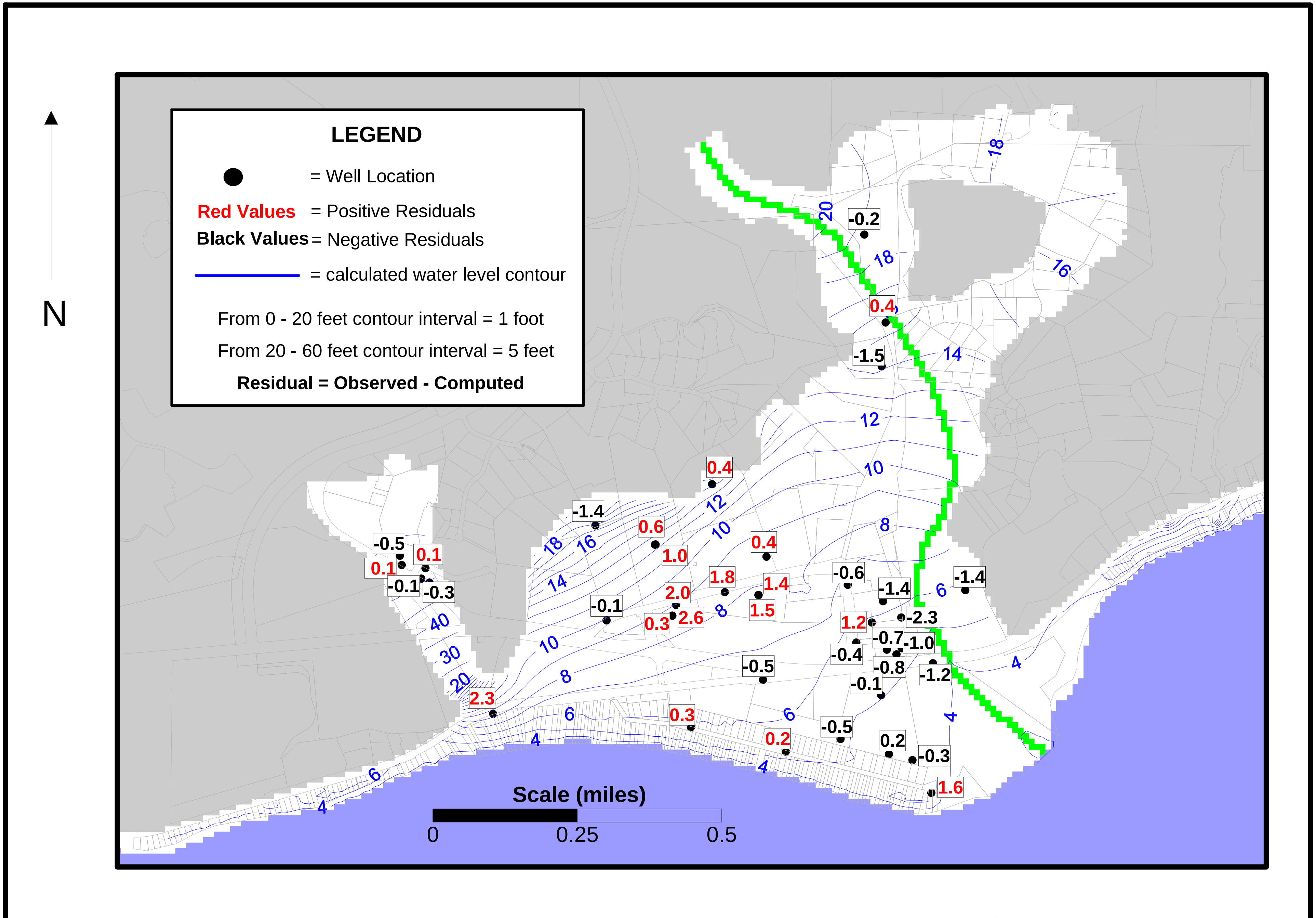

Figure 23 - Map showing distribution of residuals for model calculated water levels -- breached lagoon condition

McDonald Morrissey ASSOCIATES, Inc.

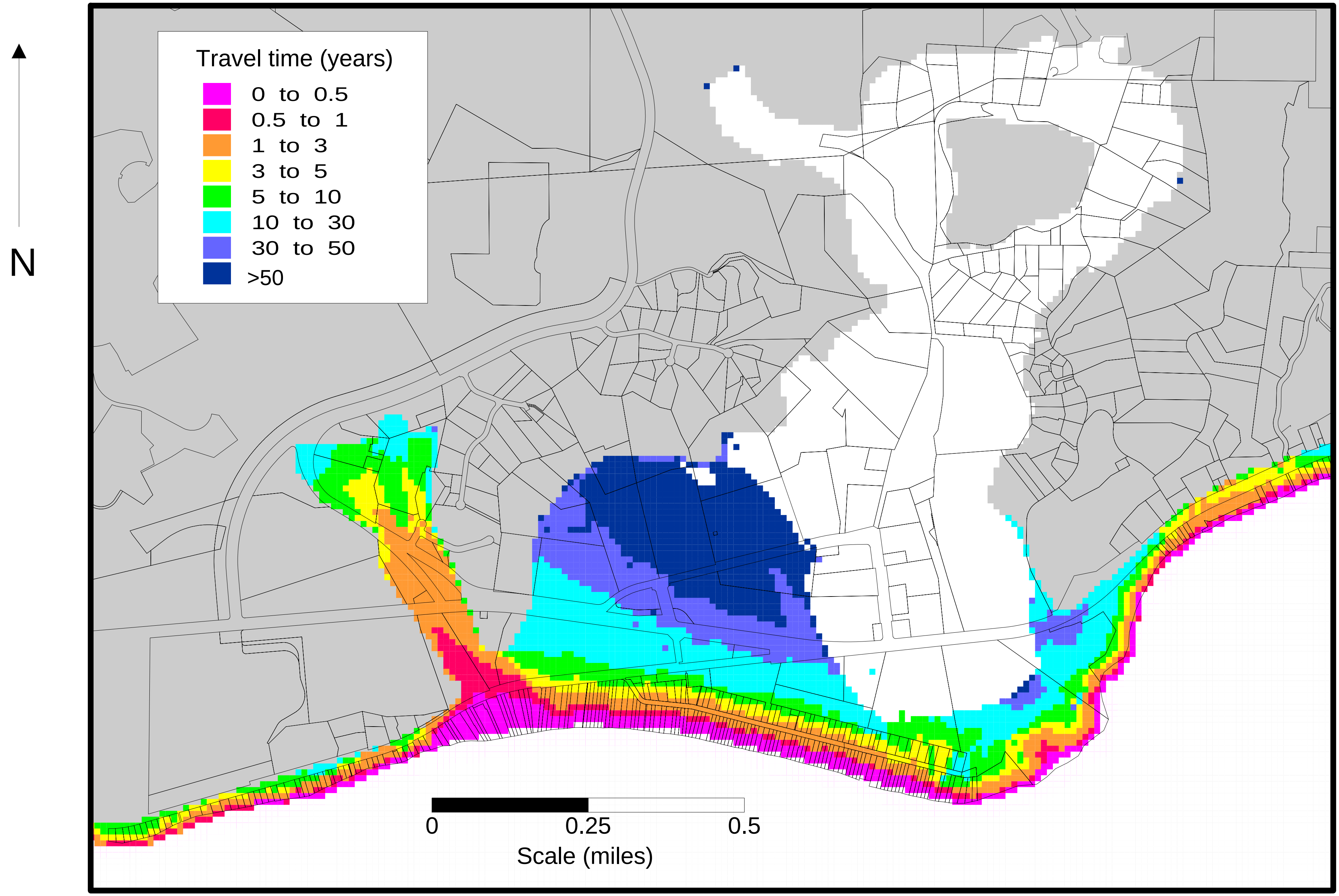

Figure 24 - Map showing model calculated contributing area and time-of-travel for the ocean with the flooded lagoon condition.

McDonald Morrissey ASSOCIATES, Inc.

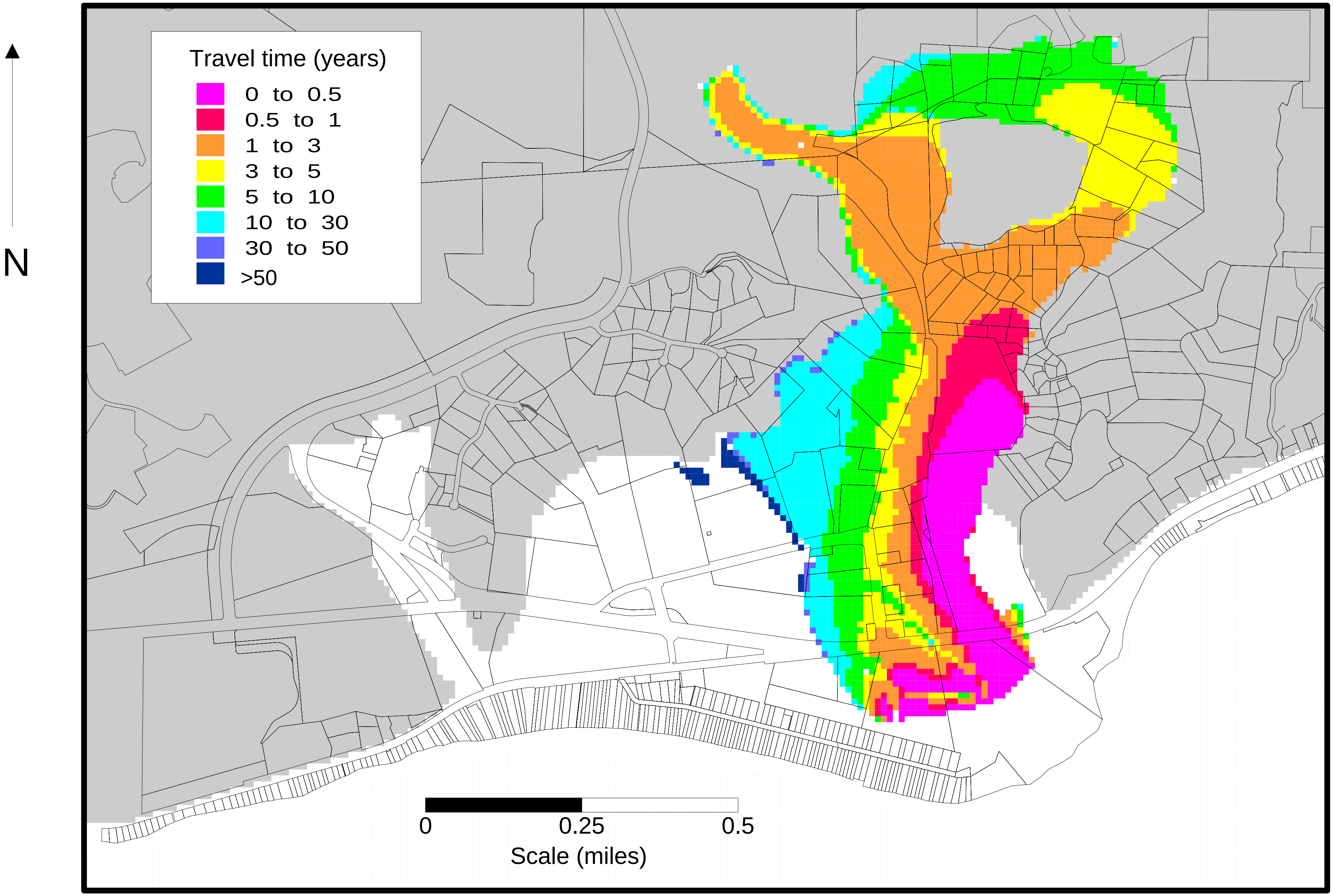

Figure 25 - Map showing model calculated contributing area and time-of-travel for the lagoon with the flooded lagoon condition.

McDonald Morrissey ASSOCIATES, Inc.

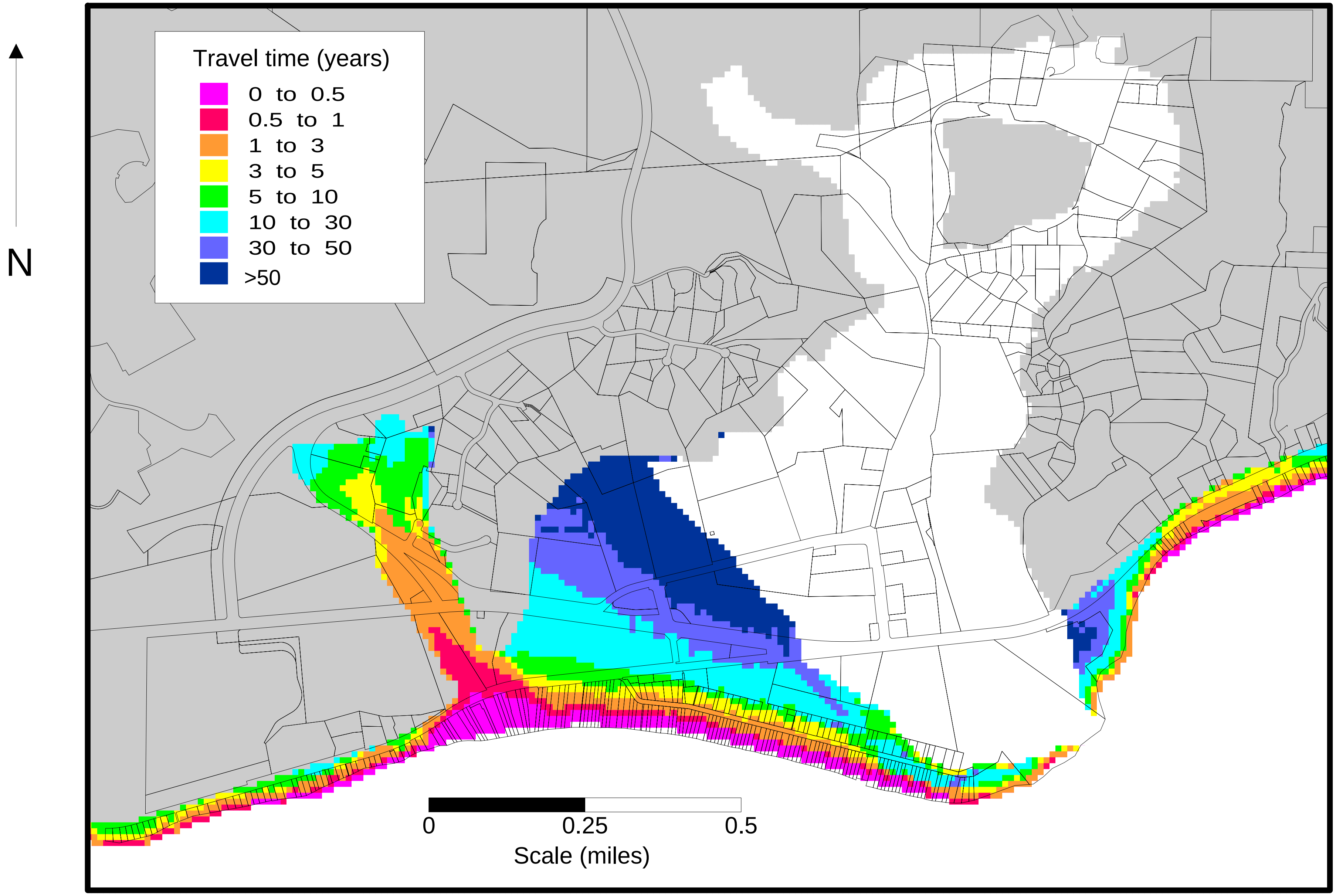

Figure 26 - Map showing model calculated contributing area and time-of-travel for the ocean with the breached lagoon condition.

McDonald Morrissey ASSOCIATES, Inc.

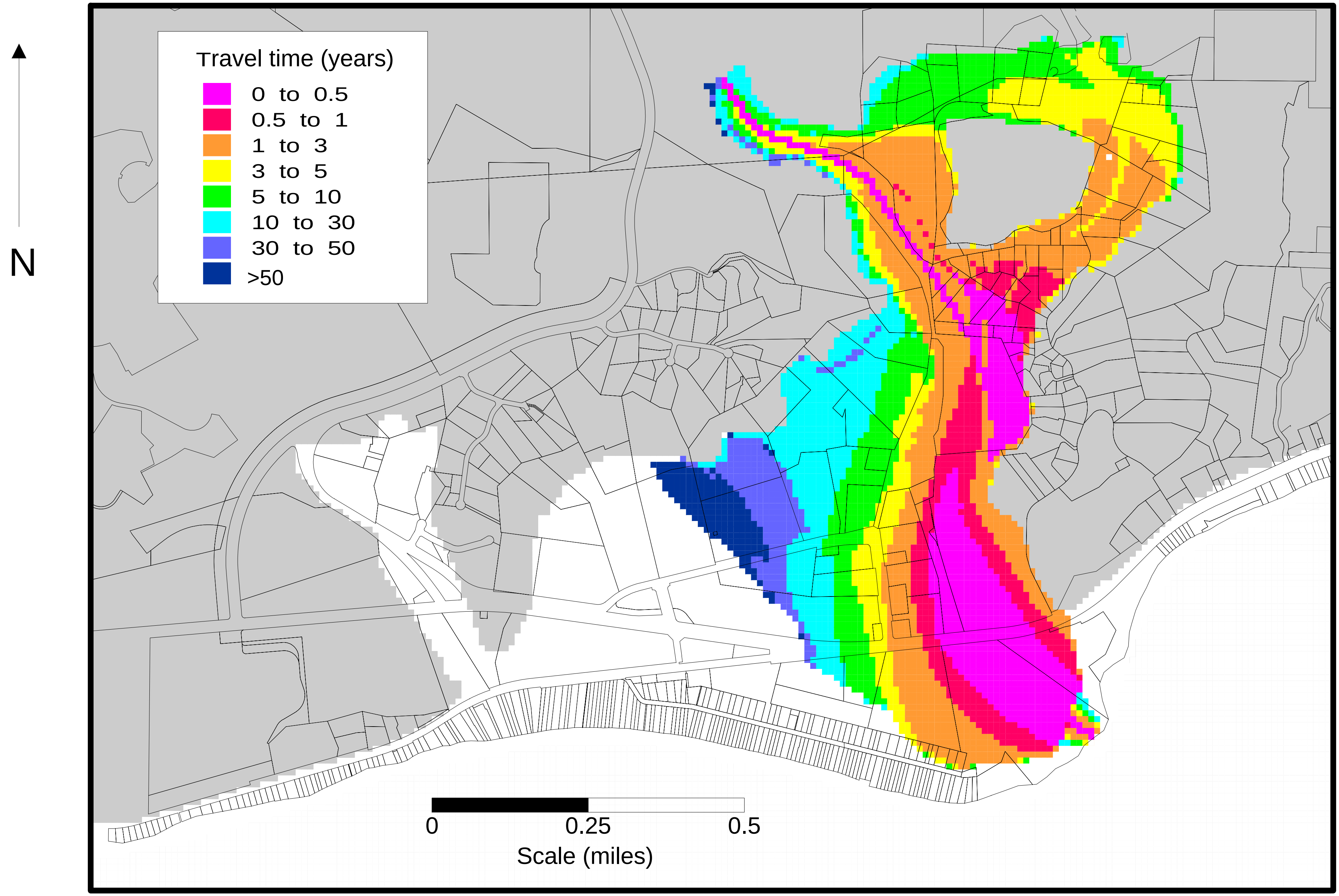

Figure 27 - Map showing model calculated contributing area and time-of-travel for the lagoon with the breached lagoon condition.

McDonald Morrissey ASSOCIATES, Inc.

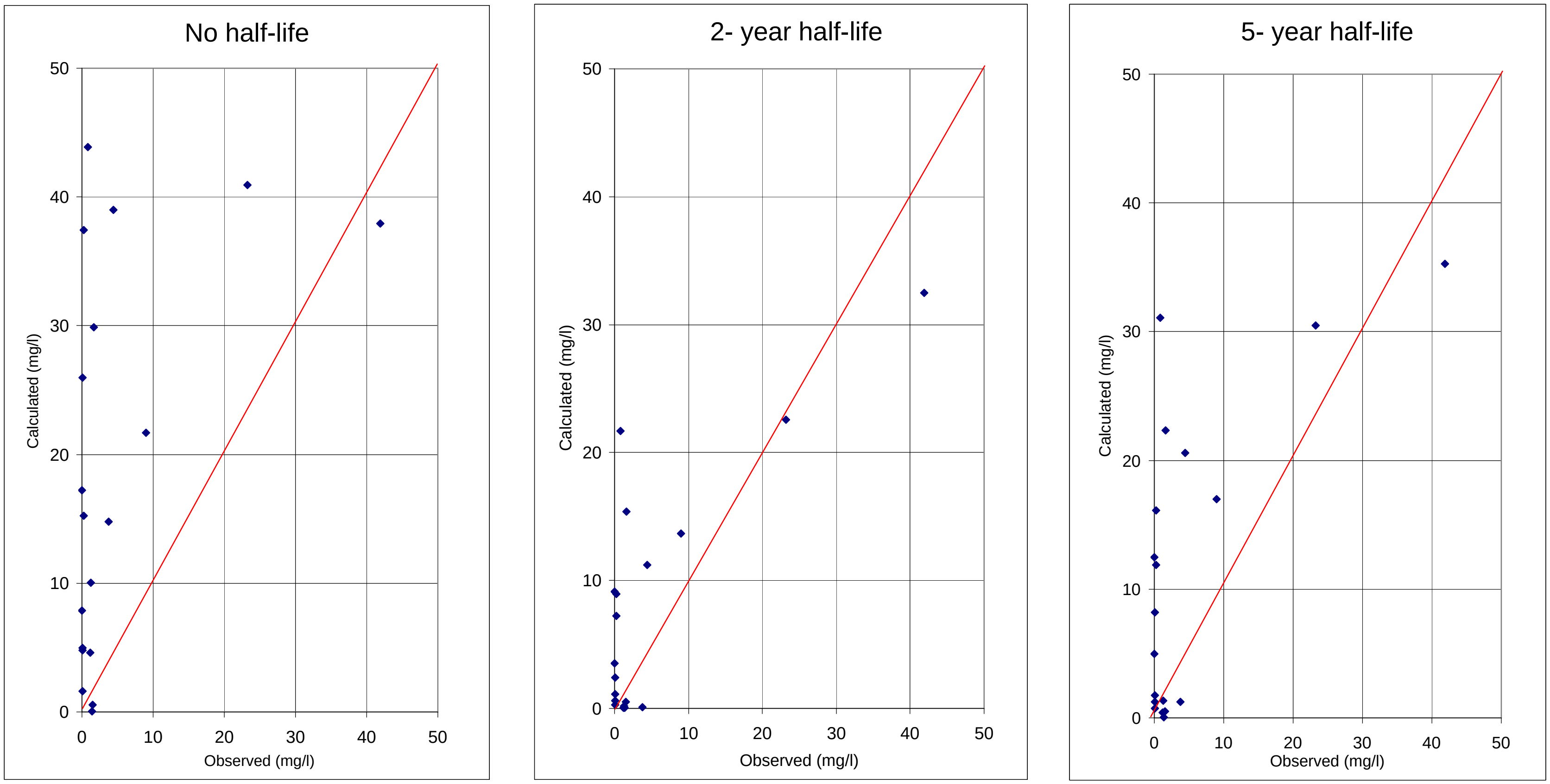

Figure 28 - Scatter plots showing comparison of model calculated and observed Nitrate levels with no degradation, 2-year half-life, and 5-year half-life.

McDonald Morrissey ASSOCIATES, Inc.

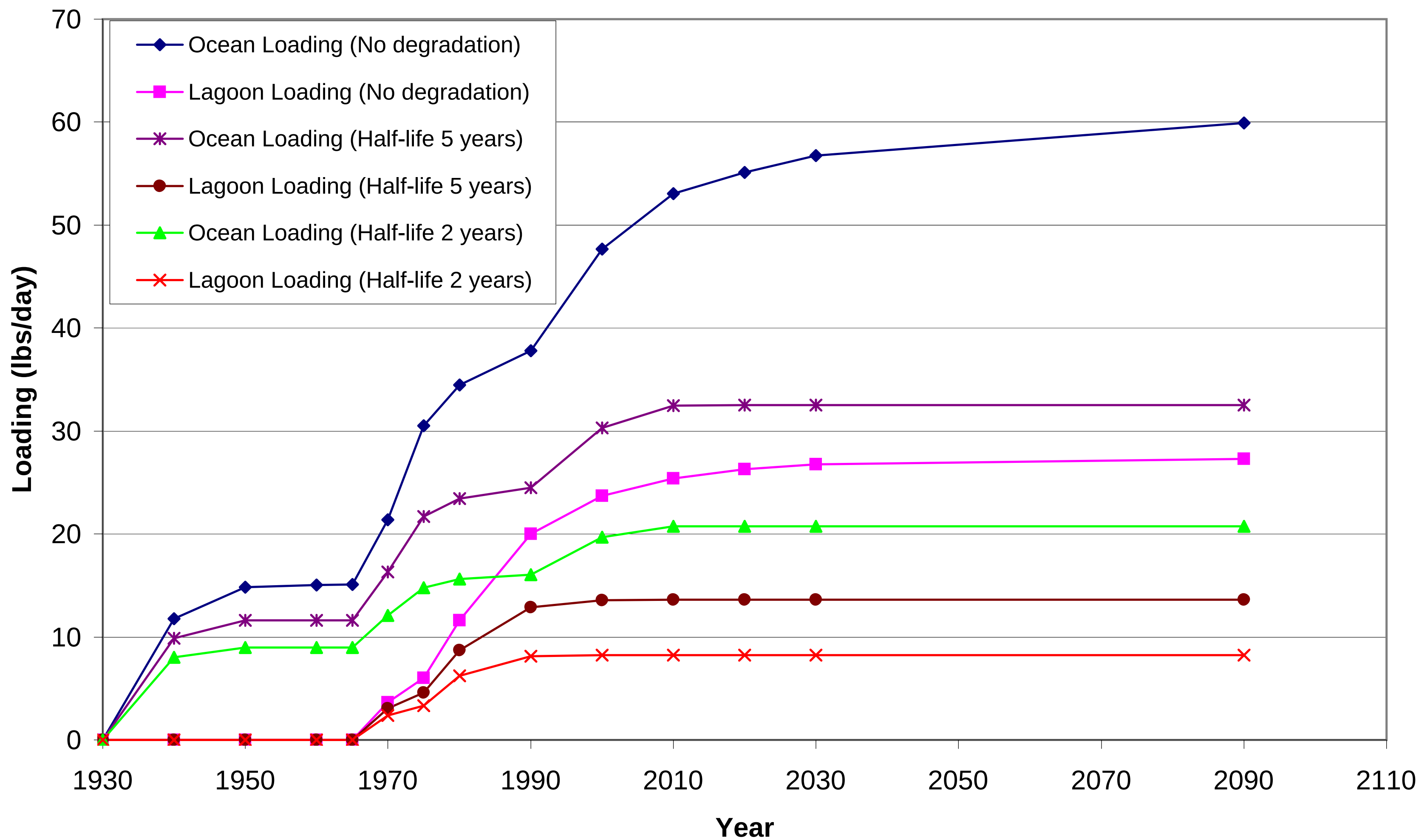

Figure 29 - Nitrate loading rates to the ocean and lagoon under flooded lagoon conditions, with no degredation, five-year half life and two-year half life.

McDonald Morrissey ASSOCIATES, Inc.

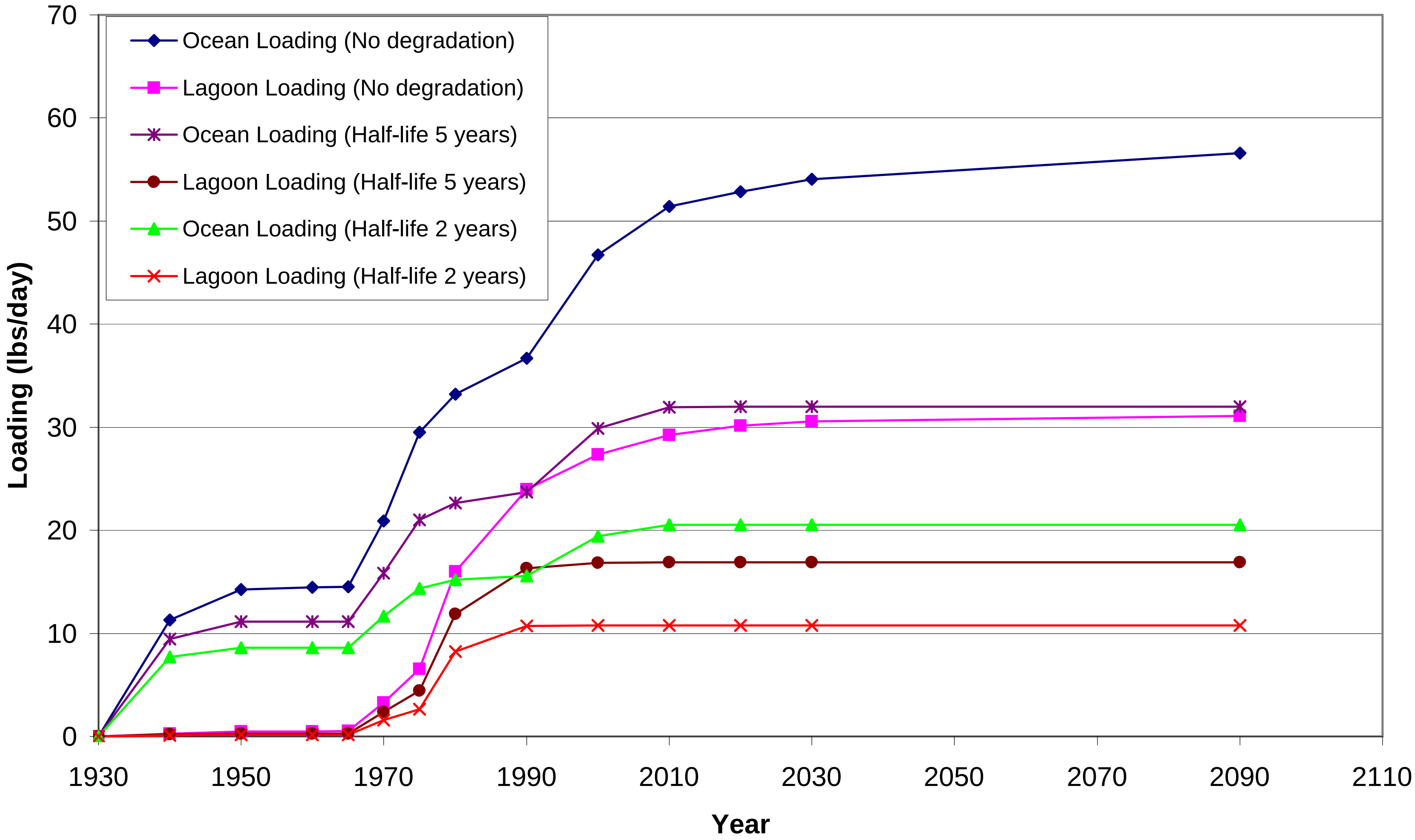

Figure 30 - Nitrate loading rates to the ocean and lagoon under breached lagoon conditions, with no degredation, five-year half life and two-year half life.

McDonald Morrissey ASSOCIATES, Inc.

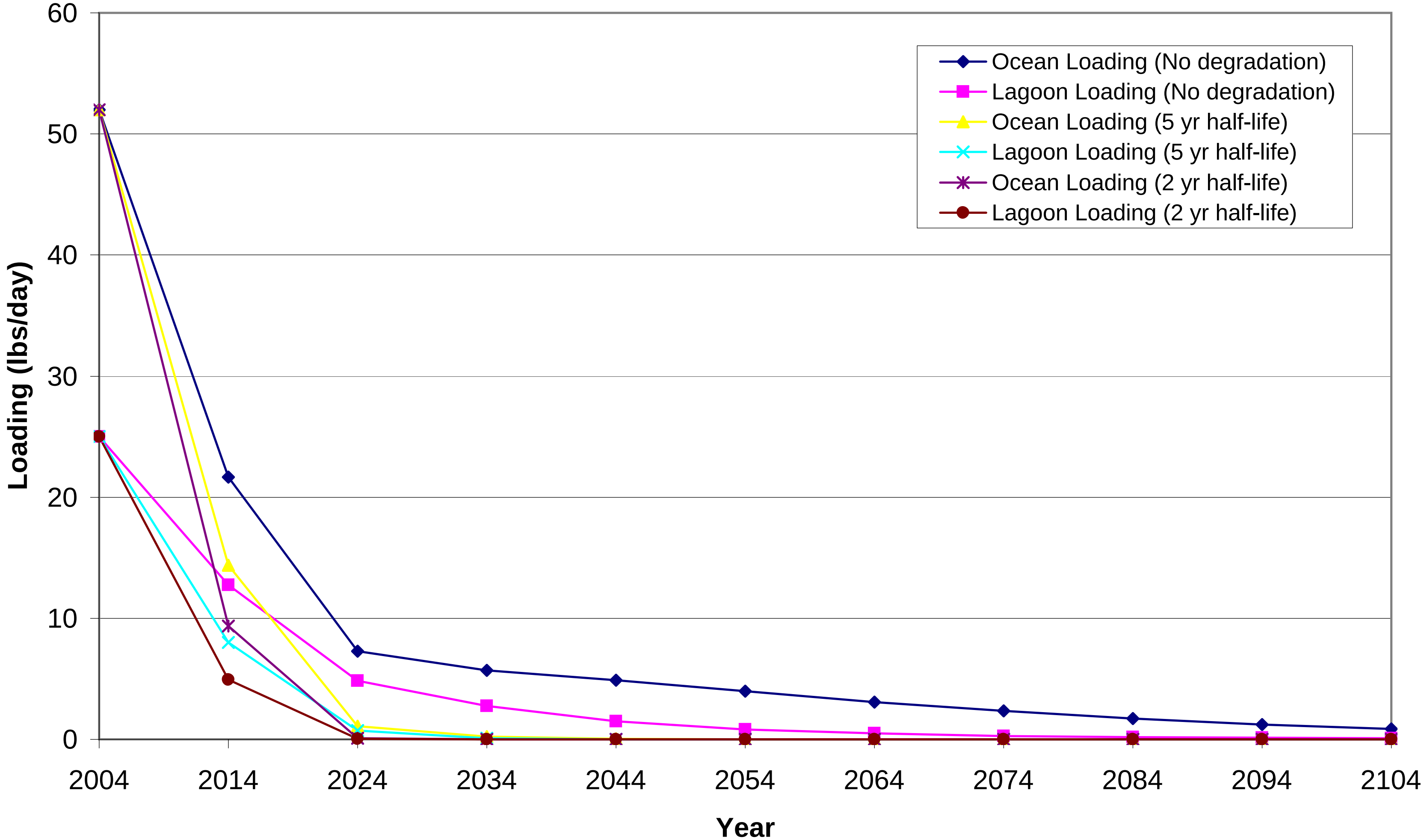

Figure 31 - Nitrate loading rates to the ocean and lagoon under flooded lagoon conditions, with no degredation, five-year and two-year nitrate half-lives, if all loading ceases in 2004.

McDonald Morrissey ASSOCIATES, Inc.

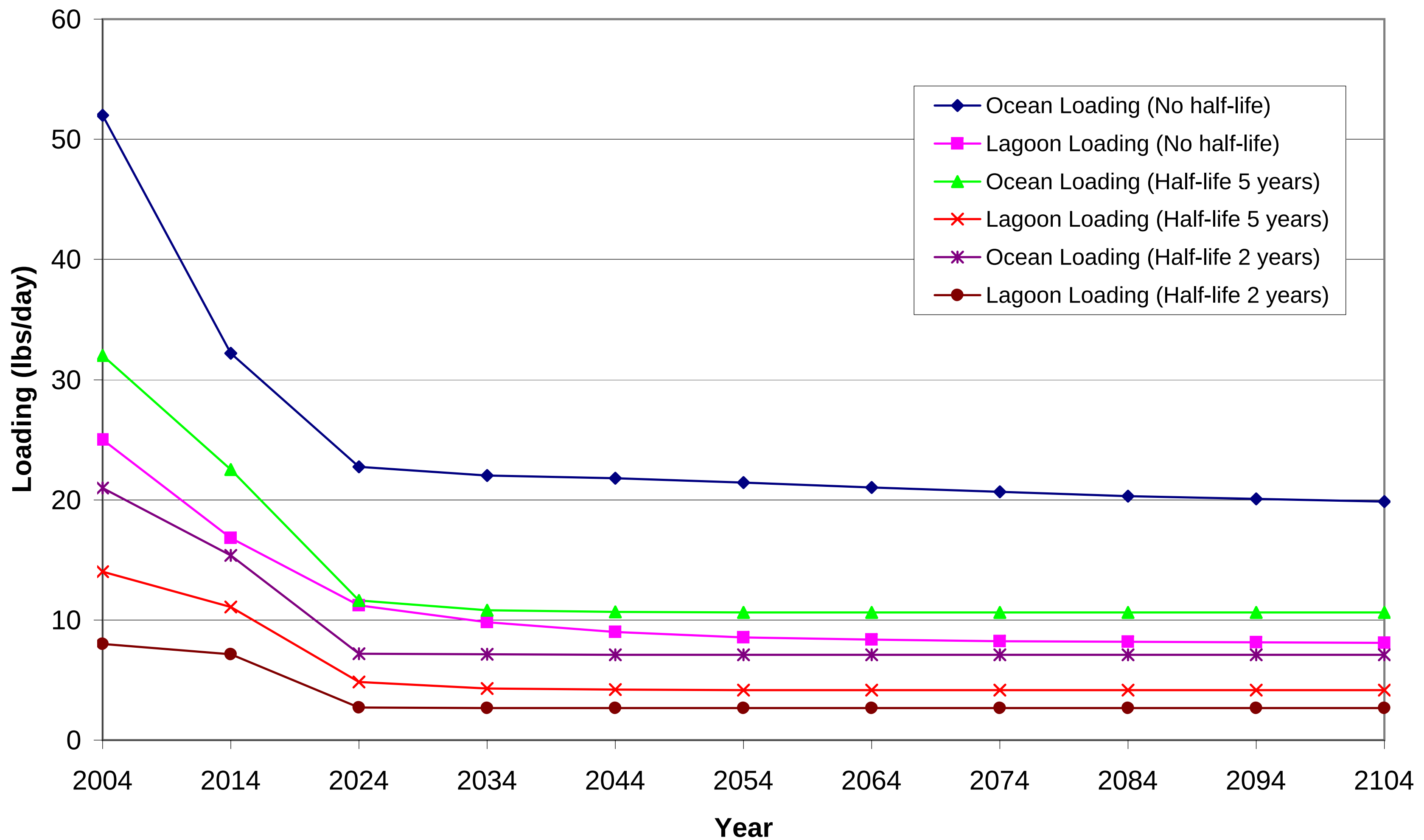

Figure 32 - Nitrate loading rates to the ocean and lagoon under flooded lagoon conditions, with no degredation, five-year half life, and two-year half life if nitrate concentrations are reduced to 10 mg/l in 2004.

McDonald Morrissey ASSOCIATES, Inc.

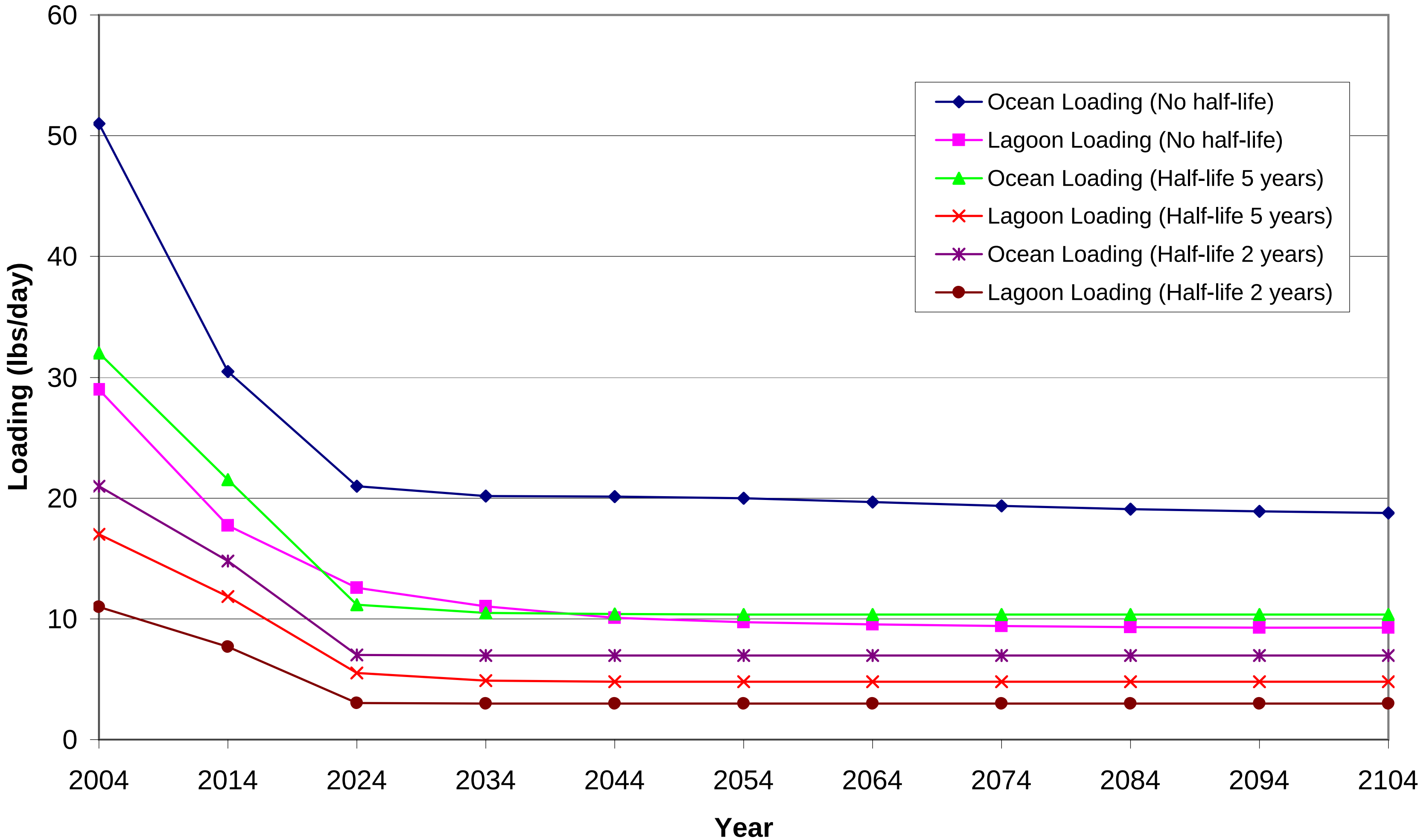

Figure 33 - Nitrate loading rates to the ocean and lagoon under breached lagoon conditions, with no degredation, five-year half life, and two-year half life if nitrate concentrations are reduced to 10 mg/l in 2004.

McDonald Morrissey ASSOCIATES, Inc.

Table 1. -- Saturated Zone Hydraulic Conductivity Estimates - Malibu, CA

Monitoring Well	Hydraulic Conductivity (ft/s)	(ft/min)	(ft/day)	(m/s)
SMBRP-1*	1.2E-04	7.1E-03	10.3	3.6E-05
SMBRP-2	2.7E-06	1.6E-04	0.2	8.1E-07
SMBRP-3c	3.2E-05	1.9E-03	2.8	9.9E-06
SMBRP-6	6.7E-05	4.0E-03	5.8	2.0E-05
SMBRP-7b*	3.6E-05	2.2E-03	3.1	1.1E-05
SMBRP-8	2.1E-06	1.3E-04	0.2	6.4E-07
SMBRP-9	2.5E-05	1.5E-03	2.2	7.7E-06
SMBRP-10c	9.2E-07	5.5E-05	0.1	2.8E-07
SMBRP-11	6.7E-05	4.0E-03	5.8	2.1E-05
SMBRP-12	6.9E-05	4.1E-03	6.0	2.1E-05
SMBRP-13*	1.4E-03	8.5E-02	122.5	4.3E-04
SMBRP-14	1.1E-04	6.5E-03	9.4	3.3E-05
SMBRP-15b	9.0E-05	5.4E-03	7.8	2.8E-05
SMBRP-16	6.7E-06	4.0E-04	0.6	2.0E-06

Source: SEI field notes, 2003

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Note: * = average of two tests, ft/s = feet per second, ft/min = feet per minute, ft/day = feet per day, m/s = meters per second

Path: O:\Proj-01\1269-W-MalibuCA\Sampling_Slug Tests\HydraulicConductivitySummary.xls

5/19/03 ANM

Table 2. -- Summary of well construction intormation for abandoned Malibu Water Company supply wells.

Well ID	Date Constructed	Total Depth (ft)	Screened Interval (ft)	Pumping Capacity (gpm)	Specific Capacity (gpm/ft. of drawdown)	Specific Capacity Reference	Transmissivity * (sq. ft./day)
1	1902	179	-	-	-	-	-
2	2/15/1902	213	60 - 105	125	-	-	-
3	6/26/1937	95	25 - 63	380	55.6	Well Construction sheet w/ Production Test Results for June 29, 1937	11,100
4	3/30/1943	96	29.5 - 56	800	61.5	Log of Well and Record of Test for 3/30/43	12,300
5	2/23/1946	93.5	60 - 80	175	-	-	-
6	12/11/1948	100	54 - 72	100	-	-	-
7	1/18/1949	150	120 - 132, 132 - 138	150	-	-	-
8	5/2/1959	158	40 - 138	400	113	Test Results for September 10, 1968	22,700

* Transmissivity: Driscoll Formula - Unconfined:

Q/s = T/1500

1 ft^3 = 7.48 gal:

200.53

Q/s = T/200.53

Table 3. -- Estimated average annual recharge from upland sub-drainage areas.

Sub-Basin	Area (ft^2)	Average Annual Runoff (ft^3/d)**
Winter Canyon	9,358,536	4,274
West Alluvium	8,511,010	3,887
North Alluvium	2,104,362	961
Malibu Tributary	9,949,806	4,544
East Alluvium	5,531,324	2,526
Serra	906,042	414
East Shore	1,080,000	493
West Shore	5,560,000	2,539
TOTAL	43,001,079	19,639

**assumes 14.28% of average annual precipitation or 0.1667 ft/yr,
(2 inches upland recharge out of 14 in/yr)

Table 4. -- Summary of wastewater dispersal in the model area.

Winter Canyon	ft^3/day	gal/day
Winter Canyon Upland	534	3,994
Winter Canyon Alluvium	2,171	16,239
Commercial from outside Winter Canyon	4,011	29,999
County Treatment Facility	5,014	37,503
Subtotal	11,729	87,736
Main Alluvium		
Commercial	8,311	62,166
East Shore/Malibu Pier	1,285	9,612
North Alluvium	3,485	26,068
Malibu Colony	12,091	90,441
Subtotal	25,172	188,287
Upland		
Southwest Upland	1,269	9,492
West Upland	2,538	18,984
East Upland	2,538	18,984
East Shore	868	6,493
West Shore	267	1,997
Subtotal	7,480	55,950
Total Wastewater Dispersal	44,381	331,973

Table 5.-- Malibu Creek Average Monthly Streamflow Water Years 1931-1986, 1968-1983, and 1984-1998. (After Entrix, 1999)

Month	1931-1968 (cfs)	1968-1983 (cfs)	1984-1998 (cfs)
October	1.2	3.9	8.2
November	9.5	18.3	13.3
December	19.8	22.6	31.4
January	75.2	164.6	69.8
February	73.6	109	182.2
March	68.8	121.5	101.2
April	20.6	27.3	32.8
May	5.5	12.7	19.9
June	2.8	7.4	22
July	1.5	4.9	5.8
August	1.2	4.3	3.5
September	1.3	4.2	4.3

Table 6 -- Model calculated water budget for the flooded lagoon condition

IN (ft^3/day)			OUT (ft^3/day)	
Natural Upland Runoff			***ET***	-12,464
Upland Winter	4,270			
Upland West	3,887		***Ocean***	-54,949
Upland North	957			
Upland Tributary	4,544		***River/Lagoon***	-78,397
Upland East	2,528			
Upland Serra	414			
Upland East Shore	490			
Upland West Shore	2,540	*19,630*		
Precipitation Recharge *(Area with no irrigation return)*	2,962	*2,962*		
Irrigation Return Recharge				
Golf Course Irrigation (*and Precipitation*)	1,123			
North Alluvium Irrigation (*and Precipitation*)	8,872			
Nursery Irrigation (*and Precipitation*)	570			
Irrigation East Alluvial Upland	6,562			
Irrigation East Shore Upland	2,139			
Irrigation South Alluvium West Upland	445			
Irrigation West Alluvial Upland	1,972			
Winter Canyon Upland Irrigation	501	*22,184*		
River Leakage	50,000	*50,000*		
Lagoon Leakage	6,788	*6,788*		
Waste-Water Recharge Winter Canyon				
Winter Canyon Upland	534			
Winter Canyon Alluvium	2,171			
MBC Plant	4,011			
County Plant	5,014	*11,729*		
Waste-Water Recharge Main Alluvium				
Commercial	8,311			
East Shore/Malibu Pier	1,285			
North Alluvium	3,485			
Malibu Colony	12,091	*25,172*		
Waste-Water Recharge Upland				
Southwest Upland	1,269			
West Upland	2,538			
East Upland	2,538			
East Shore	868			
West Shore	267	*7,480*		
Total IN		145,946	Total OUT	-145,810

Table 7 -- Model calculated water budget for the breached lagoon condition

IN (ft^3/day)			**OUT (ft^3/day)**	
Natural Upland Runoff			***ET***	-14,381
Upland Winter	4,270			
Upland West	3,887		***Ocean***	-44,283
Upland North	957			
Upland Tributary	4,544		***River/Lagoon***	-126,800
Upland East	2,528			
Upland Serra	414			
Upland East Shore	490			
Upland West Shore	2,540	*19,630*		
Precipitation Recharge *(Area with no irrigation return)*	2,962	*2,962*		
Irrigation Return Recharge				
Golf Course Irrigation (*and Precipitation*)	1,123			
North Alluvium Irrigation (*and Precipitation*)	8,872			
Nursery Irrigation (*and Precipitation*)	570			
Irrigation East Alluvial Upland	6,562			
Irrigation East Shore Upland	2,139			
Irrigation South Alluvium West Upland	445			
Irrigation West Alluvial Upland	1,972			
Winter Canyon Upland Irrigation	501	*22,184*		
River Leakage	96,345	*96,345*		
Lagoon Leakage				
Waste-Water Recharge Winter Canyon	534			
Winter Canyon Upland	2,171			
Winter Canyon Alluvium	4,011			
MBC Plant	5,014	*11,729*		
County Plant				
Waste-Water Recharge Main Alluvium	8,311			
Commercial	1,285			
East Shore/Malibu Pier	3,485			
North Alluvium	12,091	*25,172*		
Malibu Colony				
Waste-Water Recharge Upland	1,269			
Southwest Upland	2,538			
West Upland	2,538			
East Upland	868			
East Shore	267	*7,480*		
West Shore		185,503	Total OUT	-185,464

APPENDIX 4: MATERIALS FROM STAKEHOLDER PRESENTATIONS

Risk assessment for decentralized wastewater treatment systems in high priority areas in the City of Malibu, California

- City of Malibu
- Stone Environmental, Inc.

Goals of presentation

- Give an overview of the project and explain its significance
- Lay the groundwork for input from you

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Working assumptions

- Malibu's onsite wastewater treatment systems are here to stay
- Malibu Creek, Malibu Lagoon, and the beaches are valuable water resources, worth protecting

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Study area

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Main question

- What can be done to minimize the impact on these water resources from onsite wastewater systems?

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Tackling the main question

- What are the facts?
  - How vulnerable are Malibu's surface water resources to harm from onsite systems?
  - What areas or systems contribute the most to water vulnerability?
- If we document a problem, what alternative technologies and wastewater management options are priorities?

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What are the facts? Creating a hydrogeological model

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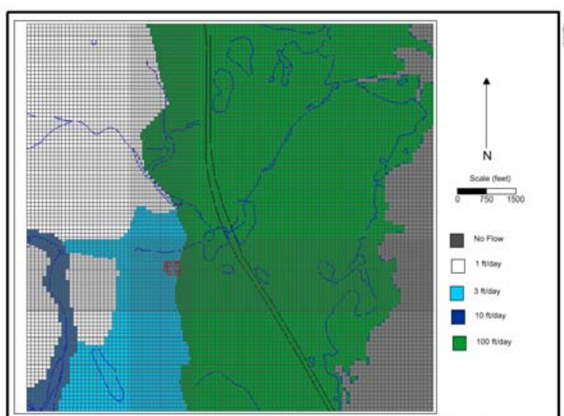

Figure 3. Model hydraulic conductivity distribution.

What are the facts?
Testing the model

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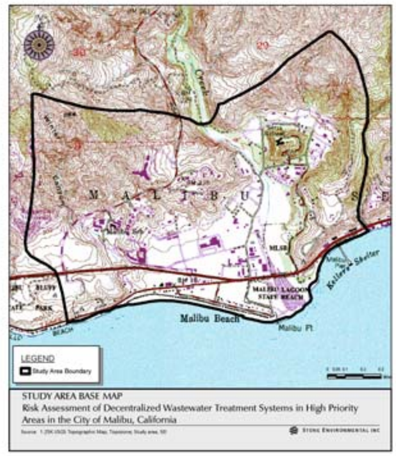

Types of conclusions

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Context

Then what?

- Continue with proposed management program?
- Retrofit some systems for better performance?
- Increase monitoring of some onsite systems?
- Increase water reuse?
- Increase water use efficiency?

These are among possible action items that we will suggest and whose anticipated effects we will quantify

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What we need from you
Made possible by a grant to the City of Malibu from the California State Coastal Conservancy with Prop. 12 funds and adminstered by the Santa Monica Bay Restoration Project

Risk assessment for decentralized wastewater treatment systems in high priority areas in the City of Malibu, California

Conceptual hydrogeologic model

Authors: Dan Morrissey, Mary K. Clark, Bruce Douglas, Amy Macrellis, Vic Peterson, and Chris Dean

Presenters: Carl Etnier and Bruce Douglas

ASAE Tenth National Symposium on Individual and Small Community Sewage Systems

Sacramento, California

22 March 2004

Water quality controversy at Surfrider Beach

Working assumptions

- Malibu Creek, Malibu Lagoon, and the beaches are valuable water resources, worth protecting
- Malibu wants fact-driven, long-term decision making about wastewater management
- "Risk assessment" = resource vulnerability assessment

Main question

- What are the risks associated with the use of onsite systems for existing development in regards to groundwater and surface water quality impacts?
- What can be done to mitigate those risks?

Tackling the main question

- What are the facts?
  - How vulnerable are Malibu's water resources to harm from onsite systems?
  - What areas or systems contribute the most to groundwater and surface water vulnerability?
- What alternative technologies and wastewater management options are priorities?

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Contributing Area for Malibu Creek

Source: Ambrose and Orme, 2000

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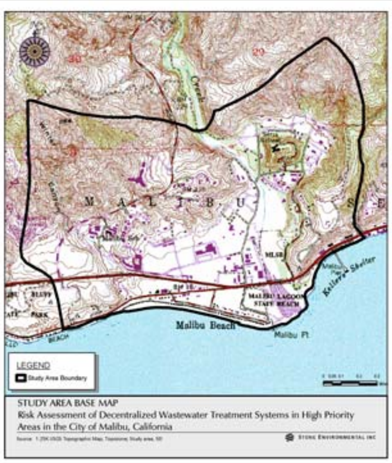

Study area

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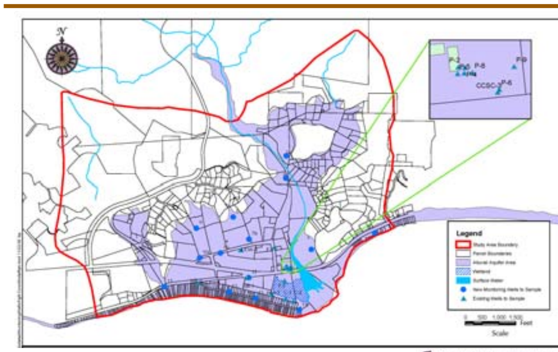
Data Collection Locations



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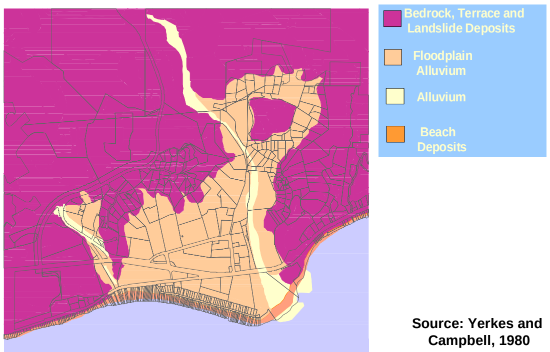
System Extent / Surficial Geology



Source: Yerkes and Campbell, 1980

System Extent / Bedrock-Alluvial Contact

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Surface Water Boundaries / Malibu Lagoon

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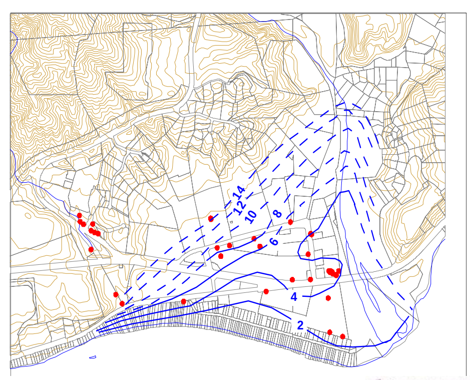
System Extent / Water Table Surface



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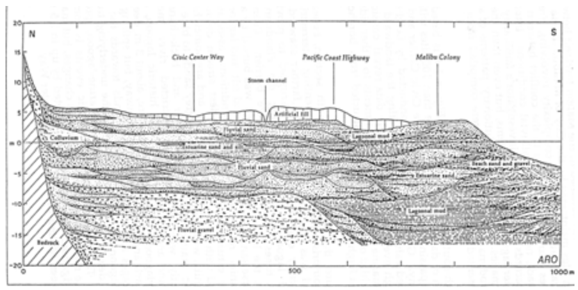
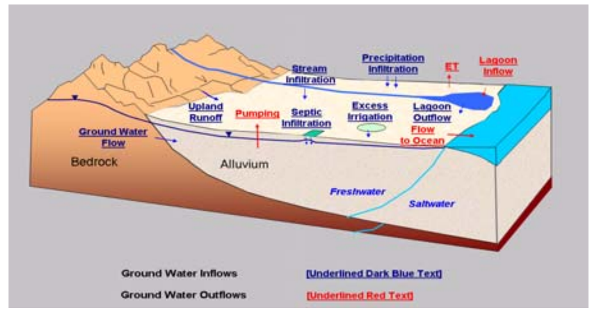
Stratigraphy / North-South Section

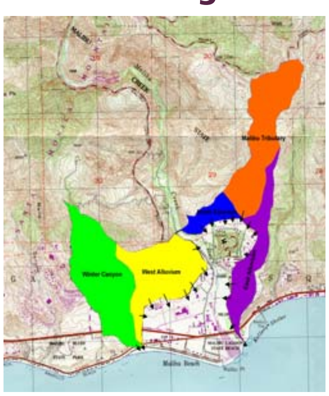


Source: Ambrose and Orme, 2000

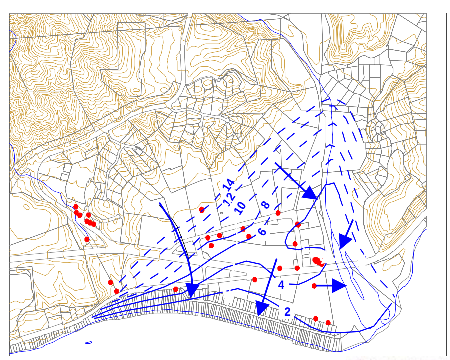
Recharge / Discharge Components



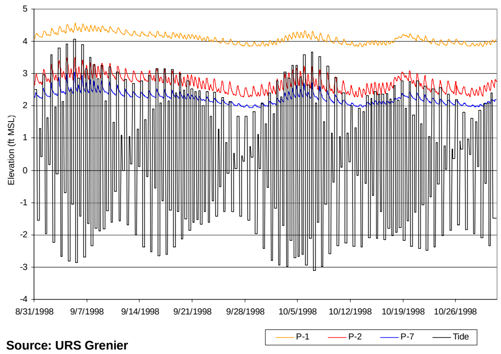
Contributing Areas



Generalized Directions of Ground Water Flow



Effects of Tidal Fluctuations on Ground Water Levels



Source: URS Grenier Woodward Clyde, 1999

Effects of Malibu Lagoon on Ground Water Levels

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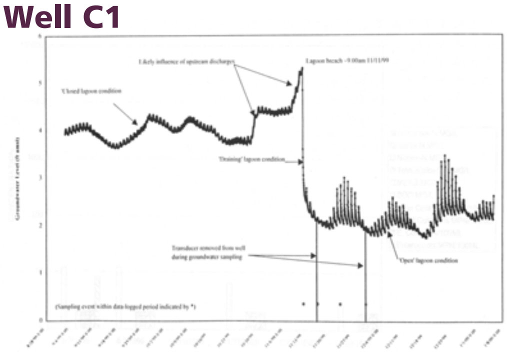
Effect of Malibu Lagoon at Well C1



Source: URS Grenier Woodward Clyde, 2000

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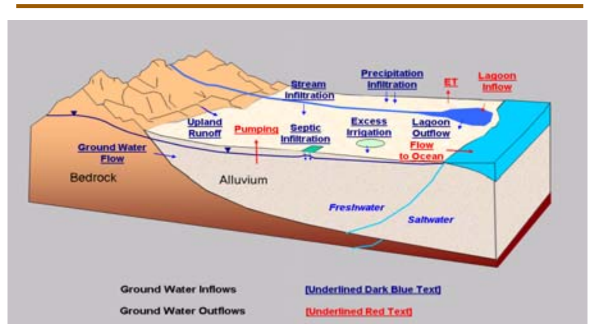
Malibu Conceptual Model



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Workplan in future

- Groundwater monitoring complete in March 2004
- Numerical model calibrated with new, primary data
- Risk management strategy presented for Malibu
- Results of model summarized, findings presented

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Risk Assessment of Decentralized Wastewater Management in High Priority Areas of the City of Malibu, California

Preliminary Overview of Draft Report

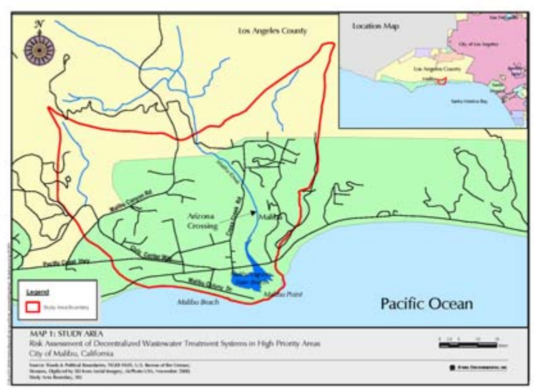
Funded by the California Coastal Conservancy
and administered by the Santa Monica Bay Restoration Commission

City of Malibu
Environmental and Community Development Department

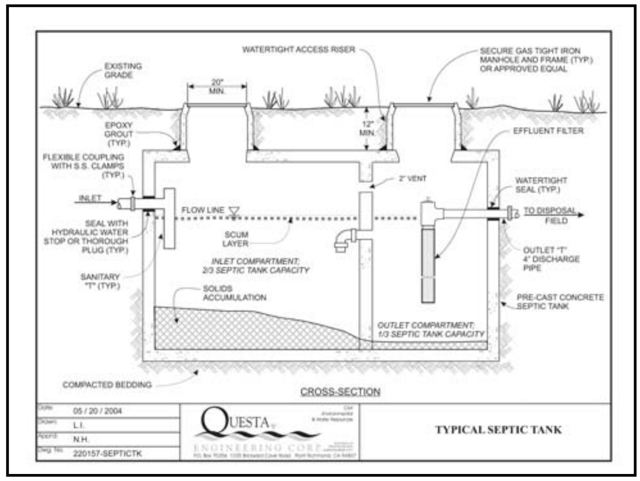
Fact-Driven and Outcome-Driven Assessment of Risk

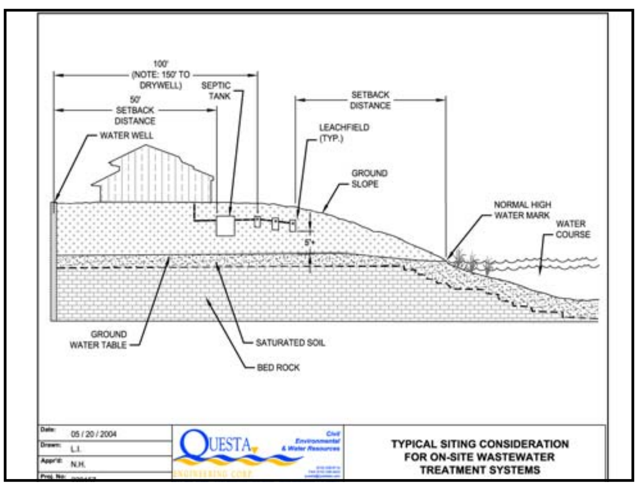
Project Chronology

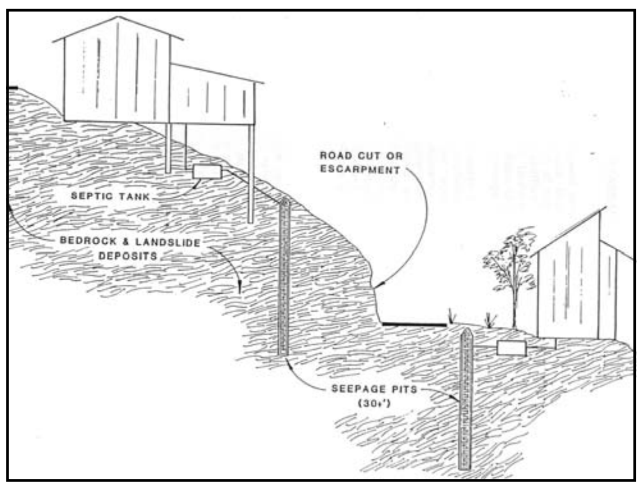
- *2001*
  - *Begin Project*
  - *Stakeholder Workshop*
- *2002*
  - *Collect Existing Data*
  - *Develop IWIMS & Conceptual Model*
  - *Locate monitoring wells and begin to install*
- *2003*
  - *Finish Monitoring Well Installation*
  - *Begin Water Quality Monitoring*
- *2004*
  - *Finish Water Quality Monitoring*
  - *Risk Assessment*
  - *Draft Report and workshop*
  - *Final Report and workshop*

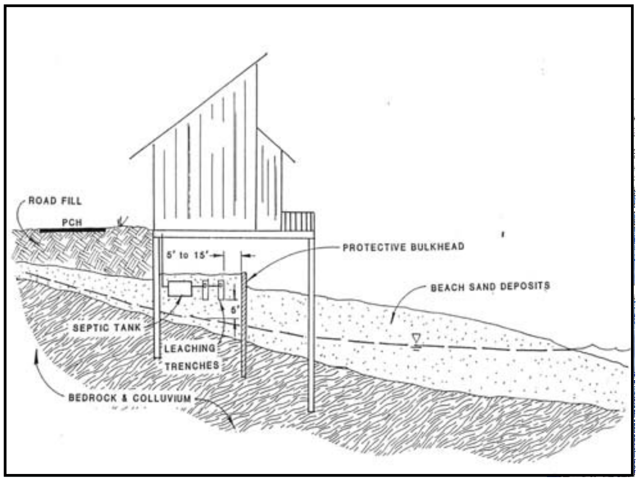



United States
Environmental Protection
Agency
EPA
Onsite Wastewater
Treatment Systems Manual


WATERTIGHT ACCESS RISER
SECURE GAS TIGHT IRON MANHOLE AND FRAME (TYP.) OR APPROVED EQUAL
EXISTING GRADE
20" MIN.
12" MIN.
EPOXY GROUT (TYP.)
EFFLUENT FILTER
FLEXIBLE COUPLING WITH S.S. CLAMPS (TYP.)
2" VENT
WATERTIGHT SEAL (TYP.)
INLET
FLOW LINE
TO DISPOSAL FIELD
SEAL WITH HYDRAULIC WATER STOP OR THOROUGH PLUG (TYP.)
SCUM LAYER
OUTLET "T" 4" DISCHARGE PIPE
INLET COMPARTMENT: 2/3 SEPTIC TANK CAPACITY
SANITARY "T" (TYP.)
SOLIDS ACCUMULATION
PRE-CAST CONCRETE SEPTIC TANK
OUTLET COMPARTMENT: 1/3 SEPTIC TANK CAPACITY
COMPACTED BEDDING
CROSS-SECTION
Date: 05 / 20 / 2004
Drawn: L.I.
Appr'd: N.H.
Dwg. No: 220157-SEPTICTK
QUESTA
ENGINEERING CORP.
Civil Environmental & Water Resources
TYPICAL SEPTIC TANK


100' (NOTE: 150' TO DRYWELL)
SEPTIC TANK
50' SETBACK DISTANCE
SETBACK DISTANCE
WATER WELL
LEACHFIELD (TYP.)
GROUND SLOPE
NORMAL HIGH WATER MARK
WATER COURSE
5'+
GROUND WATER TABLE
SATURATED SOIL
BED ROCK
Date: 05 / 20 / 2004
Drawn: L.I.
Appr'd: N.H.
Proj. No:
QUESTA
Civil Environmental & Water Resources
ENGINEERING CORP
TYPICAL SITING CONSIDERATION FOR ON-SITE WASTEWATER TREATMENT SYSTEMS


ROAD CUT OR ESCARPMENT
SEPTIC TANK
BEDROCK & LANDSLIDE DEPOSITS
SEEPAGE PITS (30±')



Mandatory Management Levels

Onsite System Category	*USEPA Management Models[1]*		
	1	***2***	***3***
Residential Traditional			
Residential Advanced Treatment			
Commercial/ Multi-Family			

[1]Green = Existing Systems

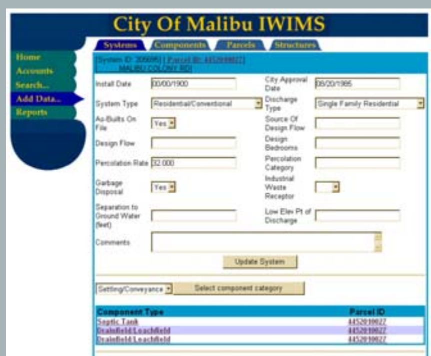
[1]Blue = New, Repair, Renovation or Replacement

Stakeholder Involvement

Stakeholders

- ***Internal***
  - *Residents*
  - *Business Owners*
  - *Property Owners*
  - *Homeowner's Associations*
  - *Public Land Owners*
    - *CA State Parks*
    - *County of Los Angeles*
    - *SMMUSD*
- ***External***
  - *LARWQCB*
  - *SMBRC*
  - *Heal the Bay*
  - *Surfrider Foundation*
  - *Santa Monica Baykeeper*

OWTS Information Management

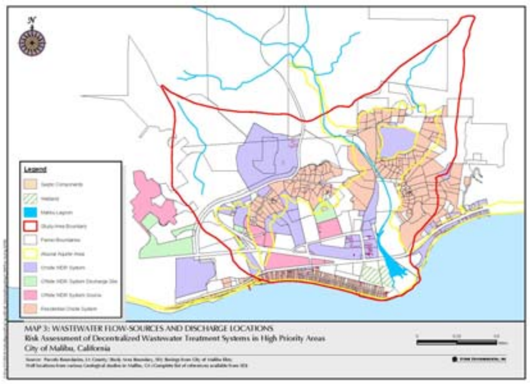


Understanding of Groundwater Flow

- *Area Contributing Groundwater to Malibu Creek and Lagoon*
- *Area Contributing Groundwater to Surfzone*
- *Aquifer Characteristics*
  - *Breached vs Unbreached*
  - *Time of Travel*

Understanding of Groundwater Quality Processes

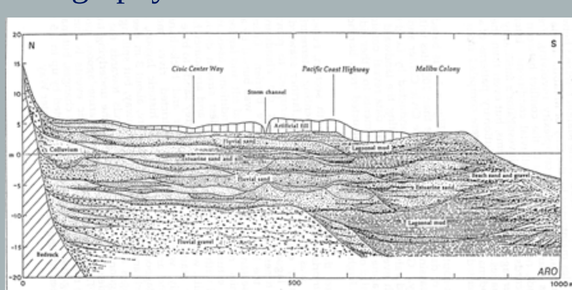
- *Nitrogen*
  - *Removal Occurs in Groundwater Flow System*
- *Bacteria*
  - *Other Sources of Bacteria in Groundwater*
  - *Long Times of Travel Allow for Die-Off*



Contributing Area for Malibu Creek

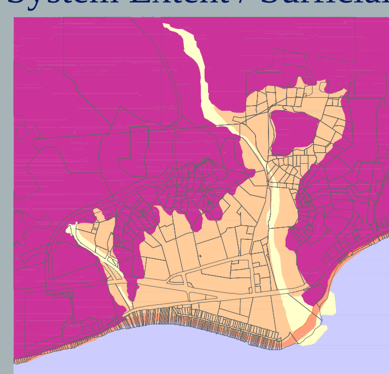
Source: Ambrose and Orme, 200

Stratigraphy: North-South Section



Source: Ambrose and Orme, 2000

System Extent / Surficial Geology



- Bedrock, Terrace and Landslide Deposits
- Floodplain Alluvium
- Alluvium
- Beach Deposits

Source: Yerkes and Campbell, 1980

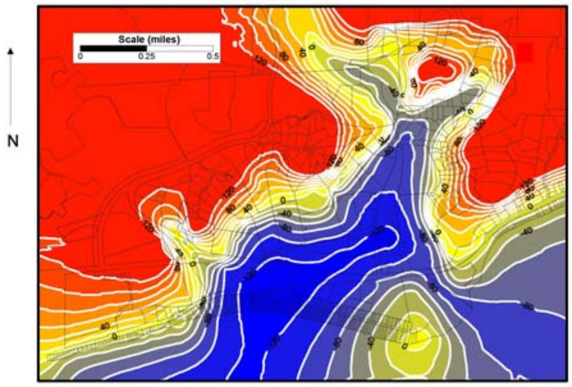


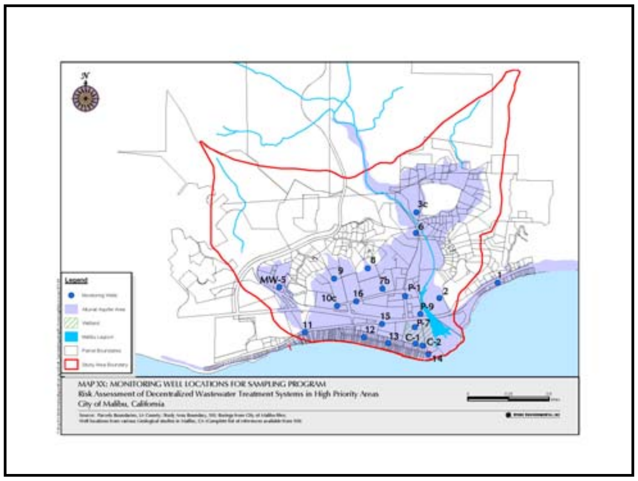
Figure 2 - Map showing top of bedrock elevations.

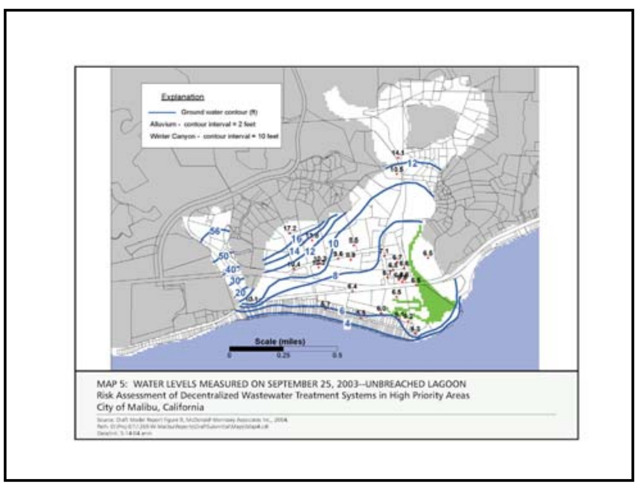
McDonald Morrissey

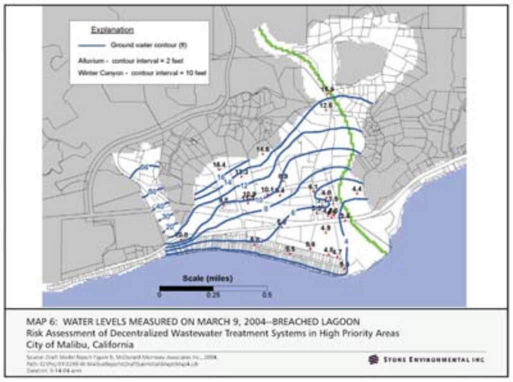
Synoptic Water Table Elevations

- *Unbreached Lagoon*
  - September 25, 2003
- *Breached Lagoon*
  - March 9, 2004

Upland Contributing Areas


MW-5
9
8
10c
16
7b
P-1
2
1
P-9
15
P-7
11
12
13
C-1
C-2
14
3c
6
Legend
MAP XX: MONITORING WELL LOCATIONS FOR SAMPLING PROGRAM
Risk Assessment of Decentralized Wastewater Treatment Systems in High Priority Areas
City of Malibu, California


Explanation
Ground water contour (ft)
Alluvium - contour interval = 2 feet
Winter Canyon - contour interval = 10 feet
Scale (miles)
0
0.25
0.5
MAP 5: WATER LEVELS MEASURED ON SEPTEMBER 25, 2003--UNBREACHED LAGOON
Risk Assessment of Decentralized Wastewater Treatment Systems in High Priority Areas
City of Malibu, California



MAP 6: WATER LEVELS MEASURED ON MARCH 9, 2004--BREACHED LAGOON
Risk Assessment of Decentralized Wastewater Treatment Systems in High Priority Areas
City of Malibu, California

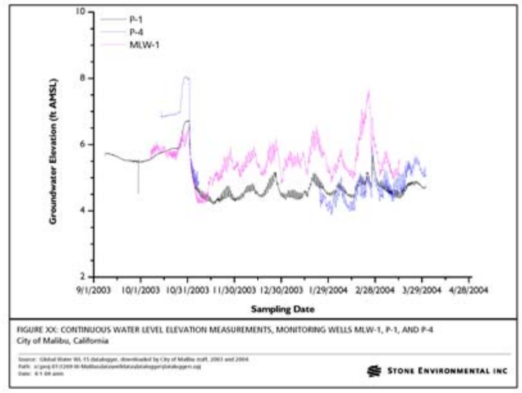


FIGURE XX: CONTINUOUS WATER LEVEL ELEVATION MEASUREMENTS, MONITORING WELLS MLW-1, P-1, AND P-4
City of Malibu, California

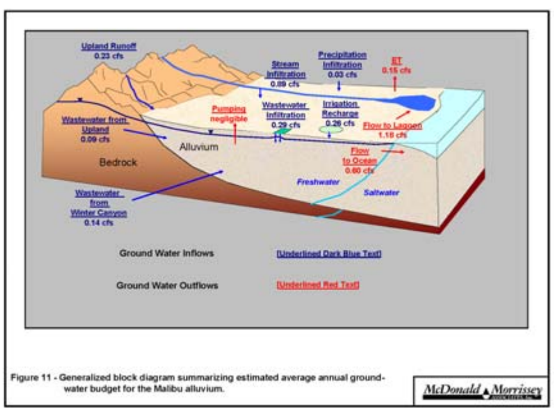
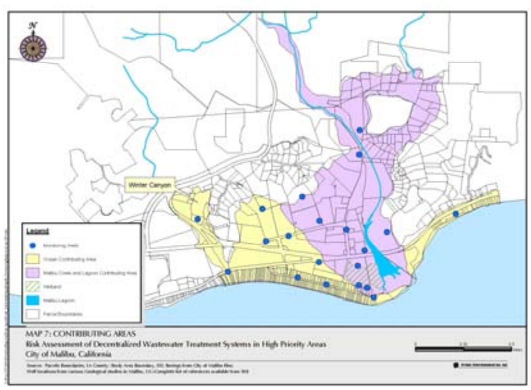


Figure 11 - Generalized block diagram summarizing estimated average annual ground-water budget for the Malibu alluvium.



MAP 7: CONTRIBUTING AREAS
Risk Assessment of Decentralized Wastewater Treatment Systems in High Priority Areas
City of Malibu, California

Hydraulic Conductivity Testing

- *Slug testing of all new wells*
- *Previous Hydraulic Conductivity Test Results*

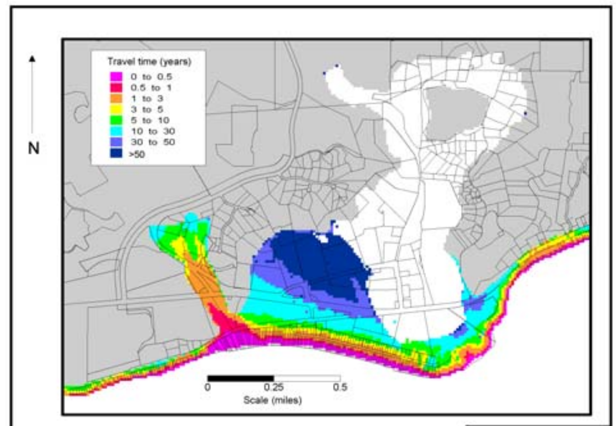


Figure 24 - Map showing model calculated contributing area and time-of-travel for the ocean with the flooded lagoon condition.

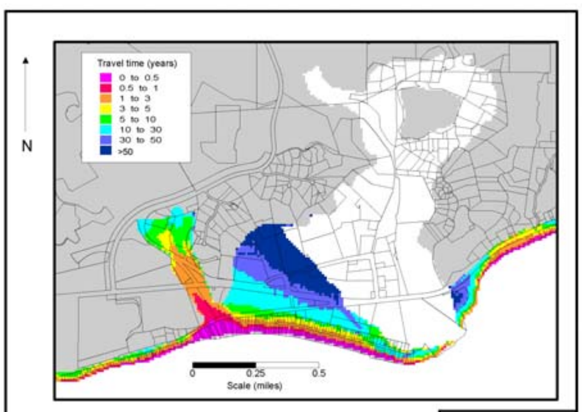


Figure 26 - Map showing model calculated contributing area and time-of-travel for the ocean with the breached lagoon condition.

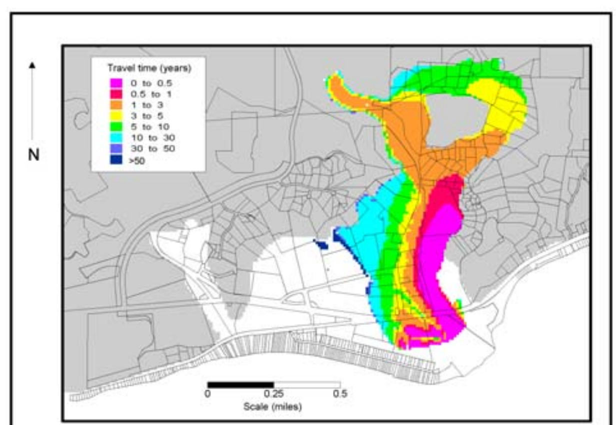


Figure 25 - Map showing model calculated contributing area and time-of-travel for the lagoon with the flooded lagoon condition.

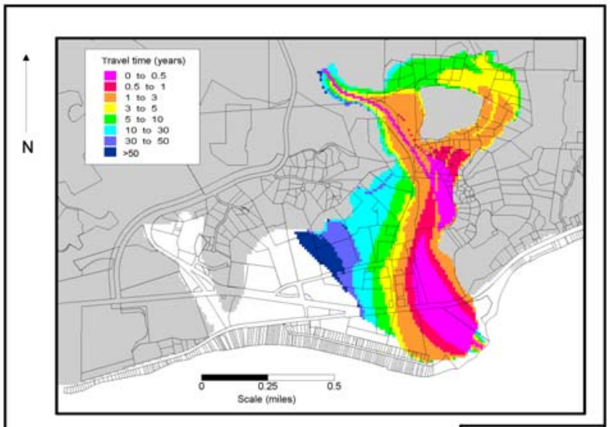
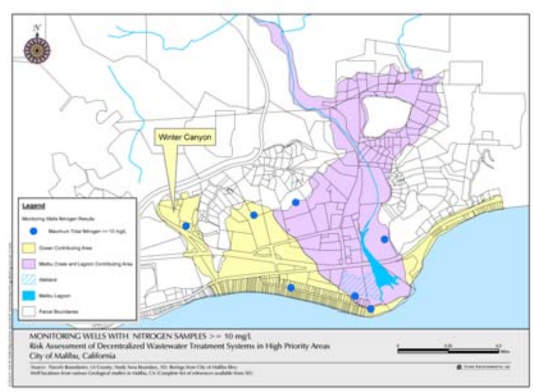


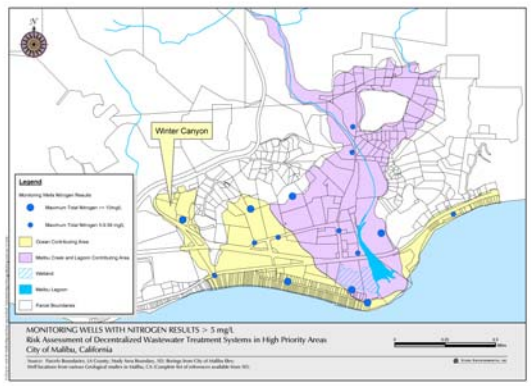
Figure 27 - Map showing model calculated contributing area and time-of-travel for the lagoon with the breached lagoon condition.

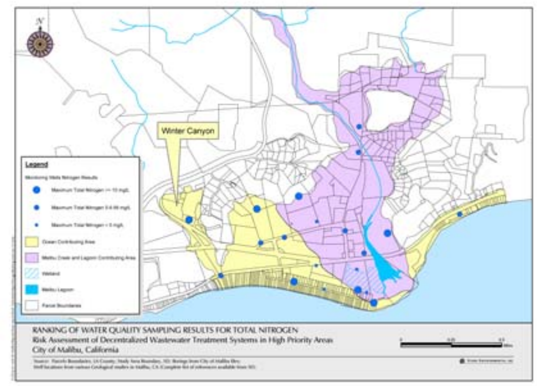
Monitor Water Quality

- *Inorganic Analyses:*
  - *Chloride*
  - *Nitrate-N*
  - *Nitrite-N*
  - *Ammonia-N*
  - *Total Kjeldahl Nitrogen (TKN)*
- *Bacteria Analyses:*
  - *Enterococcus*
  - *Fecal Coliform*
  - *Total Coliform*

Nitrogen Water Quality Data Summary





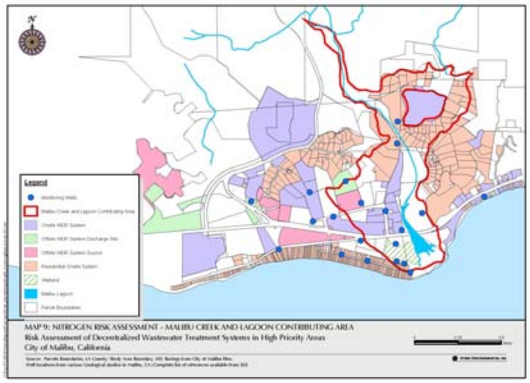


Risk Assessment - Nitrogen

- *Total Maximum Daily Load (TMDL) is the driver*
- *Current Load: 10.69 lb N/day (USEPA, TMDL)*
- *Objective: USEPA TMDL*
  - *Winter Allocation: 8 mg/l Nitrogen from OWTS)*
  - *Summer Allocation: 93% reduction*
- *LARWQCB TMDL expected in Autumn, 2004*

Nitrogen Removal Processes

- *Nitrification*
  - *Ammonia to Nitrate*
- *Denitrification*
  - *Nitrate to Nitrogen gas*



Nitrogen Removal Processes

- *Nitrification*
  - *Unsaturated flow*
- *Denitrification*
  - *Soil/Groundwater System*
  - *Advanced Treatment/ Denitrification*

Current OWTS Program Elements to Achieve Nitrogen Outcomes

- *Utilize Groundwater Model as tool to evaluate TMDL objectives*
- *Renewable Operating Permits for Commercial/ Multifamily Occupancies*
- *Renewable Operating Permits for all Single family and Duplex Occupancies w/ Repair, Upgrade or New Construction*

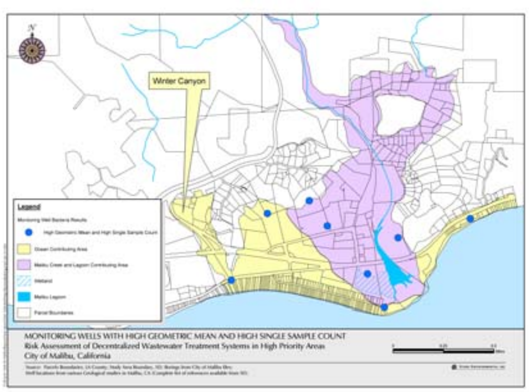
Potential Alternatives to Achieve Nitrogen Outcomes (1 of 2)

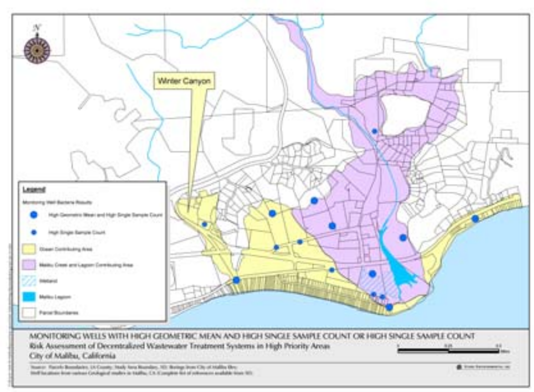
- *OWTS Inspections at Point of Sale*
- *OWTS Contributing Area Inspections*
- *Require N Removal on OWTS Serving Commercial/ Multifamily Occupancies in Contributing Area*
- *Require N Removal OWTS Serving All Occupancies in Contributing Area*

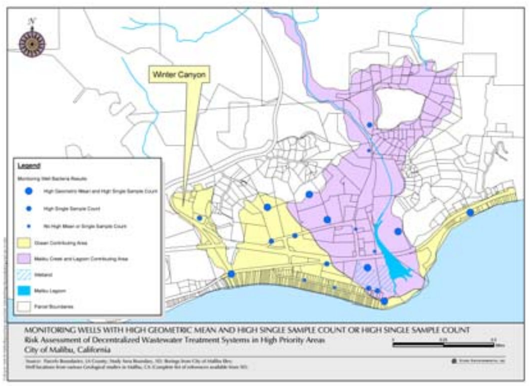
Potential Alternatives to Achieve Nitrogen Outcomes (2 of 2)

- *Community Wastewater Reclamation with Onsite Dispersal*
- *Community Wastewater Reclamation with Dispersal Outside of Contributing Area*
- *Combination of above*

Bacteria Water Quality Data Summary







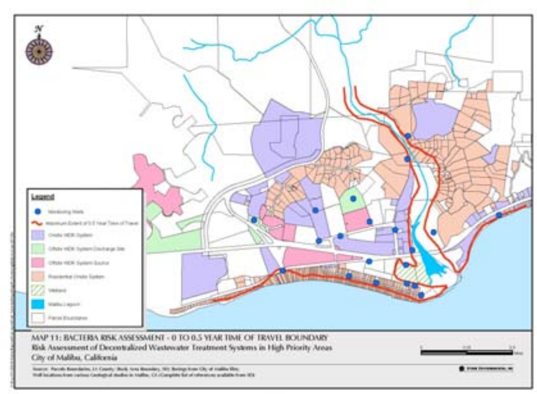
Bacteria Outcomes

- *Water Quality in Creek, Lagoon and Beaches*
- *Current Load: counts/day (LARWQCB TMDL)*
- *Objective: Contact Recreation Standards*[1]
  - *Winter Wet Weather: 3 exceedances/year*
  - *Winter Dry Weather: 1 exceedances/yr*
  - *SummerDry Weather: 0 exceedances/year*

[1]Weekly Sampling

Bacteria Removal

- *Biomat/Unsaturated Flow*
  - *Vertical Separation to Groundwater*
- *Die-Off in Groundwater*
  - *Time of Travel*
- *Advanced Treatment/Disinfection*



Current OWTS Program Elements to Achieve Bacteria Outcomes

- *Develop TMDL Implementation Plans*
- *Renewable Operating Permits for Commercial/ Multifamily Occupancies*
- *Advanced Treatment and Disinfection for Commercial/Multi-family*
- *Renewable Operating Permits for all Single family and Duplex Occupancies at time of Repair, Upgrade or New Construction*

Potential Alternatives to Achieve Bacteria Outcomes

- *OWTS Inspection at Point of Sale*
- *OWTS Inspection in 6 month Time of Travel Zone*
- *Regional Groundwater Quality Monitoring in Existing Wells using Microbial Source Tracking*
- *Cluster Wastewater Collection, Treatment, Disinfection and Dispersal*

Resources:

City of Malibu
Department of Environmental and Community Development
www.ci.malibu.ca.us

Santa Monica Bay Restoration Commission
www.santamonicabay.org

Los Angeles Regional Water Quality Control Board
www.swrcb.ca.gov/rwqcb4/

USEPA Decentralized Wastewater Web Site
www.epa.gov/owm/decent/index.htm

APPENDIX 5: COMMENTS RECEIVED ON DRAFT REPORT AND RESPONSIVENESS SUMMARY

California Regional Water Quality Control Board
Los Angeles Region
Over 51 Years Serving Coastal Los Angeles and Ventura Counties
Recipient of the 2001 *Environmental Leadership Award* from Keep California Beautiful

Terry Tamminen
Secretary for Environmental Protection

320 W. 4th Street, Suite 200, Los Angeles, California 90013
Phone (213) 576-6600 FAX (213) 576-6640 - Internet Address: http://www.swrcb.ca.gov/rwqcb4

Arnold Schwarzenegger
Governor

July 14, 2004

Ms. Adrienne Furst, Department Specialist
City of Malibu
23815 Stuart Ranch Road
Malibu, CA 20265

REVIEW OF THE FINAL DRAFT REPORT-RISK ASSESSMENT OF DECENTRALIZED WASTEWATER TREATMENT IN HIGH PRIOIRITY AREAS IN THE CITY OF MALIBU, CA

Dear Ms. Furst:

The Los Angeles Regional Water Quality Control Board staff is pleased to provide comment on the referenced report. We appreciate the City of Malibu's proactive effort in identifying high-risk areas for onsite wastewater treatment systems, and see this initial study as an excellent first step. However, we recommend that work continue to refine the estimated outer bounds of areas that may impact water quality in Malibu Creek and Lagoon. Attached are specific comments on the risk assessment report. Specifically, there needs to be more information collected on the hydraulic conductivity of the study area, since the report seems to propose using groundwater travel time as a tool for OWTS management. In addition, there is uncertainty regarding fate and transport of nitrogen in the groundwater. It is very important to understand these processes in order to assess risk and explore implementation scenarios.

If you have any questions, please contact Rod Collins of my staff at (213) 576-6691.

Sincerely,

Jonathan Bishop
Interim Executive Officer

SPECIFIC COMMENTS
OF THE LOS ANGELES REGIONAL WATER QUALITY CONTROL BOARD
[Report section excerpts are in normal font; Regional Board comments are **bold** font]

2.2.1. Groundwater

"The groundwater is the focus of this study, since it receives and provides a mixing zone for the percolating water from OWTS and transmits to the local surface water bodies." **Please delete the phrase "provides a mixing zone."**

2.4.1 Water Quality Control Plan

"The Basin Plan can be obtained at the Regional Board's website, at www.swrcb.ca.gov/rwqcb4/basinplan." **The correct website address for accessing the Basin plan is www.swrcb.ca.gov/rwqcb4/html/meetings/Bain_plan/basin_plan.htm.**

2.4.1 Water Quality Control Plan

"The Basin Plan defines the local groundwater resource, excluding Winter canyon and Serra Retreat areas, as the Malibu Valley...A footnote in the Basin Plan allows for use of marine water quality recreation standards for areas where groundwater is in connection with surface water." **The referenced definition and footnote are not in the Basin Plan. Please cite other sources used or inferences made.**

"According the Regional Board staff, the marine water quality standards are used for Waste Discharge Requirements in the vicinity of the Lagoon." **Are you referring to Ocean Plan objectives? Please cite staff communication or specific permits.**

2.4.3 Regional Board Requirements for OWTS

Under Order No. 01-031, general WDRs can be issued for systems with less than 20,000 gallons per day (gpd) flows and that have greater than 10 feet vertical separation between the point of discharge and the water table." **01-031 allows less than 10 feet separation with disinfection, but no less than five feet separation. 01-031 was adopted February 22, 2001.**

2.4.2.4 Water Quality Criteria for Malibu Lagoon: Nutrients

"Malibu Lagoon nutrient water quality targets are based on achieving water quality objectives for algal growth and scum accumulation in the creek." **The Basin Plan does not have water quality objectives for algae. The numeric targets are translations of the narrative water quality objectives for biostimulatory substances.**

2.4.2.3. Water Quality Criteria for Malibu Lagoon: Bacteria

"This TMDL will not become effective until it is reviewed and approved by the SWRCB." **The TMDL must be approved by the SWRCB, the Office of Administrative Law (OAL), and USEPA before it is in effect.**

"The Malibu Creek Watershed Bacteria TMDL source allocation for Malibu Lagoon Subwatershed estimates to require a 93% reduction of bacteria from anthopogenic sources on a watershed wide basis..." **The actual estimated reduction is 94%, Table 21 of the Regional Board's Malibu Creek Bacteria TMDL. Please note the TMDL only requires compliance with the WLAs and these estimated reductions are for informational purposes only.**

2.4.2.4 Water Quality Criteria for Malibu Lagoon: Nutrients

"...Malibu Lagoon subwatershed has a current 10.7 lbs/day mass nitrogen loading. Applying a 93% reduction will result in a target nitrogen loading of 0.75 lbs/day." **The estimated current loading of 10.7 lbs/day is an error as pointed out in a conversation with Questa Engineering staff. This will be corrected in the final report.**

2.4.2.5 TMDL Assumptions for Bacteria and Nitrogen

"[Tetra Tech] report states there are...30 "commercial" OWTS near the lagoon." **The Tetra Tech document actually reports 20 commercial OWTS systems.**

"For the "failed" OWTS, it was assumed that 40% of the bacteria reach the lagoon and 50% of the nitrogen reaches the lagoon." Tetra Tech assumed that the nitrogen loading was the same from operational and failed OWTS. That is, 13% of nitrogen loss through plant uptake, with the remaining 87% being discharged to surface waters. "

"Tetra Tech estimates for OWTS contribute to the Lagoon: 1,176,760 counts per year (3224 counts per day) fecal coliform; 16,925,150 counts per year (46,370 counts per day) total coliform and nutrient loads of 3902 pounds per year (10.7 lbs/day)." **These loading numbers are incorrect, and were based on previous calculation error of 10.7 lbs/day from section 2.4.2.3.**

3.6.3.2. Solute Transport Model

"Source concentration of nitrogen from OWTS were assumed to be 20 mg/l from domestic wastewater disposal systems and 50 mg/l from commercial systems." **The concentration value of 20 mg/l is low. The Regional Board used 59.2 mg/l of total nitrogen for each residential and commercial based on effluent measurements. In section 4.4.1, it states that total nitrogen concentration in septic tank effluent vary typically from about 20 mg/l to more than 100 mg/l, which was based on an EPA document. Regional Board staff suggests that the use of either measured effluent concentrations or at least a mid-range value (e.g., 50 mg/l) to ensure the basis for the pollutant loading estimates represents the local conditions.**

3.6.3.2. Solute Transport Model

"Although no attempt was made to do a rigorous calibration of transport model results, the calculated nitrate levels were compared with average nitrate levels observed at each of the project wells in the monthly monitoring network." **Explain results of comparison. (Scatter plots are shown in Figure 28 of the groundwater study. Did the study attempt to correlate calculated and measured levels?)**

3.7. Risk Assessment

"Time of travel is a method used for establishing separation distances between OWTS and drinking water wells, and water use areas." **Please provide a reference for this statement. Since groundwater time travel is recommended in this report as the basis for determining priority OWTS management areas, it is important for the Regional Board to be able to assess the applicability of the methods to this study area.**

4.4.1.3 Nitrate

"Based on the apparent decrease in nitrate-N concentration in groundwater in monitoring wells that are located farther away from the leachfield, denitrification maybe occurring." **Are there other factors that may explain the lower concentrations, such as greater assimilative capacity in groundwater due to increased groundwater flow conditions or time of travel. The Regional Board would recommend additional information or study on the fate and transport of nitrogen in the groundwater be conducted in order enhance the models ability to predict nitrogen loads.**

4.4.1.3 Nitrate

"This well (MW-5) is also immediately upgradient of, but in very close proximity to, a large wastewater dispersal field for the Los Angeles County Maison de Ville treatment facility." **Is the study identifying this site as a potential source of nitrate exceedances in MW-5?**

4.4.2.4 Results of Bacterial Water Quality Sampling Program

There is no comparison of study results with groundwater bacteria objectives. Even if the focus of the study is risks to surface water, impacts to groundwater must be recognized.

4.6.1.1 Mass Loading of Nitrogen

"The single family residential nitrogen mass loading (11 grams per person per day) was based on the upper end of the typical range of nitrogen produced and 2.42 person per household." **The 2.42 persons per household is low when considering the NRCS (1995) study estimated an average of 3.4 persons per septic system (based on the total population and number of houses in the watershed. Is there a reason that the EPA numbers were used instead of estimates made in the Warshall Report of the NRCS study?**

"The groundwater quality sampling program results indicate that nitrogen is being attenuated to a significant degree on the groundwater, and that denitrification is the most probable explanation." **The data presented does not establish that the nitrogen is being attenuated in the groundwater. The data shows that concentrations are lower farther from leach fields. Could there be other explanations for this occurrence, such as dilution by groundwater of lower nitrogen concentrations.**

4.6.1.3. Groundwater Vulnerability to Nitrogen

"Since the alluvial aquifer is not used for drinking water, . . . the groundwater system does not appear to be vulnerable to nitrogen loading." **The aquifer is vulnerable to degradation and thus still must be protected as required under State's antidegradation policy. As indicated in the Draft Modeling Report, the alluvial aquifer was used in the past for municipal water supply and the groundwater basin is designated as potential MUN beneficial use. All designated beneficial uses must be protected.**

4.6.2.4 Groundwater Vulnerability to Bacteria

"Therefore, independent of the suitability for OWTS, the designation and beneficial use of the alluvial aquifer as a drinking water source does not appear to be either an appropriate or achievable objective." **See previous response.**

4.6.3. Surface Water Vulnerability

"Preliminary information from that study [SCCWRP Lagoon sediment study] indicates a significant potential for removal of nitrogen in the groundwater that flows into the lagoon."

"The attenuation of nitrogen flowing into the Lagoon through the hyporheric zone could have a significant impact on the vulnerability of the lagoon to nitrogen loading via groundwater"

The study indicates that there is fluxing of nitrogen between the lagoon water column and sediment. Although the potential may exist for removal of nitrogen from groundwater that passes through the sediment, the nitrogen may still remain in the lagoon where it may exacerbate the already advanced eutrophic state of the "restored" section of the Lagoon.

4.7.1.1 Bacteria

"The advantages and disadvantages of the bacteria attenuation infrastructure are presented in Table 29." More discussion of Table 29 would be useful, such as the origin of water quality targets and reasoning behind uncertainty determinations.

4.8 List of Potential Action Items

A clear delineation of which action items are proposed and which action items are already underway is needed.

5.2.3 Water Quality Monitoring - Nitrogen

"The alluvial aquifer area has less than 50-foot depth to groundwater and significant areas with less than 10-feet to groundwater and apparently under the influence of and connected to surface water; this conflicts with the Basin Plan's beneficial use designation of an existing or potential drinking water source." **The groundwater basin is designated as having a potential MUN beneficial use, which must be protected. Separation to groundwater is not a recognized criteria for exemption from this beneficial use designation according to State Board Resolution No. 88-63 (Sources of Drinking Water).**

5.4 Overall conclusions

"The risks posed by OWTS to groundwater quality was assessed relative to bacteria and nitrogen outcomes." **This statement is incorrect. The risk assessment defined surface waters as the applicable receiving waters and risks were evaluated based on surface water quality objectives.**

Comments on Appendix 3- Draft Malibu Modeling Report

Table 5 – Malibu Creek Average Monthly Flows

The period represented in the second column should be "1931 to 1968", not "1931 to 1986".

Boundary Conditions

"the lower boundary, which is at the contact between alluvium and underlying bedrock was assumed to be impermeable." **Page 7 of the Modeling Report indicates that at some locations the bedrock is fractured or faulted. While it may be correct to assume that a large percentage of the bedrock is impermeable, it may not be appropriate to assume that the lower boundary is entirely impermeable.**

Calibration

"Model calibration was accomplished with two steady-state simulations based upon water levels and streamflow data collected on September 25, 2003 for a flooded lagoon condition, and March 9, 2004 for a breached lagoon condition." **Although the intensity of the monitoring on the each of the calibration dates was high (42 measurements), the calibration period is very limited. In addition, the modeling report does not indicate a validation period for the model. Our concern is that the calibration dates may not adequately represent the study areas.**

"During model calibration average annual rates of recharge for all sources were specified in the model and adjustments were made to conductivity values in order to match measured water levels." **If using groundwater travel time will be an important tool in the City's OWST management strategy for bacteria, then we would suggest that site-specific conductivity data be gathered instead of backing into the values during model calibration.**

Transport Parameters and Source Concentrations

"Depending upon the degradation, the maximum loading rate caused by present activities may not be realized until 2010 or much later." **We see the absence of reliable nitrogen degradation information to be a significant data gap. The projects initial scope did involve a nitrogen fate and transport component. We would recommend that any plans to enhancement the model include a nitrogen fate and transport study.**

-------- Original Message --------
Subject: Comments on the draft report
Date: Tue, 13 Jul 2004 17:53:51 -0700
From: Sim, Youn <YSIM@ladpw.org>
To: Bruce Douglas (E-mail) <bdouglas@questaec.com>
CC: Chimienti, Michele <MCHIMIEN@ladpw.org>

Dear Bruce:
Thanks for giving me the opportunity to review and comment on this report.
I found the most part of the report was well written and considerable amount of effort was put into this work.

Most of my comments are regarding the modeling effort as you may have expected considering our previous discussion.
I should first note that the current modeling should be quite different compared to the other groundwater/environmental type of modeling projects. It is because the current issues are focused on the onsite wastewater treatment system (OWTS) and its potential impact on the groundwater quality. One of the key factors that shall be emphasized in this work is the role of the unsaturated zone in removing contaminants including nutrients and bacteria. It is because the OWTS are solely relying on the unsaturated zone to remove or reduce theses contaminants. There are many literatures available for the groundwater modeling and contaminant transport in the unsaturated zone, which are uniquely distinguished from the saturated zone modeling in its mechanisms in contaminant removal.

However, the modeling used in this report are based on:

- Groundwater flow in saturated zone only using MODFLOW with assumed vertical seepage surface water and wastewater loading at the water table boundary. This seepage rates shall be calculated based on the unsaturated soil properties and hydraulics of groundwater flow in unsaturated zone. But I was glad to note that at least hydraulic conductivities were measured through tests rather than estimated.
- For the transport modeling to predict the fate of nutrients in the subsurface, MT3D was used. As you know MT3D is widely used for the typical environmental modeling of contaminants to estimate the transport of the contaminants and to predict and prepare a cleanup activities, where transport simulation can be limited to saturated zone to serve its purpose since it is to cleanup the contaminants in the groundwater. However, the current case is to closely predict the contaminants from the ground level sources (OWTS) to groundwater table by accounting for the mechanisms within the unsaturated zone. Although the unsaturated zone in the study area could be quite shallow (less than 20 feet or less), literatures indicate that even travel of contaminants of short distance within the unsaturated zone has a significant impact on the removal or reduction of the contaminants.
- Even with the simulation with MT3D, majority of transport parameters were obtained from standard values from existing literature such as dispersivities and porosity. And decay rates obtained from Germany with temperature adjustments. Dispersivities were borrowed from a book of Prof. Gelhar of MIT. But dispersivities are to be obtained as part of the model calibration process using the existing data to represent the field conditions. Dispersivities in the transport model is equivalent to hydraulic conductivities in the groundwater model. Therefore transport simulations are extremely sensitive to the dispersivities values used for the simulation. It is very disappointing to notice that book values of dispersivities were used for the simulation when hydraulic conductivities were carefully obtained from tests. Therefore, the quality and accuracies of the simulation results of nutrients may have been significantly compromised.
- For bacteria, no transport modeling was conducted with reasons that are not very clear. But I understand that it was due to complex mechanisms that are occurring at the unsaturated zone. Instead, Travel Time was used to represent the migration of the bacteria in the subsurface, basically assuming the bacteria will be moving by following the groundwater flow. This assumption essentially ignores all the transport mechanisms that bacteria are going through, especially within the unsaturated zone. Unlike any other typical contaminants, Bacteria grow as well as inactivate while they are migrating in the subsurface. Therefore, there are many models available in the literature specifically designed for the bacteria transport in the saturated/unsaturated zones.
- In summary, I believe the report was very well organized and very good analysis was demonstrated.

However, the report does not address important role of unsaturated zone in nutrient and bacteria removal and reduction. Consequently, the results from your analysis may have been over- or under-estimated the extent of bacteria and nutrient transport. As I stated above, the assumptions used in the modeling effort are acceptable for typical groundwater contamination project. But as you know, the OWTS project is quite distinguished from them in many aspects, especially for the mechanisms of the contaminant transport within the unsaturated zone.

I apologize for the late comments and also my poor expression. I am rushing to send this to you.

Thanks,

Youn Sim, Ph.D., P.E.
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July 12, 2004

Ms. Adrienne Furst
Department Specialist
City of Malibu
23815 Stuart Ranch Road
Malibu, CA 90265

RE: Comments on the Draft Final Report: Risk Assessment of Decentralized Wastewater Treatment Systems in High Priority Ares in the City of Malibu, California

Dear Ms. Furst:

Heal the Bay is a nonprofit environmental organization with over 10,000 members dedicated to making the waters of Southern California clean and healthy for marine life and people. On behalf of Heal the Bay, we have reviewed the Draft Final Report: Risk Assessment of Decentralized Wastewater Treatment Systems in High Priority Areas in the City of Malibu and respectfully submit the following comments.

Heal the Bay has specific questions and concerns primarily related to the assumptions and calculations used to quantify the extent of the area of influence into Malibu Creek and Lagoon and the predicted travel times of groundwater in the area of influence. In addition, Heal the Bay has comments and suggestions to further strengthen the proposed action items.

1. **What is the effect of tidal action on the predicted contributing areas into Malibu Creek and Lagoon and on estimated residence times in surrounding soils?**

The model used to simulate groundwater flow and solute transport is a steady state model that does not take into account the effects of tidal action. Heal the Bay is concerned that the omission of tidal influence may decrease the accuracy of the model to specifically predict the area of influence into the Creek and Lagoon as well as the transport of contaminants. The contributing area to the Creek and Lagoon during breached conditions is significantly larger than that calculated for closed conditions when the water level in the lagoon is extremely high. Given that this is a steady-state model, the calculation for open conditions would be made at a specific tidal height that would correspond to a specific water level in the lagoon. The tidal height corresponding to the synoptic water level measurements, and consequently the contributing area to the Creek and Lagoon, is not stated. Without knowledge of this important piece of information, it is impossible to determine how tidal influence may affect these findings.

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The synoptic assessment for open conditions took place on March 9, 2004, a day of relatively extreme tidal fluctuations of over 4 feet throughout the day. Depending on the time of the synoptic assessment on this date, groundwater measurements would encounter conditions more similar to closed conditions (4.5' high tide at 10:36 a.m.)[1] or conditions more opposed to closed conditions (0.6' low tide at 4:36 p.m.)[1]. To fully understand the maximum extent of the contributing area to the Creek and Lagoon, synoptic water measurements should have been taken to correspond to extreme low tides (*e.g.*, -1.0'), especially in late Spring or early Summer when creek flows are substantially decreased. This would have enabled a more thorough understanding of the potential for tidal action to influence ground-water levels in the study area which directly influenced the estimated area of contribution into the Lagoon and Creek.

Another potentially important aspect related to tides is the inability of the steady-state solute transport model to take into account potential pumping action caused by tidal influences. The solute transport model was stated to "simulate concentrations of miscible contaminants in groundwater considering advection, dispersion, diffusion and some basic chemical reactions, with various types of boundary conditions and external sources and sinks[2]." This model did not, however, take into account the possible movement of miscible contaminants due to transport caused by pumping resulting from daily tidal action during breached conditions. How might tidal pumping potentially influence the predicted transport of solutes into the Lagoon, Creek and ocean and how might this affect the estimated residence times of such substances?

2. **The lithology of the study area is oversimplified and appears to omit areas of relatively high hydraulic conductivity resulting in possible inaccurate estimates of travel times.**

A series of borehole tests conducted between 1960 and 1998 reveal an alluvium comprising "spatial and temporal patterns of great complexity involving frequent lateral and vertical facies changes[3]." This complexity is also revealed by the recent well logs and those of previous studies indicating that the core revealed "a sequence of fine-grained, organic-rich, medium to find sand, silt, and clay, alternating with coarse-grained, organic-poor pebbles and cobbles in a poorly sorted coarse sand matrix[4]. In addition to considerable variability in the vertical profile of the alluvium, there appears to be a great deal of variability horizontally as exhibited by the differing soil characteristics exhibited by wells or bore holes in similar areas such as well SMBRP-7b and bore hole A[4] from a previous study.

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[1] www.tidelog.com. Tides relative to NOAA chart datum, mean lower low water and are corrected to represent conditions at Santa Monica, Municipal Pier.
[2] McDonald Morrissey Associates, Inc. (2004) Draft Malibu Model Report, p. 37.
[3] Ambrose, RFA & Orme AR (2000). Lower Malibu Creek and Lagoon Resource Enhancement and Management. Final Report to the Coastal Conservancy, p. 1-15
[4] *Id* at 3. p. 1-17 (Core located at corner of Civic Center Way and La Paz Lane)

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It appears that the model is unable to account for this high degree of variability and instead, relies on the results of slug tests to determine hydraulic conductivity and associated travel times. The model predicts that the travel time in the alluvium west of the lagoon varies from 5 years to greater than 50 years within a quarter mile distance. Does the lithology and head gradient truly support this estimate? For example, wells #8 and #9 are located approximately ¼ mile from each other in the west alluvium. The boring logs show that the lithology for #8 is finer grained material than #9, but both wells appear to be in locations where the model predicts a travel time of greater than 50 years to the ocean during flooded conditions. The hydraulic conductivity for well 9 is 2.17 ft/day, significantly higher than the value for well 8, 0.181 ft/day. Why then are the wells in the same category of travel time, especially when the head at well 9 is higher than that at well 8?

Why were no tracer tests performed to quantitatively verify results of slug tests and model results? The fact that a previous study found an increase of 2 orders of magnitude in hydraulic conductivity when slug tests were compared to bromide tracer and coliphage seeding tests[5] indicates that the variation in the lithology of the alluvium is such that slug tests may not be able to accurately predict the hydraulic conductivity of the soils in the area.

Another aspect of the model which we request further clarification is the chosen grid size of 50' x 50'. Given the extremely high variability of soil types located in the study area, it seems that a grid size of this magnitude would serve to oversimplify soil conditions and decrease the accuracy of the model estimates. Why was this grid size chosen? Were other grid sizes assessed and how might the model results change if the grid size was reduced? Finally, what was the "average tide elevation"[6] that was used to represent the constant head elevation assigned between the alluvial deposits and Pacific Ocean in layer 1? How do the results of the model change if a lower tidal value is used?

3. Assumptions used to characterize the OWTS in the study need further validation.

Design information was available for less than one quarter of OWTS in the study area (p. 48). Given this dearth of data, how were estimates of pollutant loads obtained and how was the information about the known OWTS applied to the model? How many OWTS in the study area, if any, are "failed" or "short-circuited" and how might this influence model results? How can the level of risk for bacteria be calculated when there are no detailed data on the vertical separation between the infiltrative surface of the dispersal system and the water table for many of the systems in the study area?

4. Conclusions and Recommendations

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[5] URS Greiner Woodward Clyde (1999) Study of Potential Water Quality Impacts on Malibu Creek and Lagoon from On-site Septic Systems.
[6] *Id* at 2, p. 26

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Heal the Bay is concerned that errors introduced into the model primarily due to the oversimplification of soil lithology, failure to incorporate tidal action and effects of extreme low tide conditions, and uncertainties regarding input from OWTS may have resulted in inaccurate estimates of travel time and the extent of the contributing area to the Creek and Lagoon. As a result, Heal the Bay has the following suggestions to increase the level of protection of the action items presented in the study.

Water Resource Management Strategies:

1. Heal the Bay supports the continuing of regional groundwater sampling in the Civic Center area. A long term regional groundwater monitoring program must be established to help determine the efficacy of implemented solutions. As part of this monitoring program, a tracer study should be implemented to quantitatively evaluate the contributing area into the Creek and Lagoon as well as the actual travel time for miscible contaminants
2. Heal the Bay supports the maintenance and collection of continuous groundwater level from existing installed data loggers.
3. Heal the Bay supports continuing synoptic water level measurements. However, we recommend that the number of synoptic water level measurements be increased during breached conditions to capture conditions at opposite extremes of the tidal range and determine how this may influence model estimates of groundwater flow.
4. Heal the Bay supports the increase of efforts to accurately characterize the performance of individual OWTS and hydrogeologic data associated with OWTS by requiring the submission of these data to City as a condition of operating permits.
5. Due to the importance of the connectivity between the two systems, we recommend a detailed assessment of the relationship between groundwater quality data and Malibu Creek, Lagoon and surfzone surface water quality data.
6. Due to the implicit connection between groundwater and surface water in Malibu Creek, Lagoon and the surfzone, Heal the Bay is strongly opposed to the reassessment of the beneficial use designation of groundwater in Malibu Valley. This is an issue to be discussed with the Regional Board and should not be included in a scientific report.

Corrective Actions Involving Infrastructure:

1. Heal the Bay supports the recommendation for onsite disinfection and denitrification for all commercial and multi-family systems in the Lagoon contributing area. In addition, we recommend that this requirement be applied to all systems in the Lagoon and Creek contributing area.
2. If future assessments, such as those previously described to verify model assumptions, determine that the contributing area is larger than that estimated by the current study, then the aforementioned standards should be expanded to apply to all OWTS in the newly defined contributing zone.

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3. Ensure that all OWTS in the study area are in compliance with guidelines stipulated by AB 885. Up to TSS-30mg/l, BOD 30 mg/l, Nitrate as nitrogen 10 mg/l, Total Coliform < 2.2 cfu/100 ml should be required for all systems
4. Heal the Bay is concerned that OWTS impacts on loading to the Lagoon through and/or around pipes that directly discharge into the Southwest arm of the Lagoon were not assessed. Previous studies have shown that septic leachate was transported directly into the Creek and Lagoon through the substrate surrounding existing pipes[7]. Therefore, we recommend that all storm drains, conduits and pipes discharging into the Lagoon be eliminated. These conduits should be incorporated into the City's proposed dry weather flow diversion and treatment system, thus eliminating their impacts.

OWTS Management Strategies

1. Heal the Bay supports the recommendation for site specific groundwater monitoring for existing commercial and multifamily systems in Lagoon contributing areas. In addition, these requirements should be applied to all systems in the Lagoon and Creek contribution area.
2. Heal the Bay supports the recommendation for mandatory inspections and operating permits for all OWTS in the Malibu Lagoon contributing area as well as for all systems with inadequate separation to groundwater.
3. Heal the Bay supports the recommendation for point of sale inspections with operating permits for all systems.
4. If inspections and/or monitoring reveal systems that are not functioning, these systems should be required to be repaired and/or upgraded to meet the objectives listed in bullet 3 under Corrective Actions Involving Infrastructure above.
5. The City should immediately investigate the feasibility of developing a wastewater management district or utility for the Civic Center area. This would allow the City to implement a more comprehensive approach to wastewater management and reclaimed water reuse. In addition, the District would be self-funding, which would allow greater compliance assurance. Also, the City should investigate whether or not the commercial and multifamily residential properties along PCH – east of the Civic Center (about 1-2 miles) – should be part of the District. The District could be part of the City or a separate, private or quasigovernmental body (a special district).
6. The City should require that all new developments and substantial retrofits in the Malibu Creek watershed have no increase in stormwater flows leaving the site compared to undeveloped conditions.

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[7] LA-RWQCB (2000) City of Malibu Wastewater Disposal Issues: Board Briefing. p. 13.

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7. The City should require that all new developments and substantial retrofits in the Malibu Creek watershed maintain a truly balanced water budget. This will require adequate onsite storage to ensure 100% wastewater reuse so there is no net increase of nutrients or bacteria into the surrounding aquifer.

To conclude, Heal the Bay is concerned about references, conclusions and recommendations regarding TMDLs, waste load allocations and other related regulatory policies. We recommend that all references or recommendations pertaining to changing these regulations be removed from the final report. These issues should be discussed with the Regional Board and not included in a scientific report.

Thank you for the opportunity to comment on this draft and we appreciate the tremendous amount of work that has gone into its preparation. At your earliest convenience, we would like to further discuss our questions regarding the development of the model and water budget. As always, we look forward to continue working with the City of Malibu on this and other issues.

Please contact us at 310-453-0395 if you have any questions about our comments

Sincerely,

Craig Shuman, D. Env.
Staff Scientist
Heal the Bay

Mark Abramson
Stream Team Manager
Heal the Bay

Mark Gold, D. Env.
Executive Director
Heal the Bay

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A Partnership to
Restore and Protect
Santa Monica Bay

Funded by US EPA
and the State Water Resources
Control Board in cooperation
with the public, local agencies,
and industry.

Mary Clark
Stone Environmental
535 Stone Cutters Way
Montpelier, VT 05602

Re: Risk Assessment of Decentralized Wastewater Treatment Systems in High Priority Areas in the City of Malibu, CA

Dear Mary,

Thank you for the impressive draft final report generated by Stone Environmental on behalf of the City of Malibu regarding the risk assessment of onsite wastewater treatment systems to water quality for, as well as for the opportunity to comment on its content and findings.

Overall, the report is very thorough and the findings presented are scientifically sound. Following are comments for your consideration.

General Comments

- Please change all "Santa Monica Bay Restoration Project" references to "Santa Monica Bay Restoration Commission."
- There is inconsistent use of "Lagoon" (capitalization) when referring specifically to Malibu Lagoon.
- The report should mention somewhere (perhaps in the beginning or under action items) why connection to a centralized sewer system (e.g., Hyperion) is not listed as an alternative corrective strategy this report. Failing to address this issue raises a red flag regarding unbiased and viable treatment options, even if not financially realistic. Table 30 does list "Community Reclamation and Dispersal Outside of Contributing Area," but this title does not suggest sewer systems as an option.

Specific Comments:

- Page 1, Executive Summary: 4th paragraph. "The development along the lower creek area and lagoon area consists of….." This sentence does not reference commercial developments but should.
- Page 2: 3rd paragraph: "The first step in risk assessment is to define what levels of risk are appropriate." Appropriate for what? Needs clarification such as appropriate to protect human health, or to meet water quality objects established in the Basin Plan.
- Page 80, Nitrogen, 2nd Bullet: "In properly functioning ***and sited*** traditional OWTS….
- Appendices: Hydraulic conductivity rates (Maps 13-16) show that alluvial soils can transmit water much faster than the travel time spatial distribution maps actually show (Maps 25-27), on the order of days

rather than months or years. The draft text must provide some rational for the apparent difference in travel times for these areas, particularly next to the creek and lagoon where rates are the highest.

Again, thank you for the opportunity to review and comment on draft results of this comprehensive study.

Sincerely,

Stephanie Katsouleas
Project Manager, Santa Monica Bay Restoration Commission

Cc: Bruce Douglas, Questra Engineering
Vic Peterson, City of Malibu
Marianne Yamaguchi, SMBRC

Reviewer Name	Comment	Response
LARWQCB / Rod Collins	2.2.1 (per letter)	Changed in final report.
LARWQCB / Rod Collins	2.4.1, first comment (per letter)	Concur. Addressed in final report.
LARWQCB / Rod Collins	2.4.1, second comment (per letter)	Concur. Addressed in final report.
LARWQCB / Rod Collins	2.4.1, third comment	Concur. Addressed in final report.
LARWQCB / Rod Collins	2.4.3, first comment	Concur. Addressed in final report.
LARWQCB / Rod Collins	2.4.2.4, first comment	Concur. Addressed in final report.
LARWQCB / Rod Collins	2.4.2.3, both comments	Concur. Addressed in final report.
LARWQCB / Rod Collins	2.4.2.4, second comment (N loading error)	Concur. Addressed in final report.
LARWQCB / Rod Collins	2.4.2.5 (N calculations based on previous error)	Concur. Addressed in final report.
LARWQCB / Rod Collins	3.6.3.2., first comment (N mass loading low)	The model can be run with any assumed concentration for domestic waste water. The value used was based upon information supplied by Questa Engineering for this study. Additional clarification of how Questa calculated the values used for this study is included in the final report.
LARWQCB / Rod Collins	3.6.3.2, second comment (explain results of N comparison)	A comparison of model calculated nitrate values with those observed in the field was presented in the modeling report in figure 28. The purpose of this figure was simply to show the effect that model assumptions regarding denitrification had on model predicted concentrations. When denitrification was ignored the model predicted nitrate concentrations are much higher than those observed in the field. Inclusion of a denitrification process in the model appears to improve the match between calculated and observed nitrate values. A rigorous calibration of calculated and observed nitrate was not attempted because the exact timing and strength of each nitrate source was not known and de-nitrification processes were not fully understood. However, for the purposes of predicting gross loading rates to the Lagoon and Ocean the model was considered to be acceptable.
LARWQCB / Rod Collins	3.7	Concur. Addressed in final report.
LARWQCB / Rod Collins	4.4.1.3, first comment	Concur. Addressed in final report.
LARWQCB / Rod Collins	4.4.1.3, second comment	Other potential sources are located upgradient of monitoring point in Winter Canyon; however, the text will stand as written.
LARWQCB / Rod Collins	4.4.2.4 (bacteria impacts on groundwater)	Concur. Addressed in final report.
LARWQCB / Rod Collins	4.6.1.1, first comment	In the final report, we clarified why lower population numbers were used.
LARWQCB / Rod Collins	4.6.1.1, second comment	In the final report, we described in more detail that dilution alone does not account for all nitrate reduction.
LARWQCB / Rod Collins	4.6.1.3 (beneficial use)	We agree that the designated beneficial use of groundwater should be acknowledged; this is addresed in the final report.
LARWQCB / Rod Collins	4.6.2.4	We agree that the designated beneficial use of groundwater should be acknowledged; this is addresed in the final report.
LARWQCB / Rod Collins	4.6.3	Concur. Addressed in final report.
LARWQCB / Rod Collins	4.7.1.1	Concur. Addressed in final report.
LARWQCB / Rod Collins	4.8	Concur. Addressed in final report.
LARWQCB / Rod Collins	5.2.3	Comment addressed in final report relative to beneficial use.
LARWQCB / Rod Collins	5.4	Addressed in final report.

Reviewer Name	Comment	Response
LARWQCB / Rod Collins	Appendix 3 comments: Boundary Conditions	It is true that the bedrock has some permeability. However, the permeability of the alluvium is so much higher than the bedrock we made the simplifying assumption that bedrock was impermeable. For the purpose of calculating loading rates or capture zones this assumption is reasonable.
	Appendix 3: Calibration	A transient model calibration was not considered to be necessary for the stated modeling purposes. The use of two steady-state simulations that represent high and low conditions is designed to cover the possible range of flow and transport conditions. As additional water level data become available these simulations can be refined and perhaps some transient flow simulations could be attempted.
		Hydraulic conductivity estimates, especially those made with slug tests, are not definitive. Conductivites derived from large scale pump tests are generally better than those derived from slug test data but are still not absolute. Because of this, and because hydraulic conductivity can vary so widely (several orders of magnitude) it is often treated as a calibration parameter in modeling studies. Although some modification was made to initial hydraulic conductivity values during calibration for this study the final values still honor observations made in the field. Any additional information that is collected on hydraulic properties can be incorporated in future model simulations.
LARWQCB / Rod Collins	Appendix 3: N fate and transport	We believe current examination is adequate. Workplan items regarding N fate and transport were described as follows: Task 4.1 Groundwater Flow and Solute Transport Modeling: iii. Assess the impact of the combined effect of decentralized wastewater systems on groundwater quality and groundwater levels iv. Define the groundwater contributing areas for locations of groundwater discharge to surface water bodies in the study area v. Estimate wastewater chemical and pathogen loading rates from groundwater to surface water bodies including Malibu Creek, Malibu Lagoon, and the Pacific Ocean.
		We agree that more information is needed on denitrification in the Malibu ground water flow system.
Youn Sim	Groundwater flow in saturated zone only using MODFLOW with assumed vertical seepage…	We agree that the unsaturated zone can cause transformation of nitrogen and can tend to reduce bacterial concentrations. Model simulations done for our study assume that the unsaturated zone had a negligible effect on nitrogen species and bacteria. This approach is conservative in that it will tend to over predict nitrate and bacteria loading to the ocean and lagoon. For the stated purposes of the study our modeling methodology is reasonable.

Reviewer Name	Comment	Response
Youn Sim	For the transport modeling to predict the fate of nutrients in the subsurface, MT3D was used…	We agree that the unsaturated zone can cause transformation of nitrogen and can tend to reduce bacterial concentrations. Model simulations done for our study assume that the unsaturated zone had a negligible effect on nitrogen species and bacteria. This approach is conservative in that it will tend to over predict nitrate and bacteria loading to the ocean and lagoon. For the stated purposes of the study our modeling methodology is reasonable.
Youn Sim	Even with the simulation with MT3D, majority of transport parameters were obtained from standard values…	Transport parameters were assigned based upon a review of the literature. Determination of dispersivity values using tracer tests is very time consuming and expensive and beyond the scope of our study.
Youn Sim	For bacteria, no transport modeling was conducted with reasons that are not very clear…	Clarified in final report.
Heal the Bay	1. (per letter)	Contributing areas for the Creek and Lagoon were predicted with steady state model simulations of a breached condition and a flooded condition. In each of these simulations the lagoon stage was specified in the model using field stage measurements from the corresponding synoptic measurement and tide height was specified at the average elevation for the corresponding day. Examination of the monthly water levels collected at observation wells near the Lagoon and synoptic measurements shows that the breached condition was very near the low ground water levels observed during the year and the flooded condition was very near the annual highs. It is true that there may have been instantaneous highs or lows during the year, especially those associated with extreme tides that were higher or lower than our synoptic measurements. In our model runs we assumed that the high and low conditions exist for an infinite amount of time. In actuality, these conditions are very transient. We believe that the use of a steady-state simulation for the low condition will tend to over predict the size of the contributing area. The true contributing area would be an "average" of the flooded and breached condition. Modeling of daily tidal influences was not necessary to meeting the stated objectives of the modeling analysis and was therefore considered to be beyond the scope of the study. If additional studies follow the present effort, the current model could be refined with additional synoptic measurements and tested with simulations of daily tidal fluctuations. It is the opinion of this researcher that the use of a steady-state simulation with an average tide height would yield essentially the same loading predictions as a transient model simulation with daily tidal fluctuations.

Reviewer Name	Comment	Response
Heal the Bay	2., para. 1 (Study area lithology simplification)	Hydraulic conductivity values specified in the model did not rely solely on slug test results. In addition to the slug tests, information on hydraulic conductivity was determined from transmissivity values estimated for abandoned Malibu Water Company supply wells, from a previous tracer test, from laboratory testing results and from a previous modeling study. Hydraulic conductivities assigned in the model are consistent with these observations. See page 11 of the modeling report for these details
Heal the Bay	2., para. 2	The reason why the travel times to the Ocean are nearly the same for observation wells SMBRP-8 and 9 is because ground water in their vicinity flows vertically downward through the system before finally reaching the ocean. Water from each location therefore encounters essentially the same subsurface materials and is subject to essentially the same hydraulic gradient on its flow path to the ocean.
Heal the Bay	2., para. 3 (tracer tests)	Tracer tests are expensive and time consuming and beyond the scope of our study. Results of tracer test data collected in previous investigations were used to assign a hydraulic conductivity value of 400 feet per day to alluvium along the lagoon.
Heal the Bay	2., para. 4 (grid size)	The grid spacing used in the model was 50 feet along rows and columns. This grid spacing allows accurate spatial discretization of features affecting the flow system and also is consistent with data available to construct the model.
Heal the Bay	3. (characterization of OWTS)	Refer to Sections 3.6.3.2 and 4.2.1.2 for additional detailed information on how pollutant loads from OWTS were determined.
Heal the Bay	4. Water Resource Mgmt Strategies (1)	City concurs with benefits of long-term groundwater monitoring, as noted in draft MOU
Heal the Bay	4. Water Resource Mgmt Strategies (5)	City concurs with benefits as noted in draft MOU.
Heal the Bay	4. Water Resource Mgmt Strategies (6)	The relevance of the beneficial use designation is impacted by new data collected in this study, therefore this issue will be left in the report.
Heal the Bay	4. Corrective Actions - Infrastructure (1)	The current plan to upgrade commercial / multifamily systems right away and to upgrade the rest on a time-of-transfer basis provides for a reasonable and manageable rate of upgrades.
Heal the Bay	4. Corrective Actions - Infrastructure (2)	Concur.
Heal the Bay	4. Corrective Actions - Infrastructure (3)	The use of groundwater monitoring for small systems is not appropriate or productive for small OWTS. Instead of after-the-fact monitoring, the City is taking a proactive approach requiring inspections and treatment as necessary, as noted in Draft MOU.
Heal the Bay	4. Corrective Actions - Infrastructure (4)	The City of Malibu is continuing to implement stormwater management program to provide treatment of dry weather and first flush stormwater prior to discharge.
Heal the Bay	4. OWTS Management (1)	The use of groundwater monitoring for small systems is not appropriate or productive for small OWTS. Instead of after-the-fact monitoring, the City is taking a proactive approach requiring inspections and treatment as necessary, as noted in Draft MOU.

Reviewer Name	Comment	Response
Heal the Bay	4. OWTS Management (2)	This is a goal of the City. The point of sale inspection program will provide for inspection of systems and require upgrades as necessary, per the draft MOU.
Heal the Bay	4. OWTS Management (3 and 4)	Concur.
Heal the Bay	4. OWTS Management (5)	Concur. This suggestion is appreciated and is not precluded by any of the action items.
Heal the Bay	4. OWTS Management (7)	The current study has been focused on existing development. The City will utilize the results in the context of upcoming TMDL criteria and current requirements for OWTS and stormwater management.
Heal the Bay	Concluding para. 1	The City welcomes the interest and involvement of stakeholders such as Heal the Bay. The City is very willing to continue direct dialogue with Heal the Bay.
SMBRC / S. Katsouleas	Please change all "Santa Monica Bay Restoration Project" references to "Santa Monica Bay Restoration Commission."	Concur. Addressed in final report.
SMBRC / S. Katsouleas	There is inconsistent use of "Lagoon" (capitalization) when referring specifically to Malibu Lagoon	Concur. Addressed in final report.
SMBRC / S. Katsouleas	The report should mention somewhere (perhaps in the beginning or under action items) why connection to a centralized sewer system (e.g., Hyperion) is not listed as an alternative corrective strategy this report	Concur. Addressed in final report.
SMBRC / S. Katsouleas	Page 1, Executive Summary: 4th paragraph. "The development along the lower creek area and lagoon area consists of….." This sentence does not reference commercial developments but should.	Concur. Addressed in final report.
SMBRC / S. Katsouleas	Page 2: 3rd paragraph: "The first step in risk assessment is to define what levels of risk are appropriate." Appropriate for what? Needs clarification such as appropriate to protect human health, or to meet water quality objects established in the Basin Plan	Concur. Addressed in final report.
SMBRC / S. Katsouleas	Page 80, Nitrogen, 2nd Bullet: "In properly functioning and sited traditional OWTS….	Concur. Addressed in final report.
SMBRC / S. Katsouleas	Appendices: Hydraulic conductivity rates (Maps 13-16) show that alluvial soils can transmit water much faster than the travel time spatial distribution maps actually show (Maps 25-27), on the order of days rather than months or years. The draft text must provide some rational for the apparent difference in travel times for these areas, particularly next to the creek and lagoon where rates are the highest.	Hydraulic conductivity is not the only factor involved in time-of-travel calculations. Time of travel calculations must also account for hydraulic gradient.

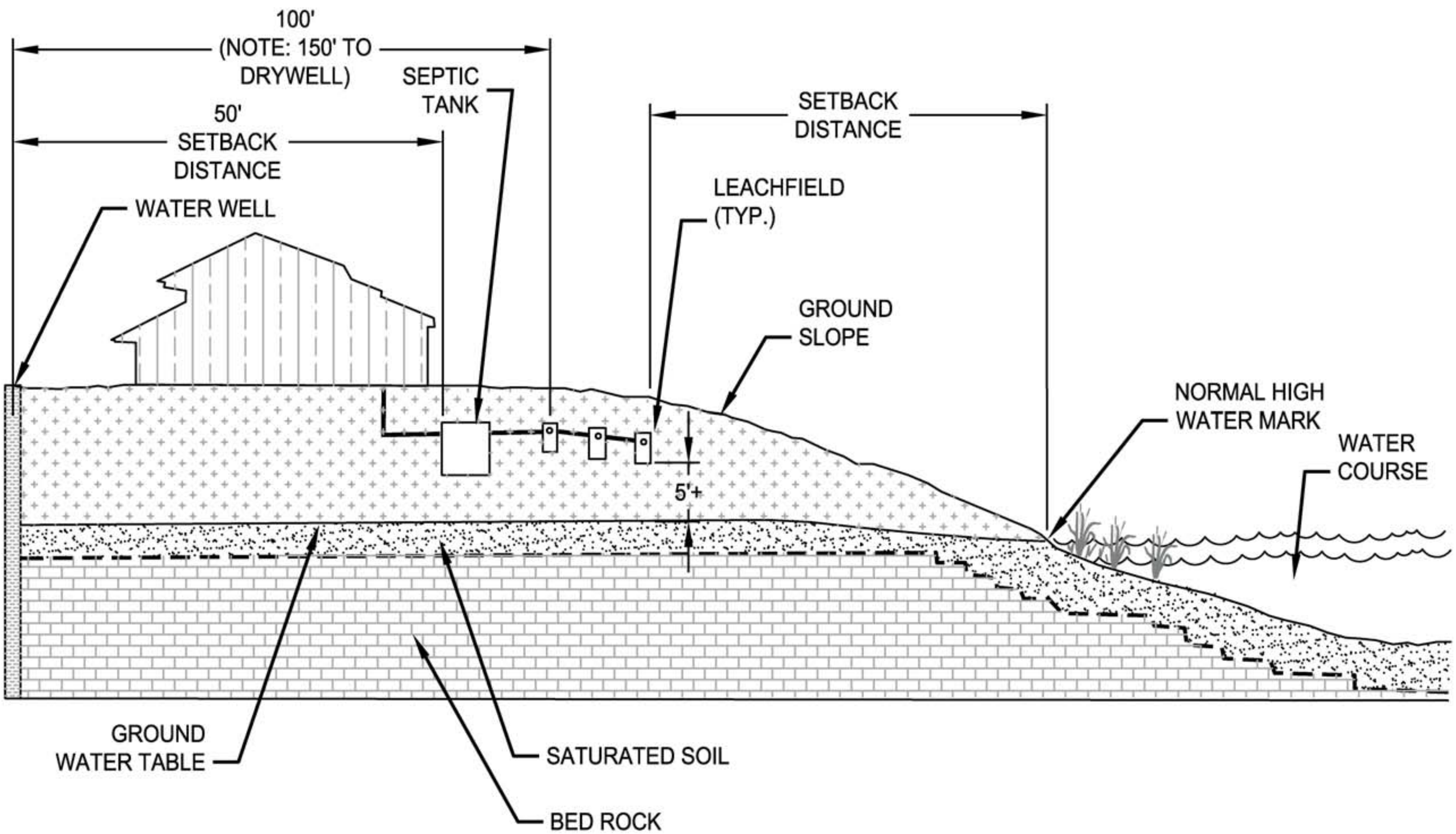

FIGURE 1: TYPICAL SITING CONSIDERATIONS FOR ON-SITE WASTEWATER TREATMENT SYSTEMS
Risk Assessment of Decentralized Wastewater Treatment Systems in High Priority Areas
City of Malibu, California

Source: Questa Engineering Corp., 2004.
Path: O:\proj-01\1269-W\Reports\Final report\Draft\Figures\Figure XX_SepticTank.cdr
Date/init: 5-20-04 JL; rev 5-27-04 anm

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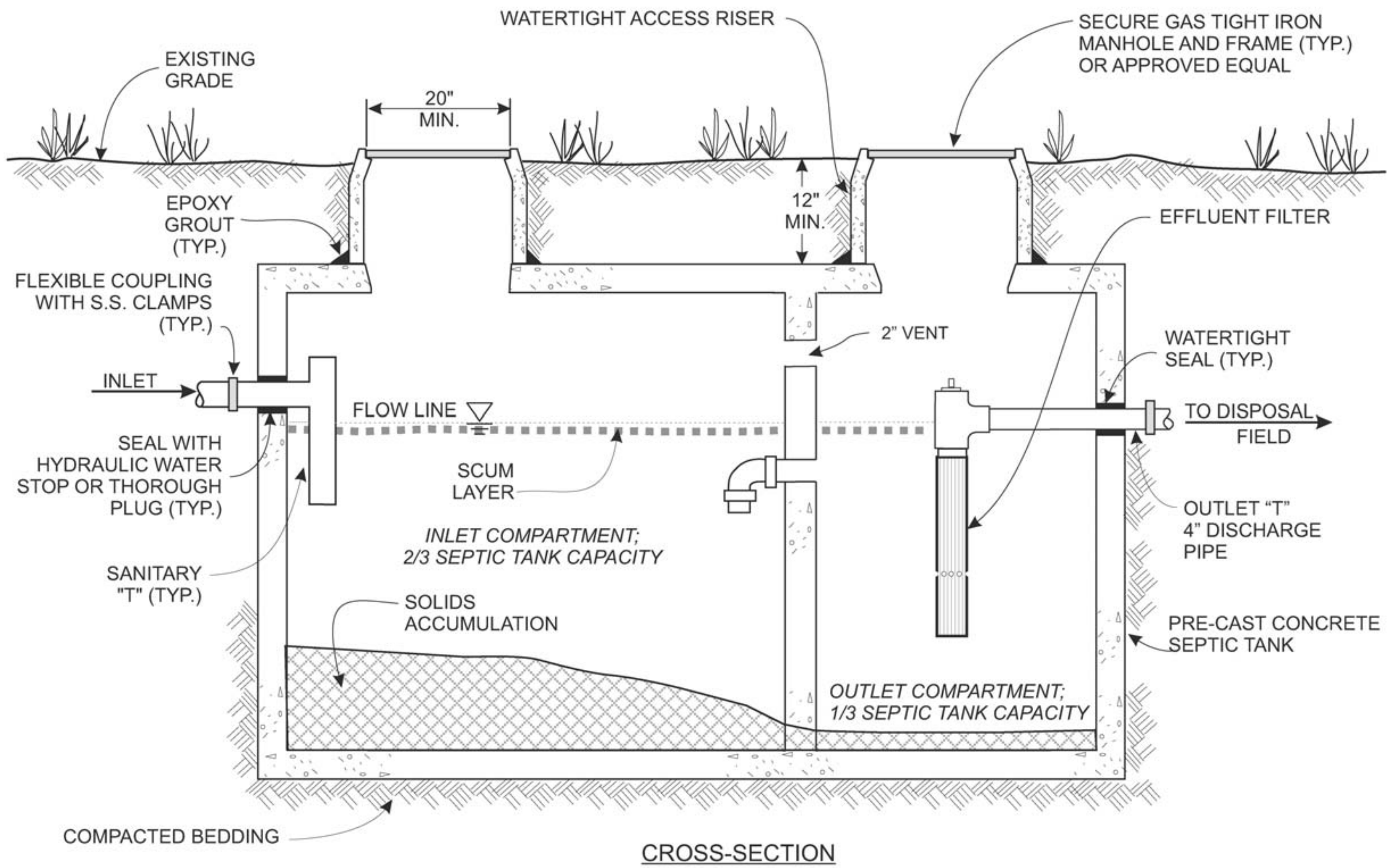

FIGURE 2: TYPICAL SEPTIC TANK

Risk Assessment of Decentralized Wastewater Treatment Systems in High Priority Areas

City of Malibu, California

Source: Questa Engineering Corp., 2004.
Path: O:\proj-01\1269-W\Reports\Final report\Draft\Figures\Figure XX_SepticTank.cdr
Date/init: 5-20-04 JL; rev 5-27-04 anm

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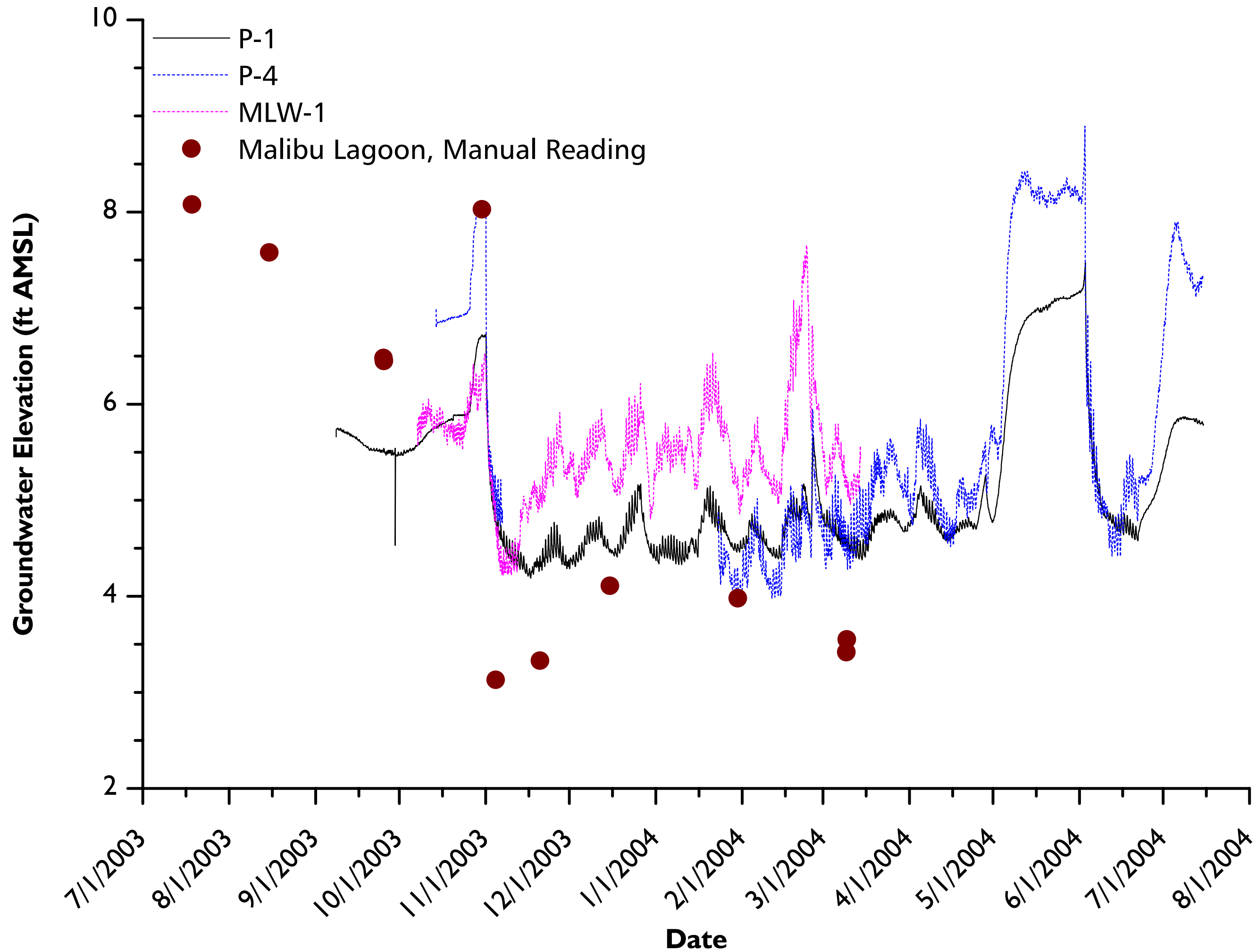

FIGURE 3: CONTINUOUS WATER LEVEL ELEVATION READINGS, MONITORING WELLS MLW-1, P-1, AND P-4 AND MALIBU LAGOON
City of Malibu, California

Source: Global Water WL-15 datalogger, downloaded by City of Malibu staff, 2003 and 2004.
Path: o:\proj-01\1269-W-Malibu\data\welldata\datalogger\dataloggers.opj
Date: 8-25-04 anm

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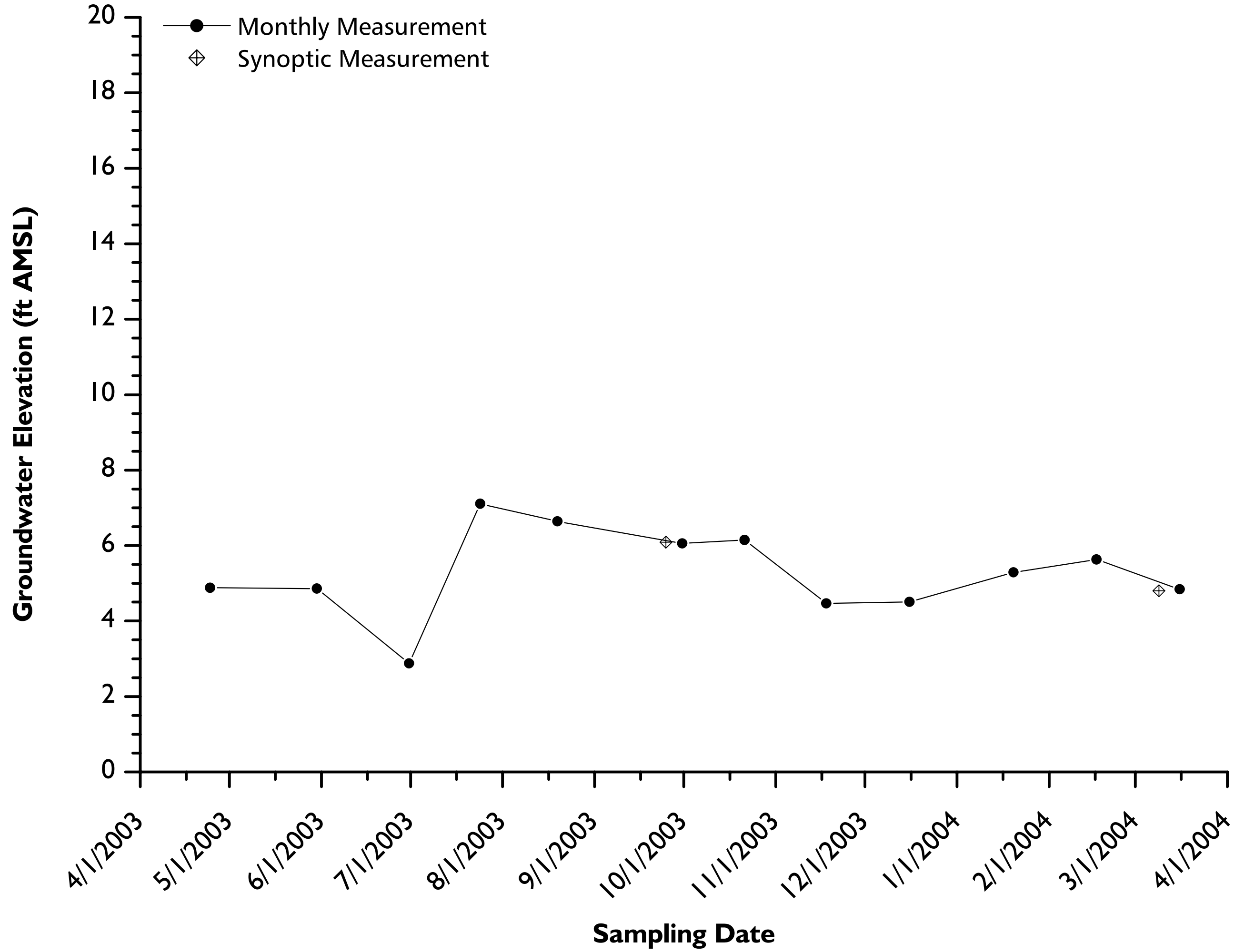

FIGURE 4: GROUNDWATER ELEVATIONS, WELL C-1
City of Malibu, California

Source: Field Observations, Biosolutions Inc., 2003-2004.
Path: O:\Proj-01\1269-W-Malibu\Data\WellData\AnalyticalResults\Figures\WaterLevels.opj
Date: 3-23-04 anm

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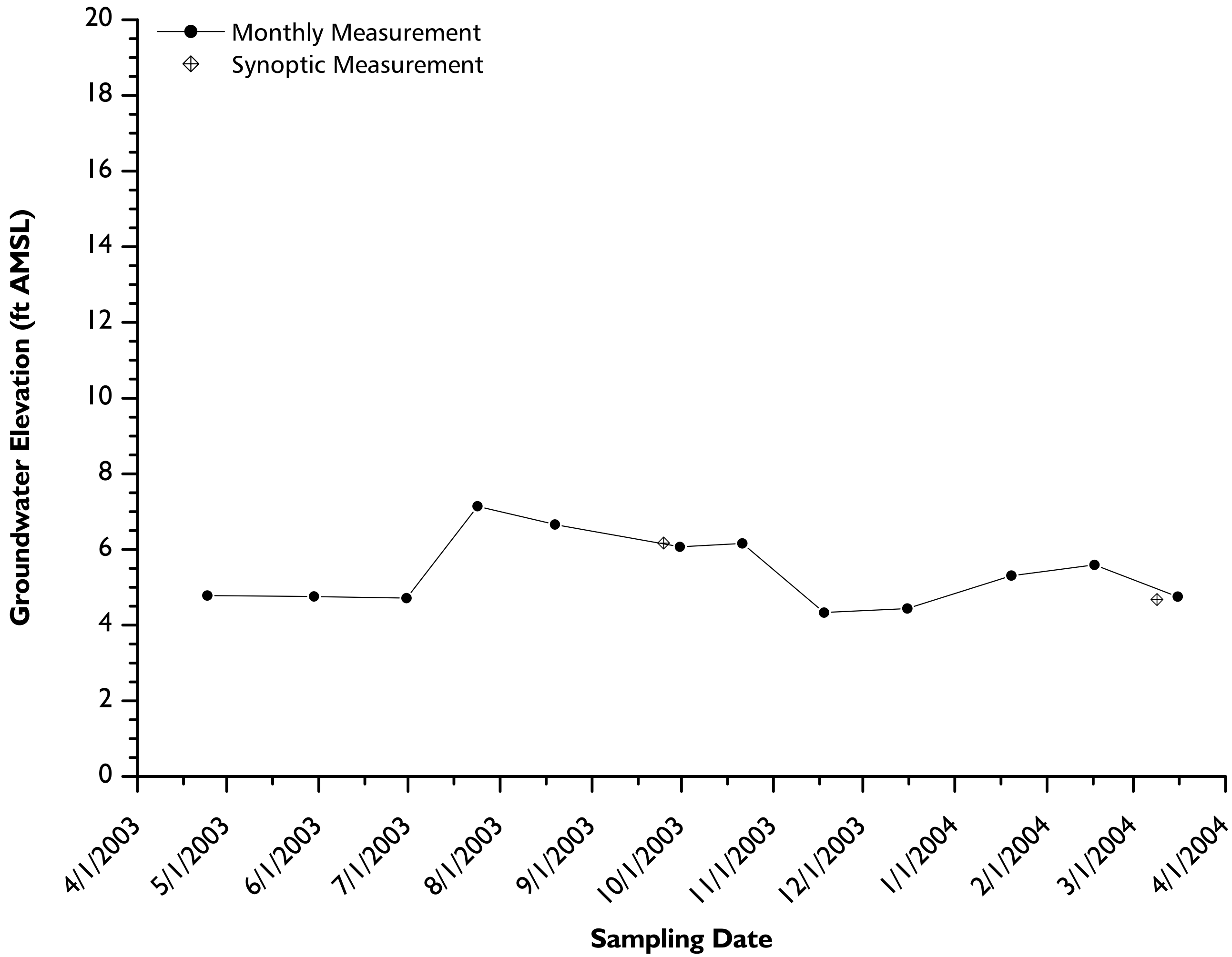

FIGURE 5: GROUNDWATER ELEVATIONS, WELL C-2
City of Malibu, California

Source: Field Observations, Biosolutions Inc., 2003-2004.
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Date: 3-23-04 anm

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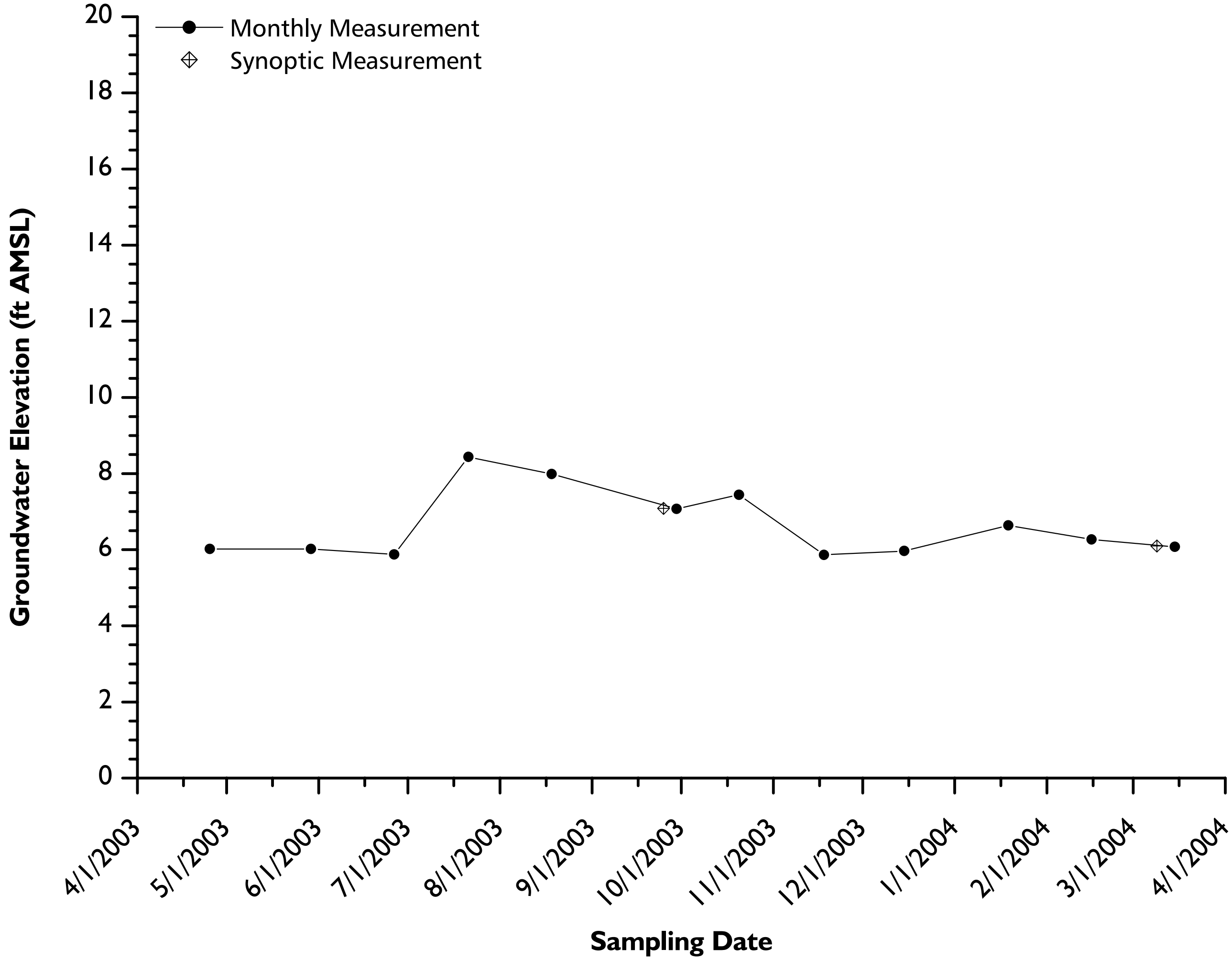

FIGURE 6: GROUNDWATER ELEVATIONS, WELL P-1
City of Malibu, California

Source: Field Observations, Biosolutions Inc., 2003-2004.
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Date: 3-23-04 anm

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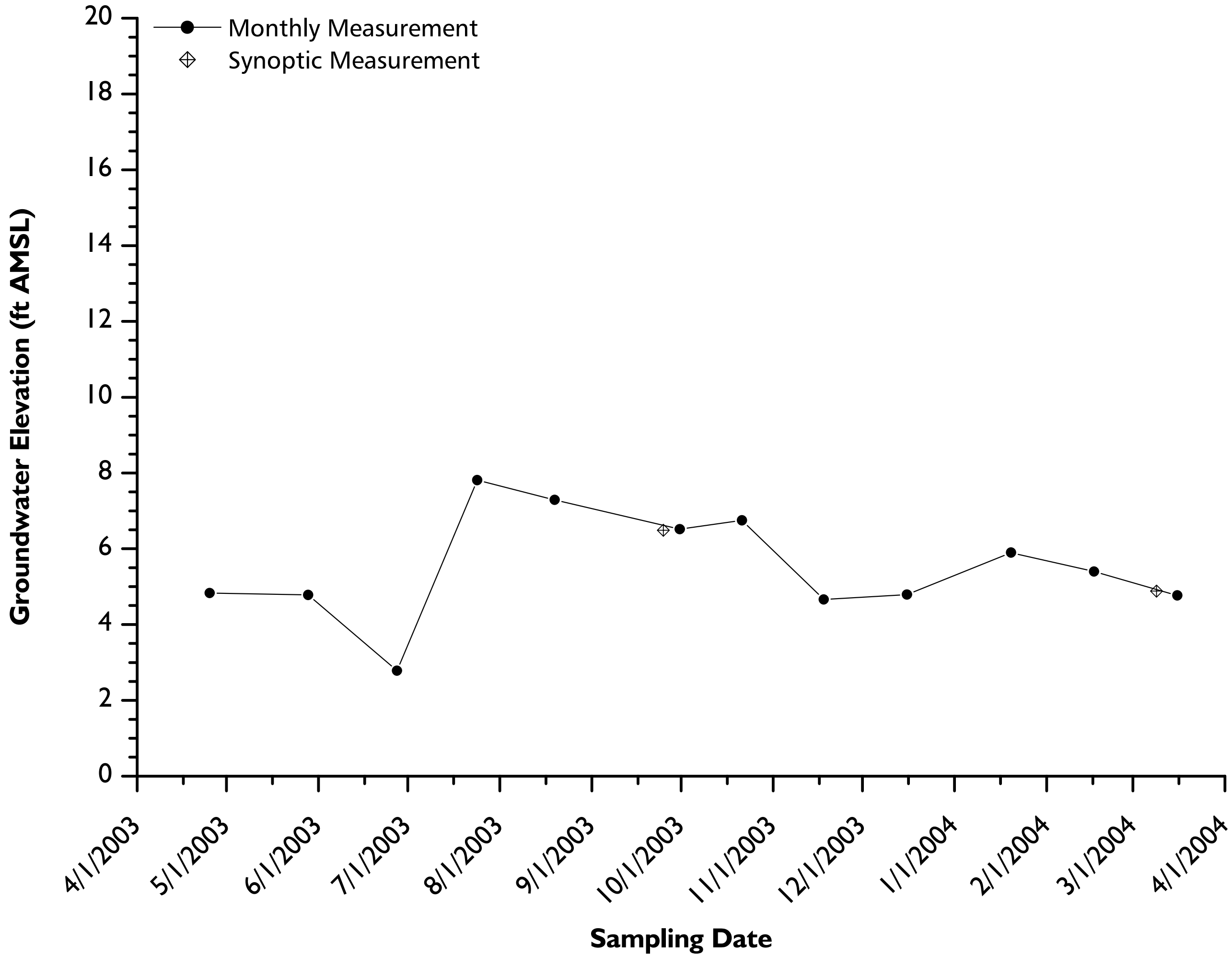

FIGURE 7: GROUNDWATER ELEVATIONS, WELL P-7
City of Malibu, California

Source: Field Observations, Biosolutions Inc., 2003-2004.
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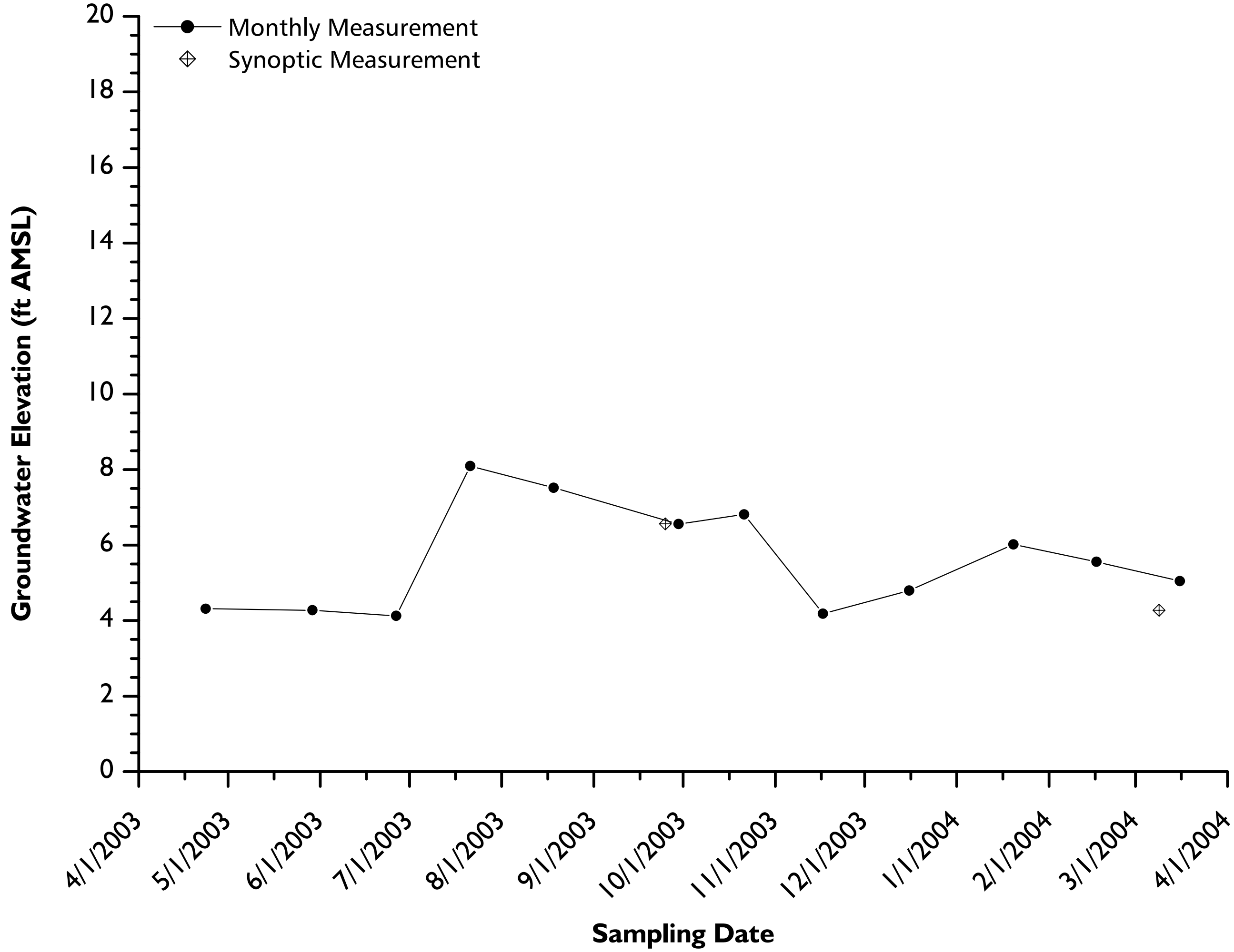

FIGURE 8: GROUNDWATER ELEVATIONS, WELL P-9
City of Malibu, California

Source: Field Observations, Biosolutions Inc., 2003-2004.
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Date: 3-23-04 anm

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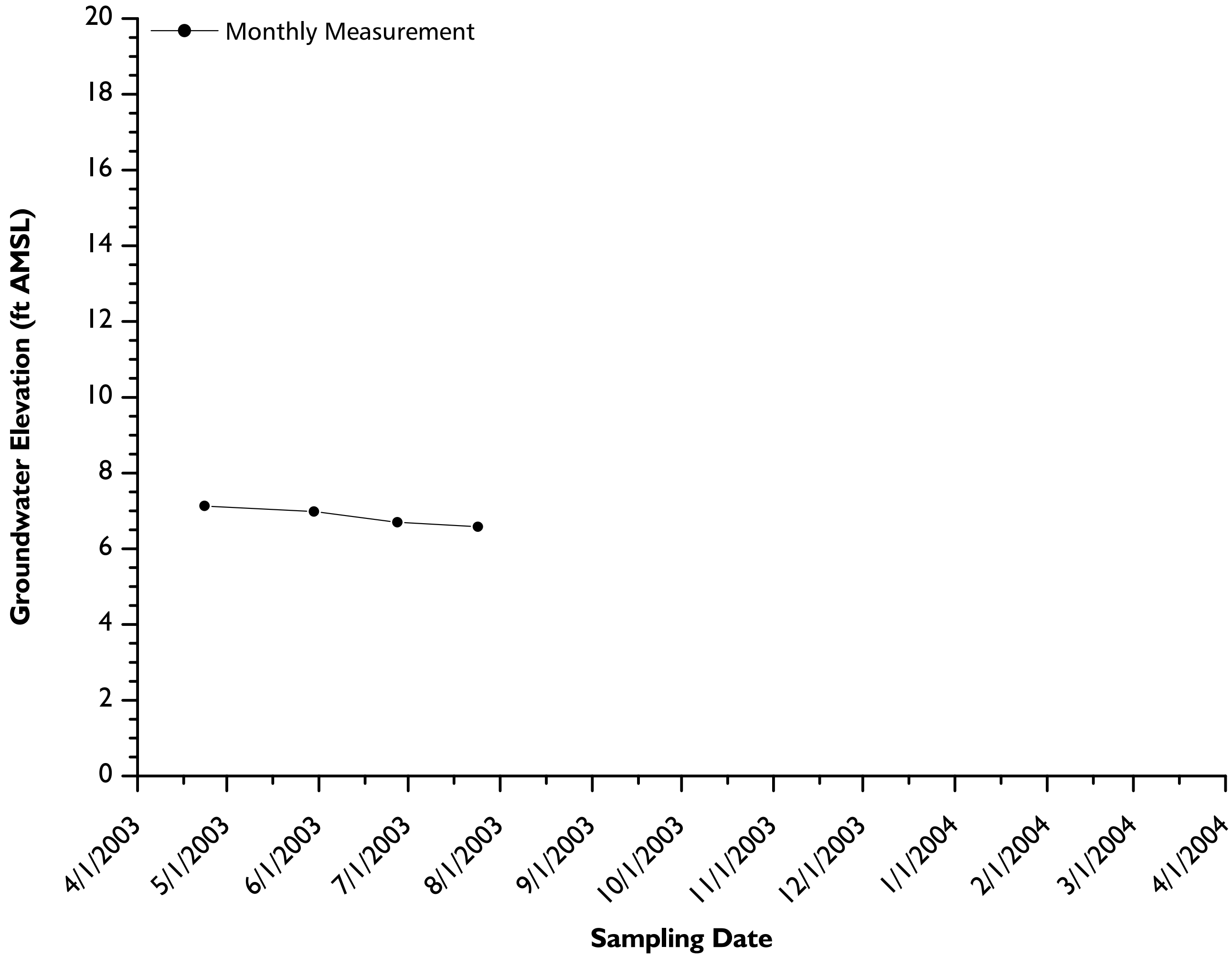

FIGURE 9: GROUNDWATER ELEVATIONS, WELL SMBRP-1
City of Malibu, California

Source: Field Observations, Biosolutions Inc., 2003-2004.
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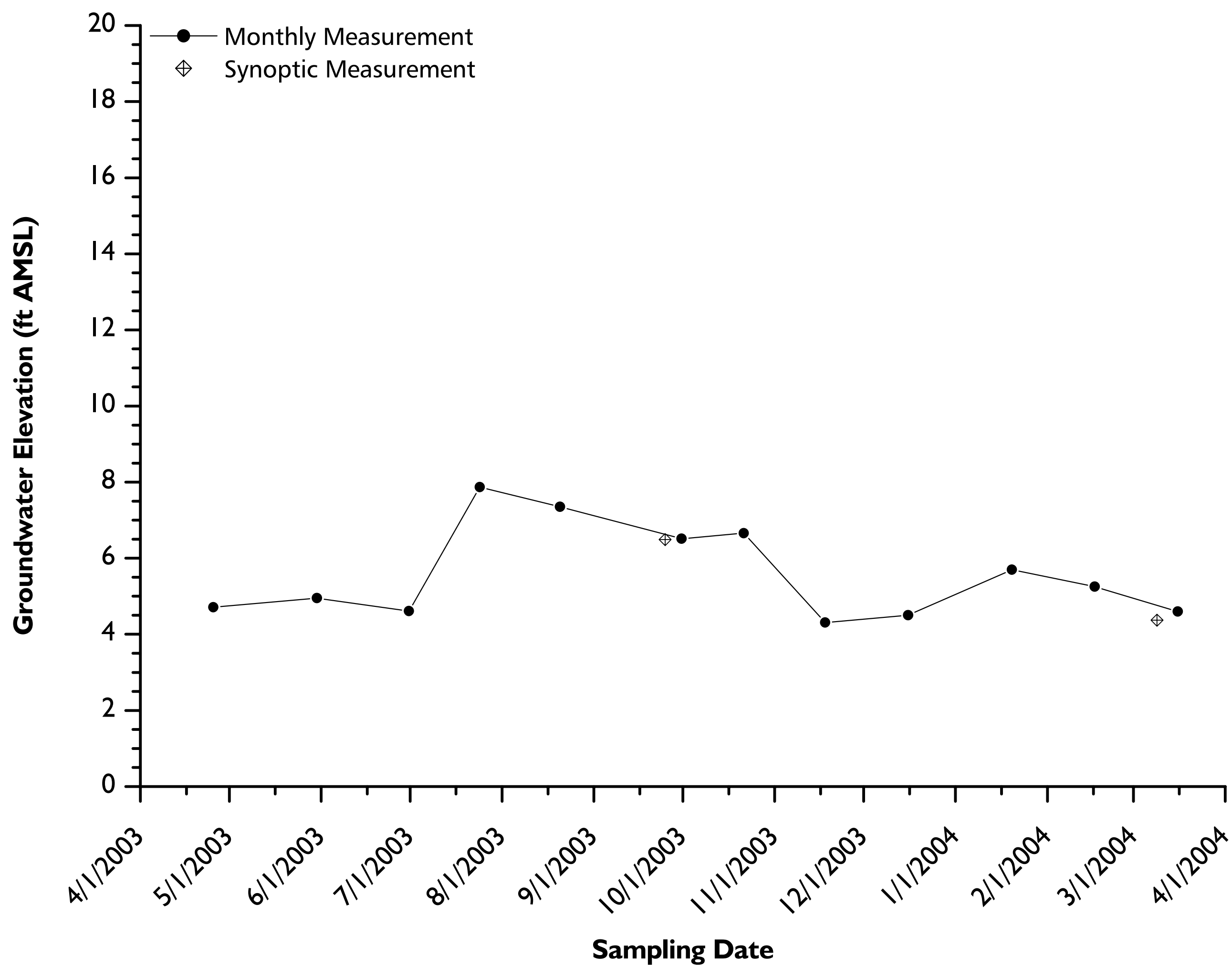

FIGURE 10: GROUNDWATER ELEVATIONS, WELL SMBRP-2
City of Malibu, California

Source: Field Observations, Biosolutions Inc., 2003-2004.
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Date: 3-23-04 anm

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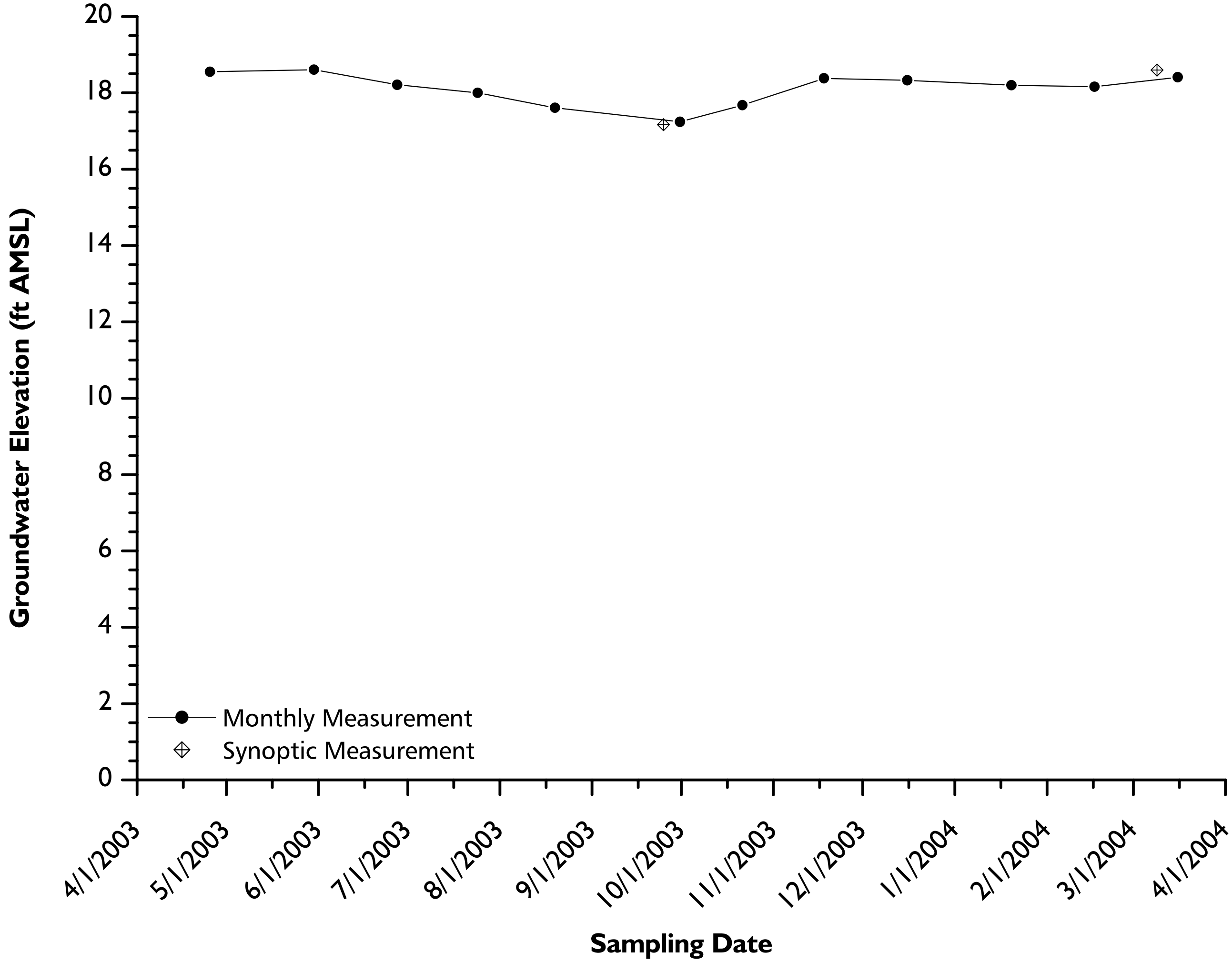

FIGURE 11: GROUNDWATER ELEVATIONS, WELL SMBRP-3c
City of Malibu, California

Source: Field Observations, Biosolutions Inc., 2003-2004.
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Date: 3-23-04 anm

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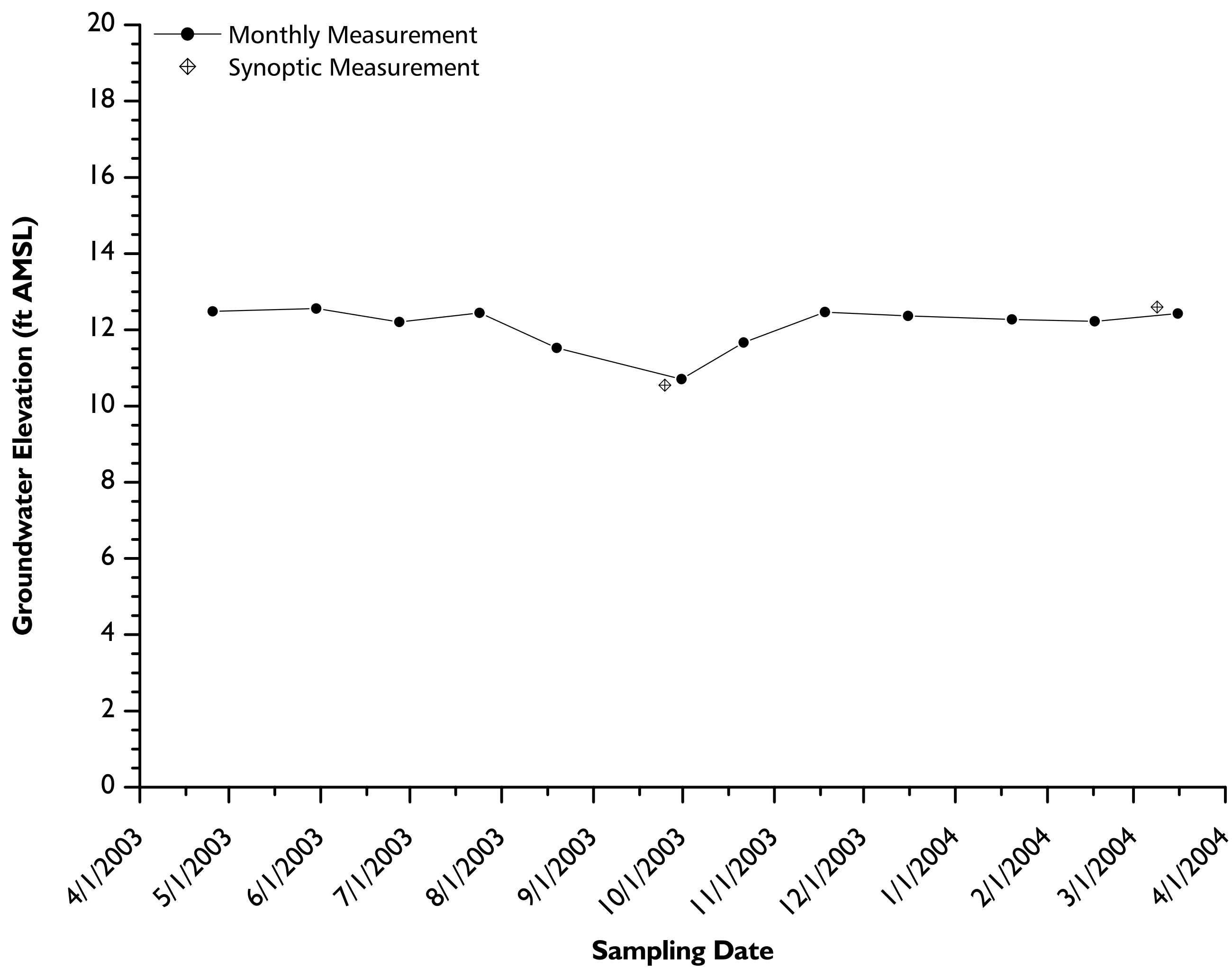

FIGURE 12: GROUNDWATER ELEVATIONS, WELL SMBRP-6
City of Malibu, California

Source: Field Observations, Biosolutions Inc., 2003-2004.
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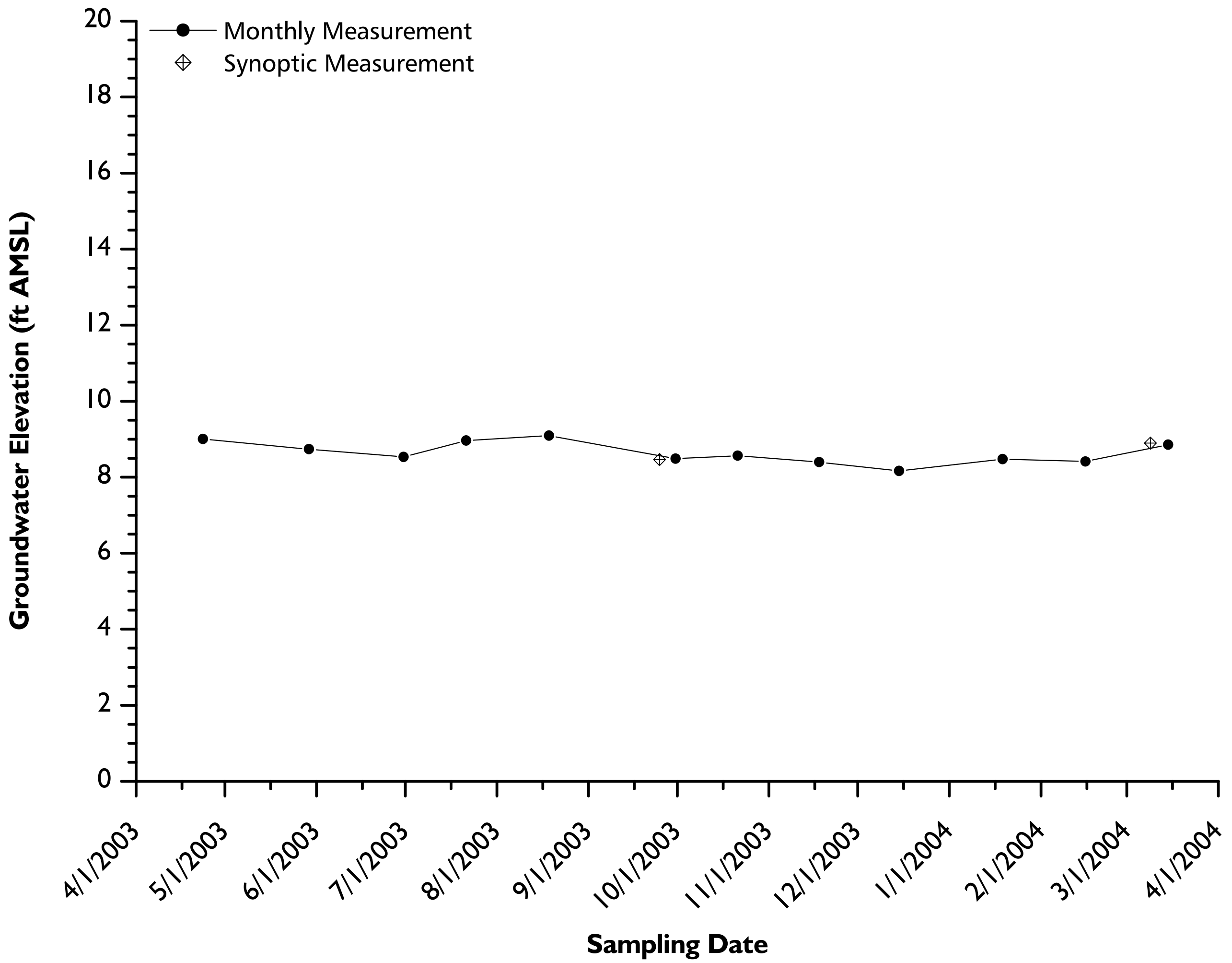

FIGURE 13: GROUNDWATER ELEVATIONS, WELL SMBRP-7b
City of Malibu, California

Source: Field Observations, Biosolutions Inc., 2003-2004.
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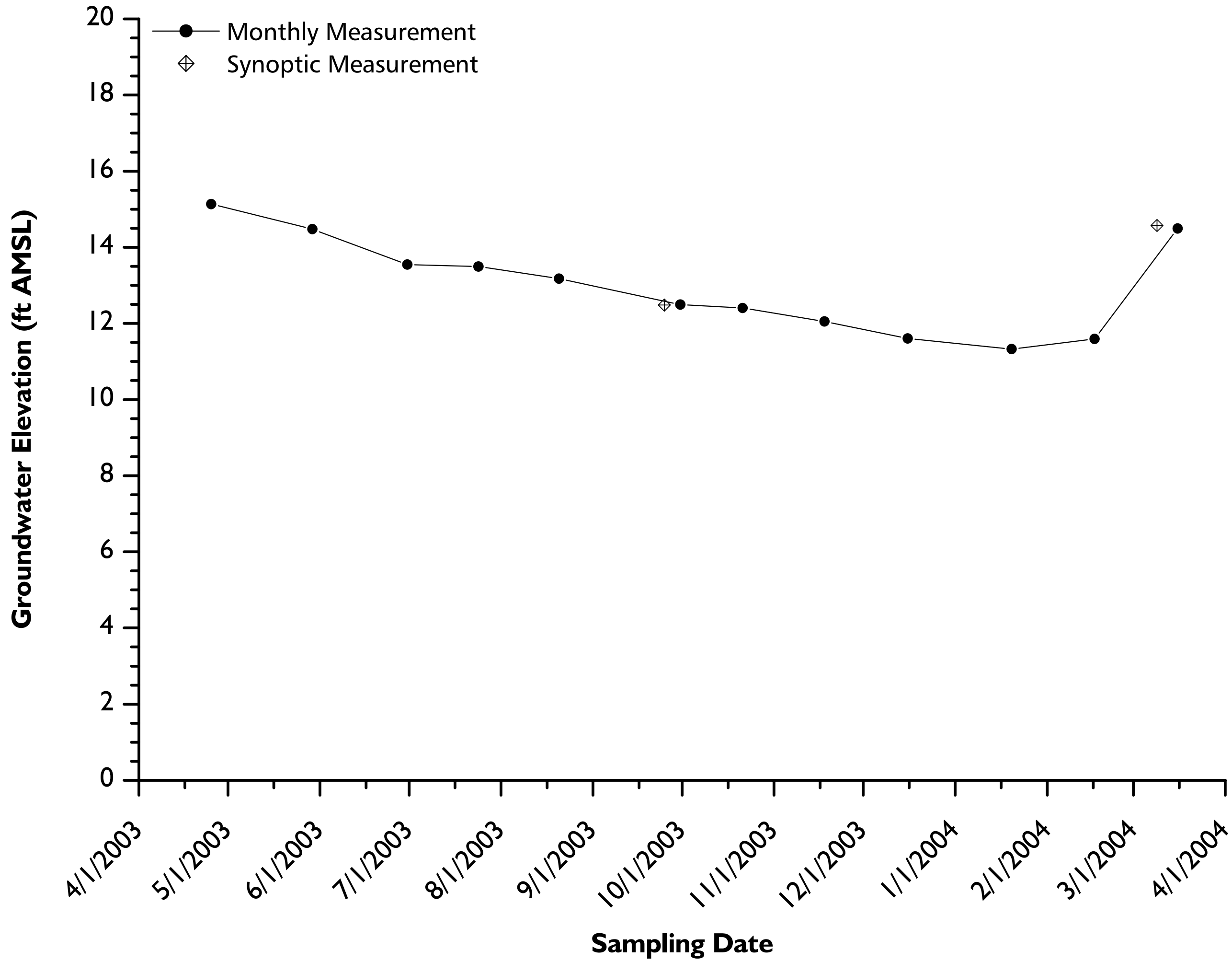

FIGURE 14: GROUNDWATER ELEVATIONS, WELL SMBRP-8
City of Malibu, California

Source: Field Observations, Biosolutions Inc., 2003-2004.
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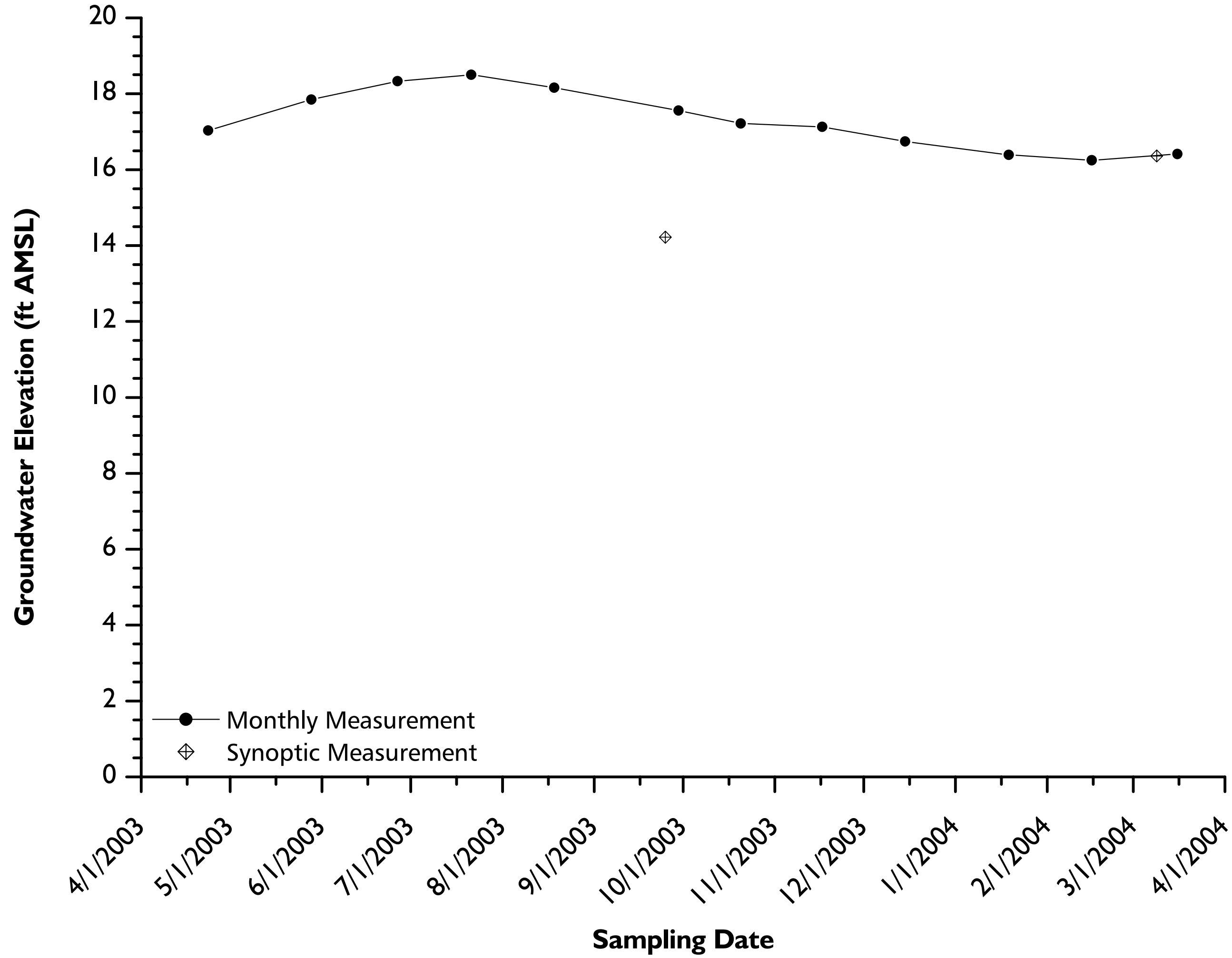

FIGURE 15: GROUNDWATER ELEVATIONS, WELL SMBRP-9
City of Malibu, California

Source: Field Observations, Biosolutions Inc., 2003-2004.
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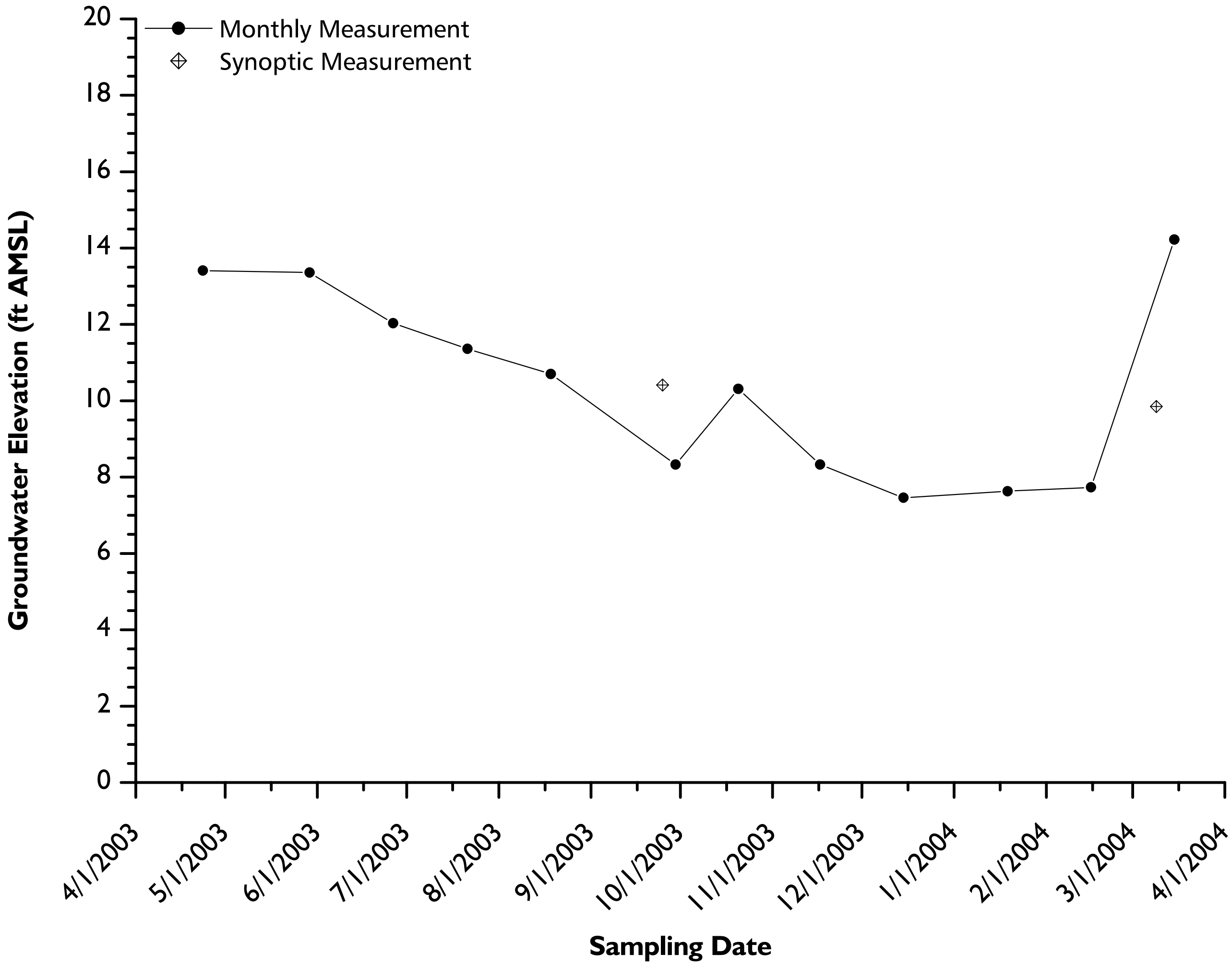

FIGURE 16: GROUNDWATER ELEVATIONS, WELL SMBRP-10c
City of Malibu, California

Source: Field Observations, Biosolutions Inc., 2003-2004.
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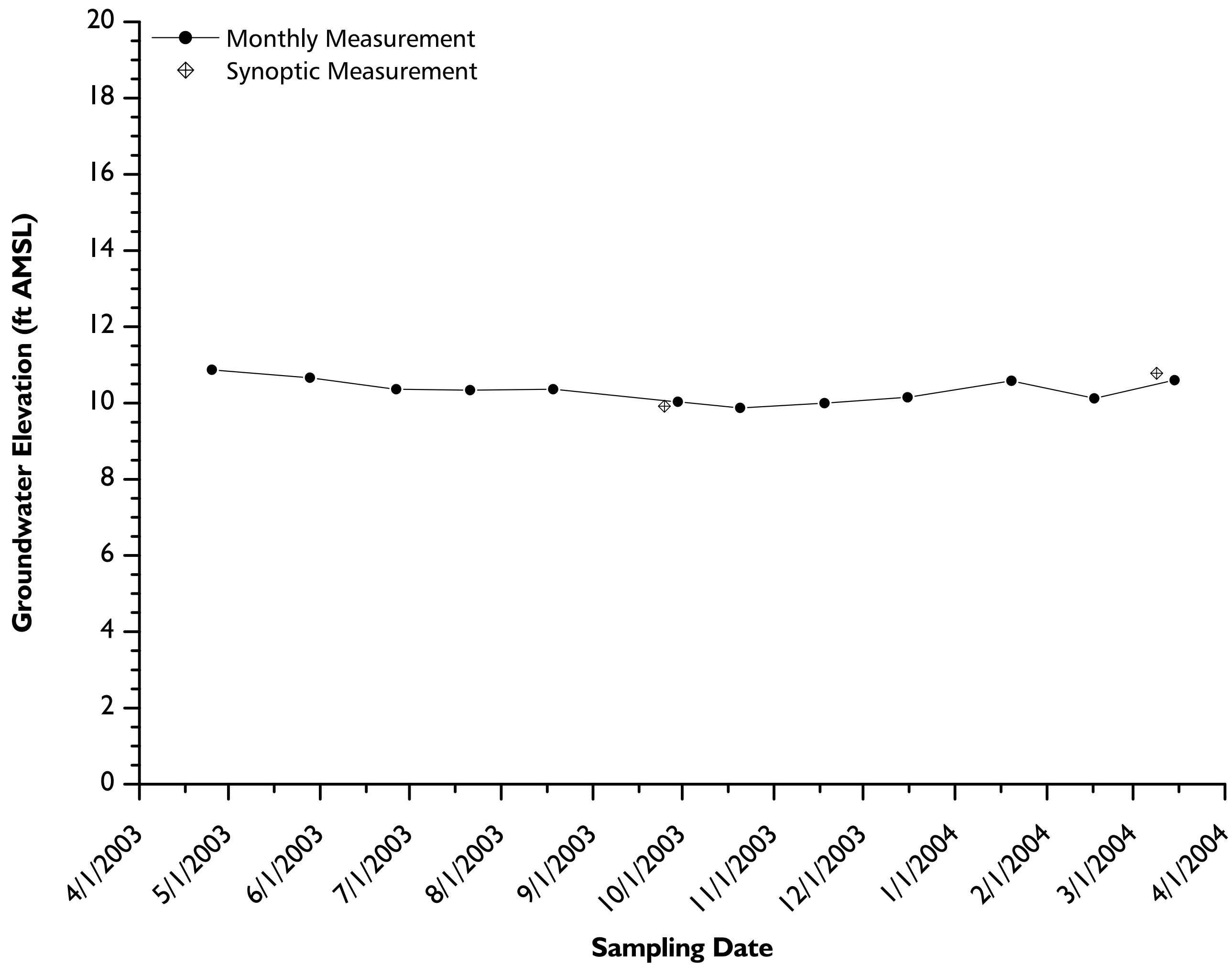

FIGURE 17: GROUNDWATER ELEVATIONS, WELL SMBRP-11
City of Malibu, California

Source: Field Observations, Biosolutions Inc., 2003-2004.
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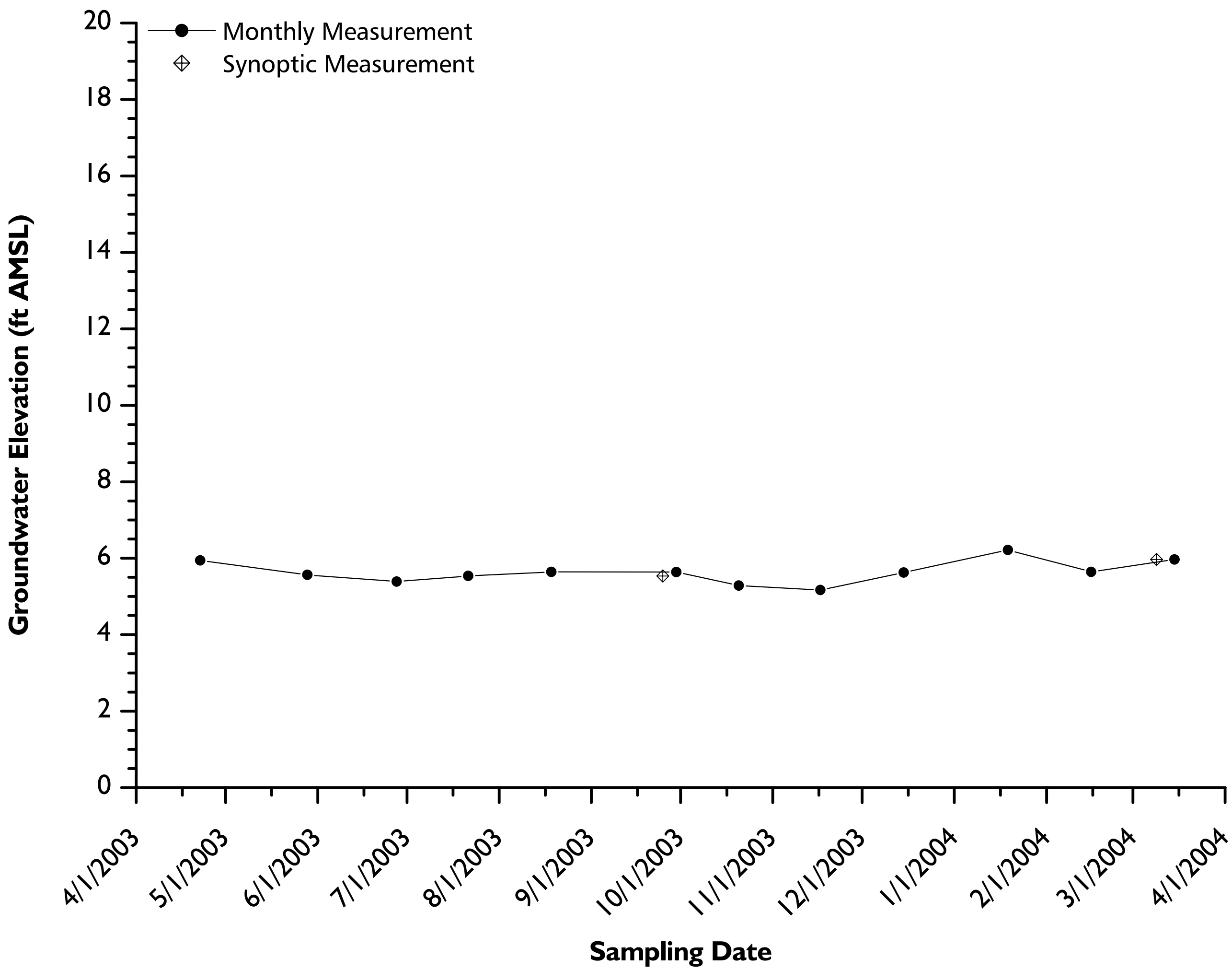

FIGURE 18: GROUNDWATER ELEVATIONS, WELL SMBRP-12
City of Malibu, California

Source: Field Observations, Biosolutions Inc., 2003-2004.
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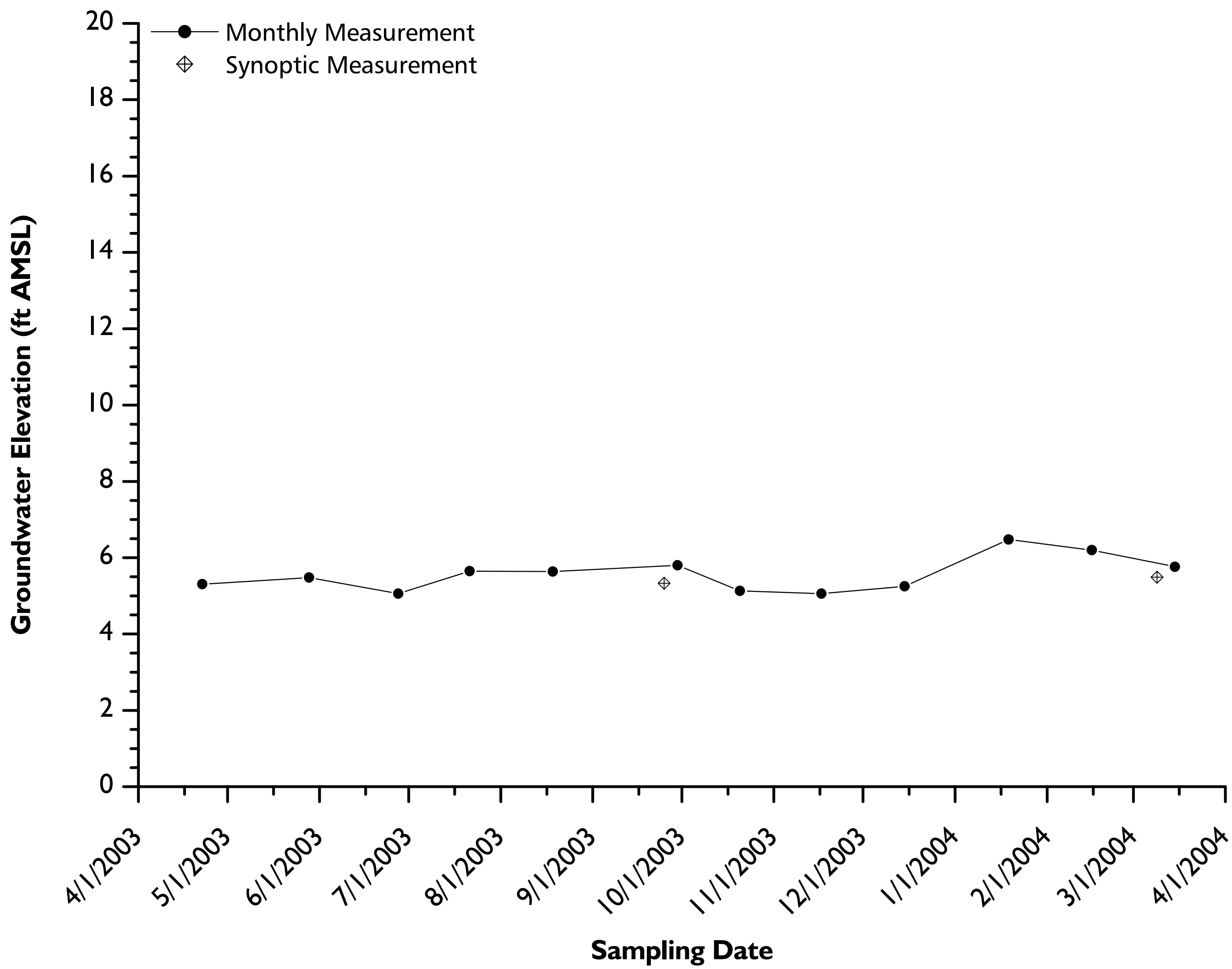

FIGURE 19: GROUNDWATER ELEVATIONS, WELL SMBRP-13
City of Malibu, California

Source: Field Observations, Biosolutions Inc., 2003-2004.
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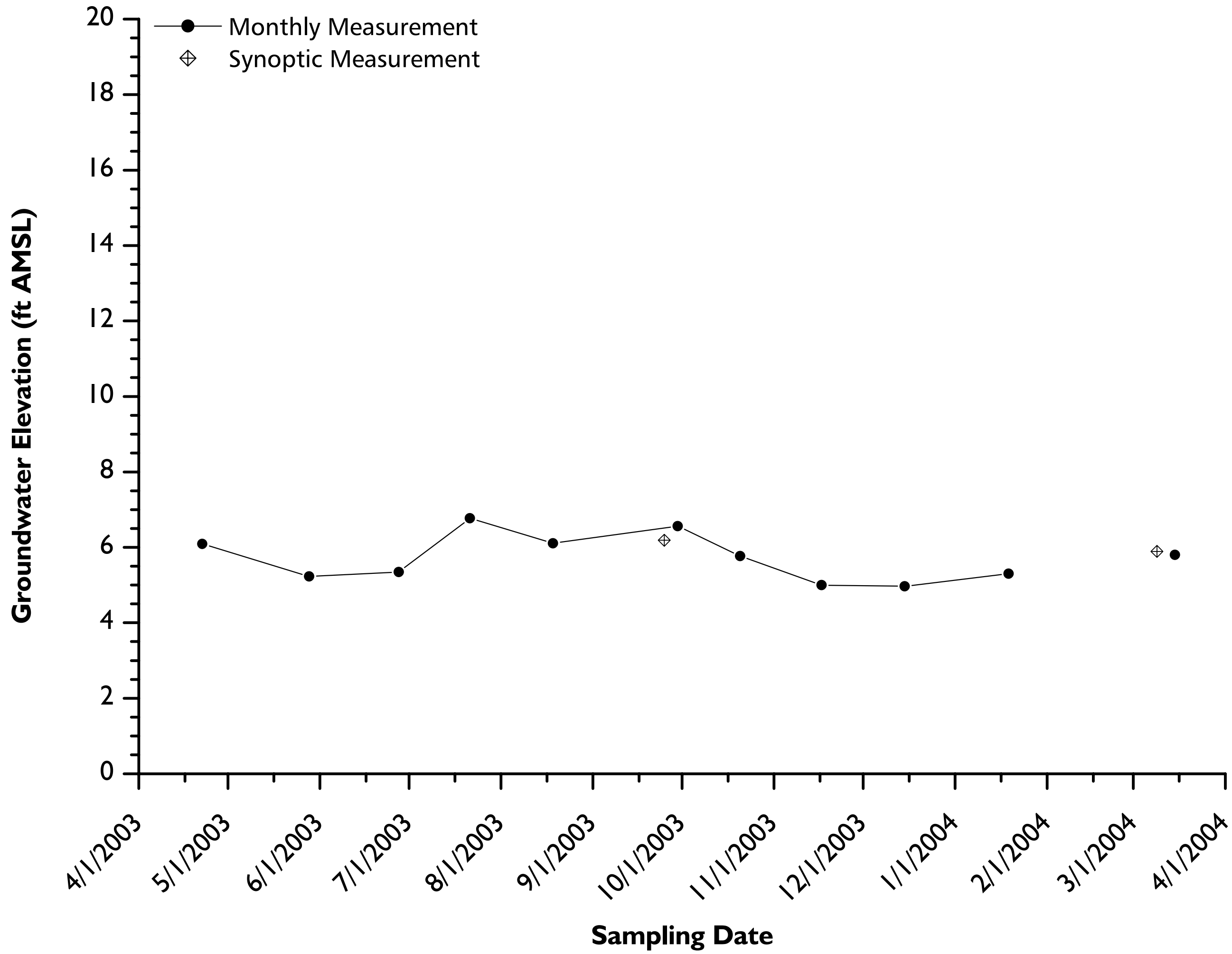

FIGURE 20: GROUNDWATER ELEVATIONS, WELL SMBRP-14
City of Malibu, California

Source: Field Observations, Biosolutions Inc., 2003-2004.
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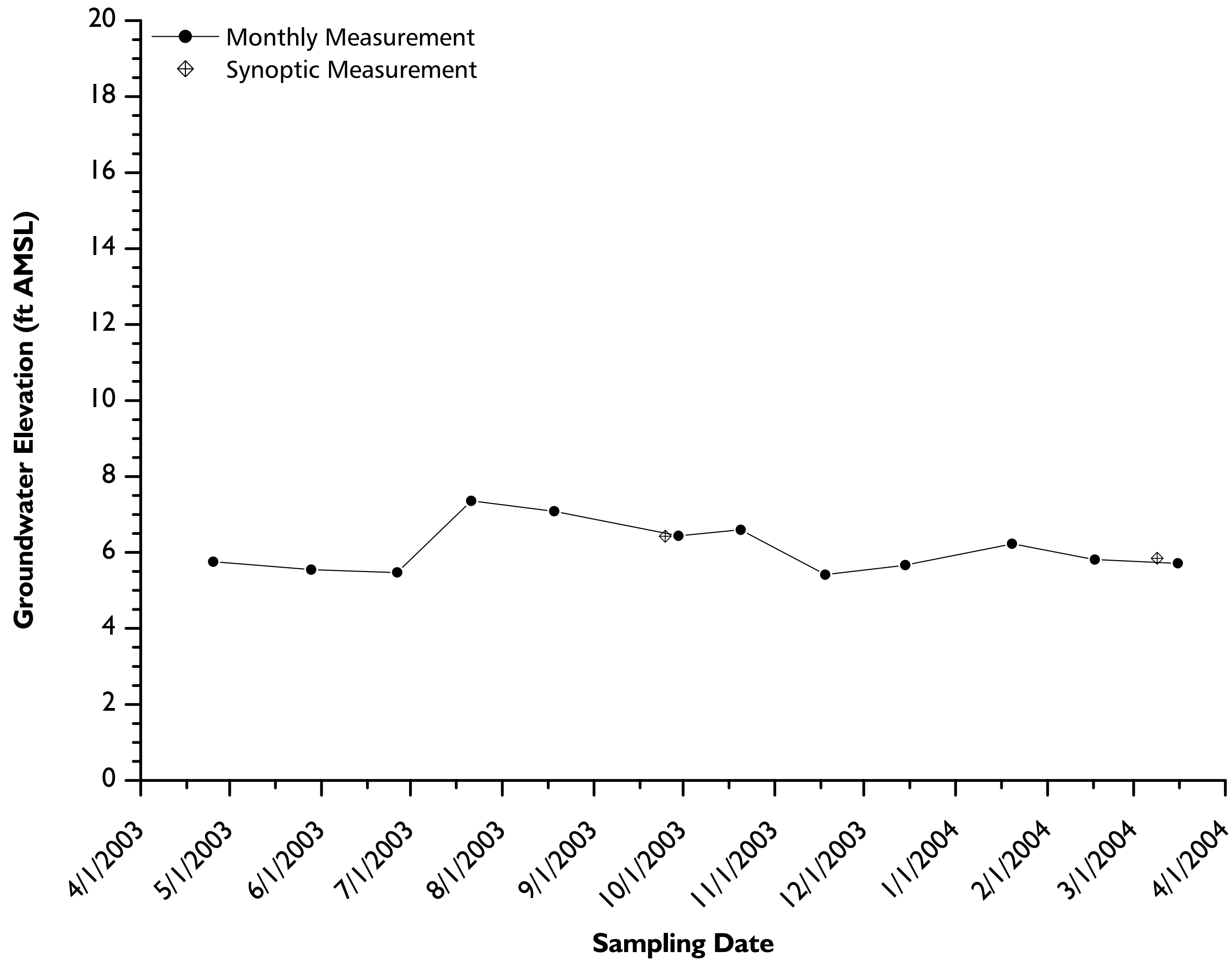

FIGURE 21: GROUNDWATER ELEVATIONS, WELL SMBRP-15b
City of Malibu, California

Source: Field Observations, Biosolutions Inc., 2003-2004.
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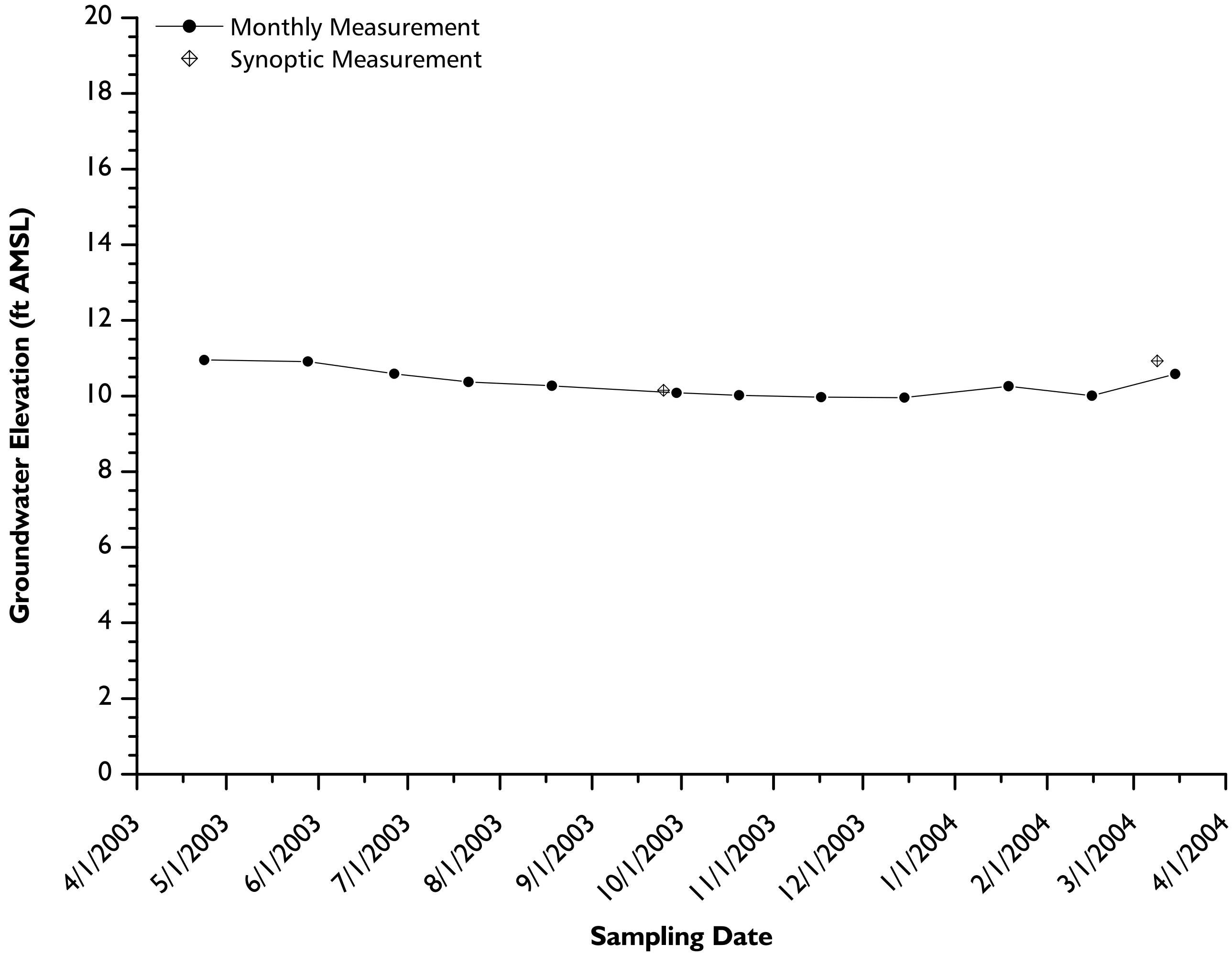

FIGURE 22: GROUNDWATER ELEVATIONS, WELL SMBRP-16
City of Malibu, California

Source: Field Observations, Biosolutions Inc., 2003-2004.
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Date: 3-23-04 anm

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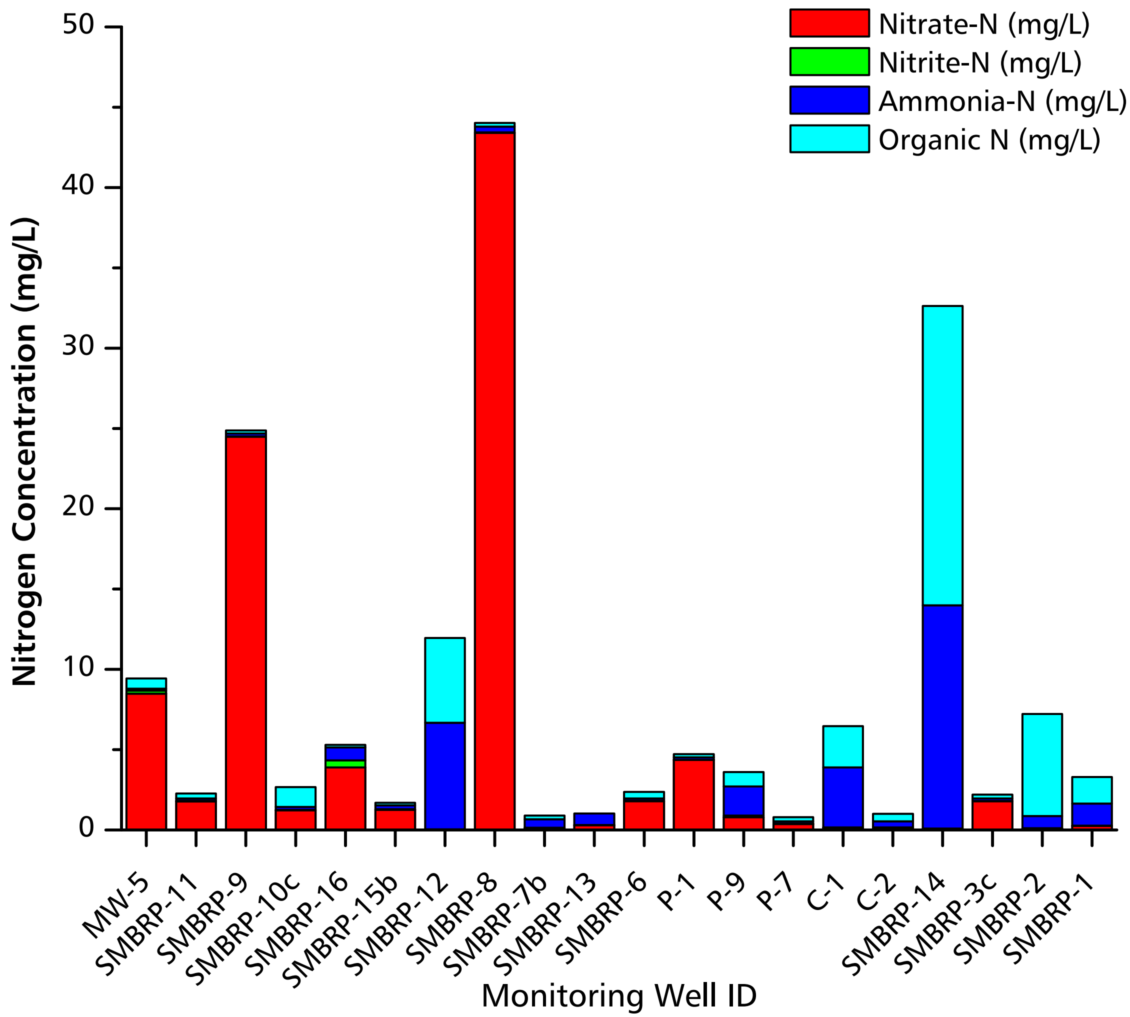

FIGURE 23: TOTAL N AVERAGE CONCENTRATIONS (mg/L) FOR ALL MONITORING WELLS
City of Malibu, CA

Source: Laboratory reports from Pat-Chem Laboratories, Inc., 2003 and 2004.
Path: o:\proj-01\1269-w-malibu\data\welldata\AnalyticalResults\Figures\AllAnalyticalFigures.opj
Date: 5-13-04 anm

STONE ENVIRONMENTAL INC

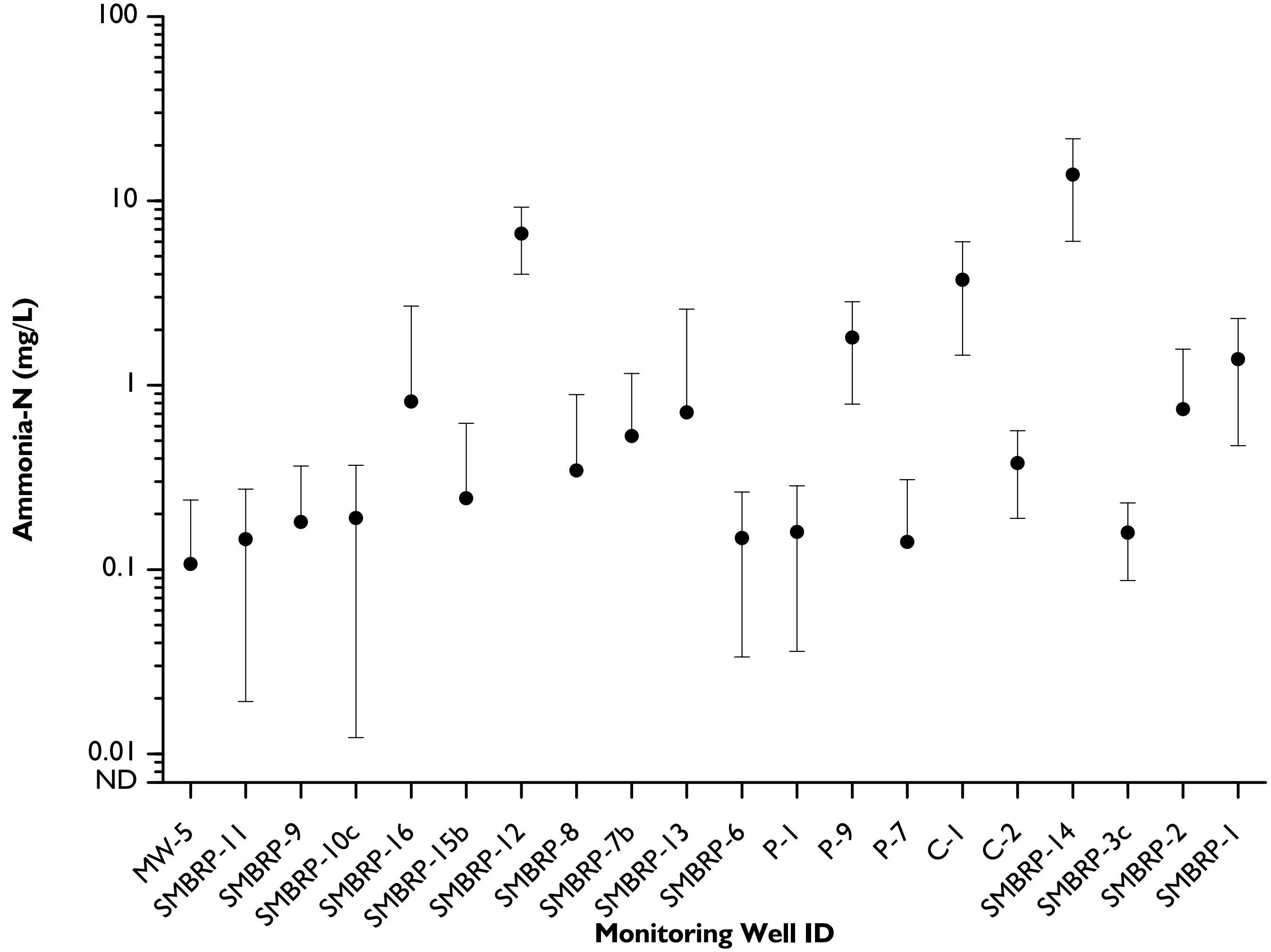

FIGURE 24: AMMONIA-N AVERAGE CONCENTRATIONS (mg/L) FOR ALL MONITORING WELLS
City of Malibu, CA

Source: Laboratory reports from Pat-Chem Laboratories, Inc., 2003 and 2004.
Path: o:\proj-01\1269-w-malibu\reports\final\figures\AnalyteAvgStdev.opj
Date: 5-11-04 anm

STONE ENVIRONMENTAL INC

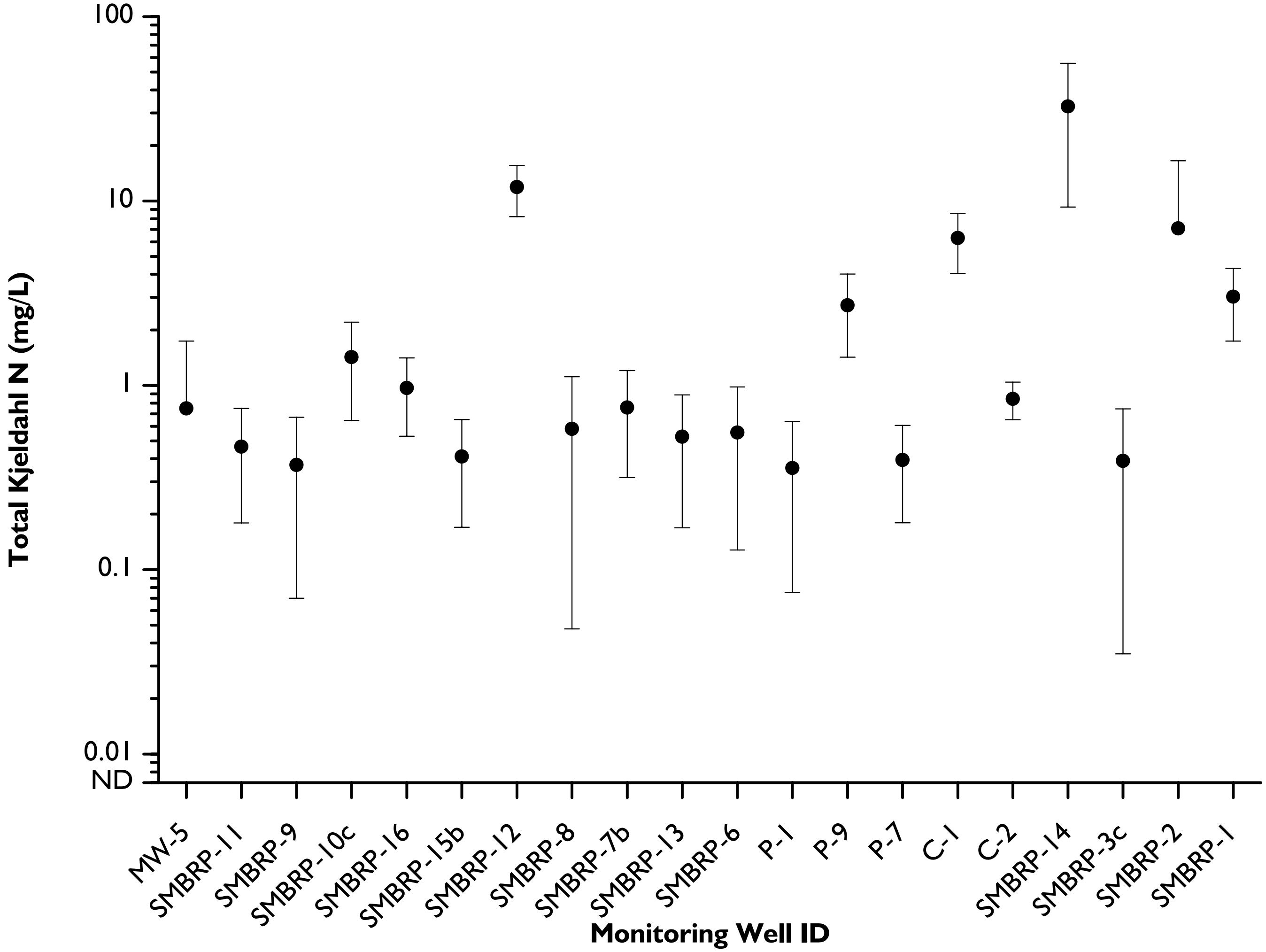

FIGURE 25: TOTAL KJELDAHL N AVERAGE CONCENTRATIONS (mg/L) FOR ALL MONITORING WELLS
City of Malibu, CA

Source: Laboratory reports from Pat-Chem Laboratories, Inc., 2003 and 2004.
Path: o:\proj-01\1269-w-malibu\reports\final\figures\AnalyteAvgStdev.opj
Date: 5-11-04 anm

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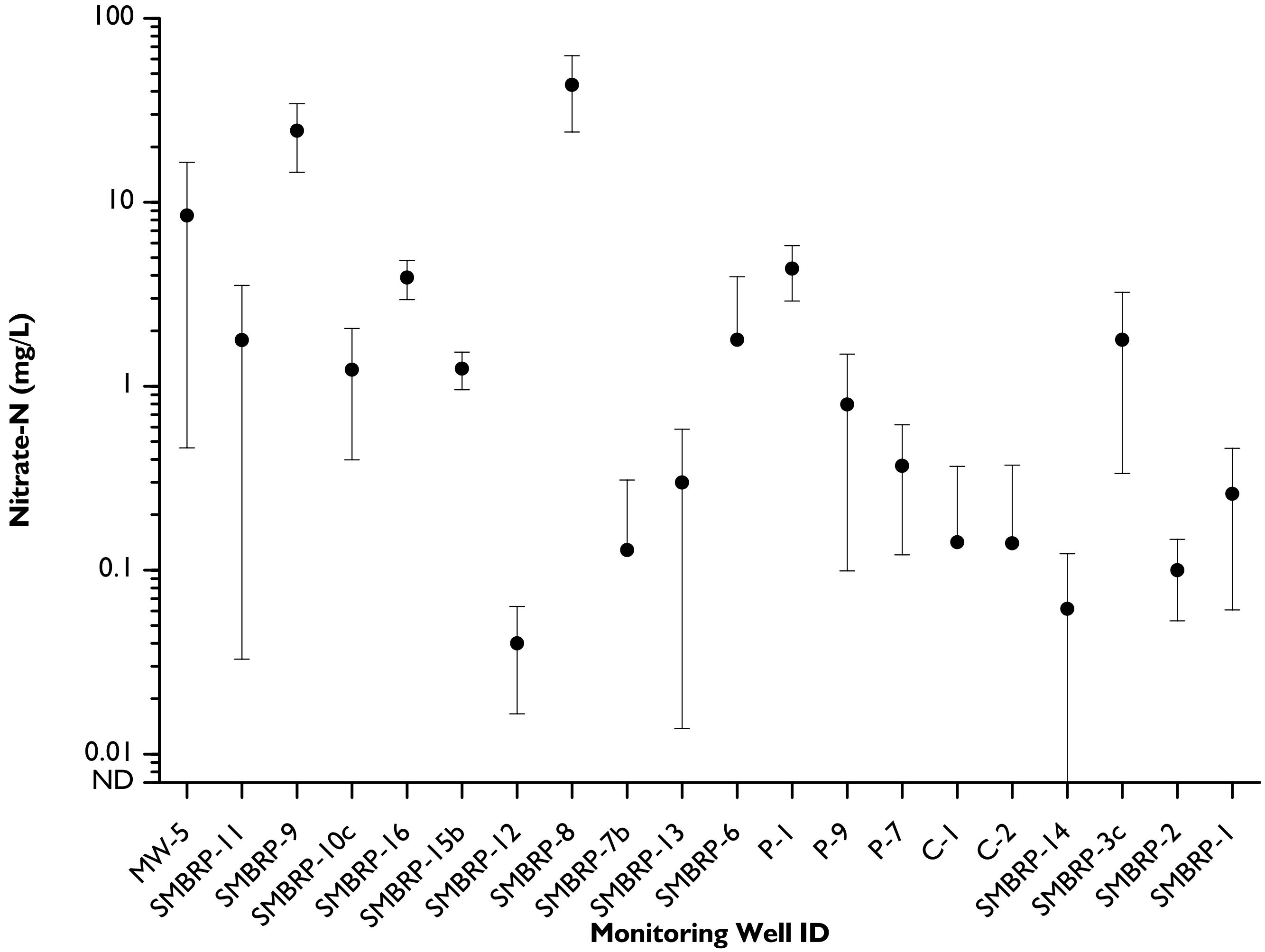

FIGURE 26: NITRATE-N AVERAGE CONCENTRATIONS (mg/L) FOR ALL MONITORING WELLS
City of Malibu, CA

Source: Laboratory reports from Pat-Chem Laboratories, Inc., 2003 and 2004.
Path: o:\proj-01\1269-w-malibu\reports\final\figures\AnalyteAvgStdev.opj
Date: 5-11-04 anm

STONE ENVIRONMENTAL INC

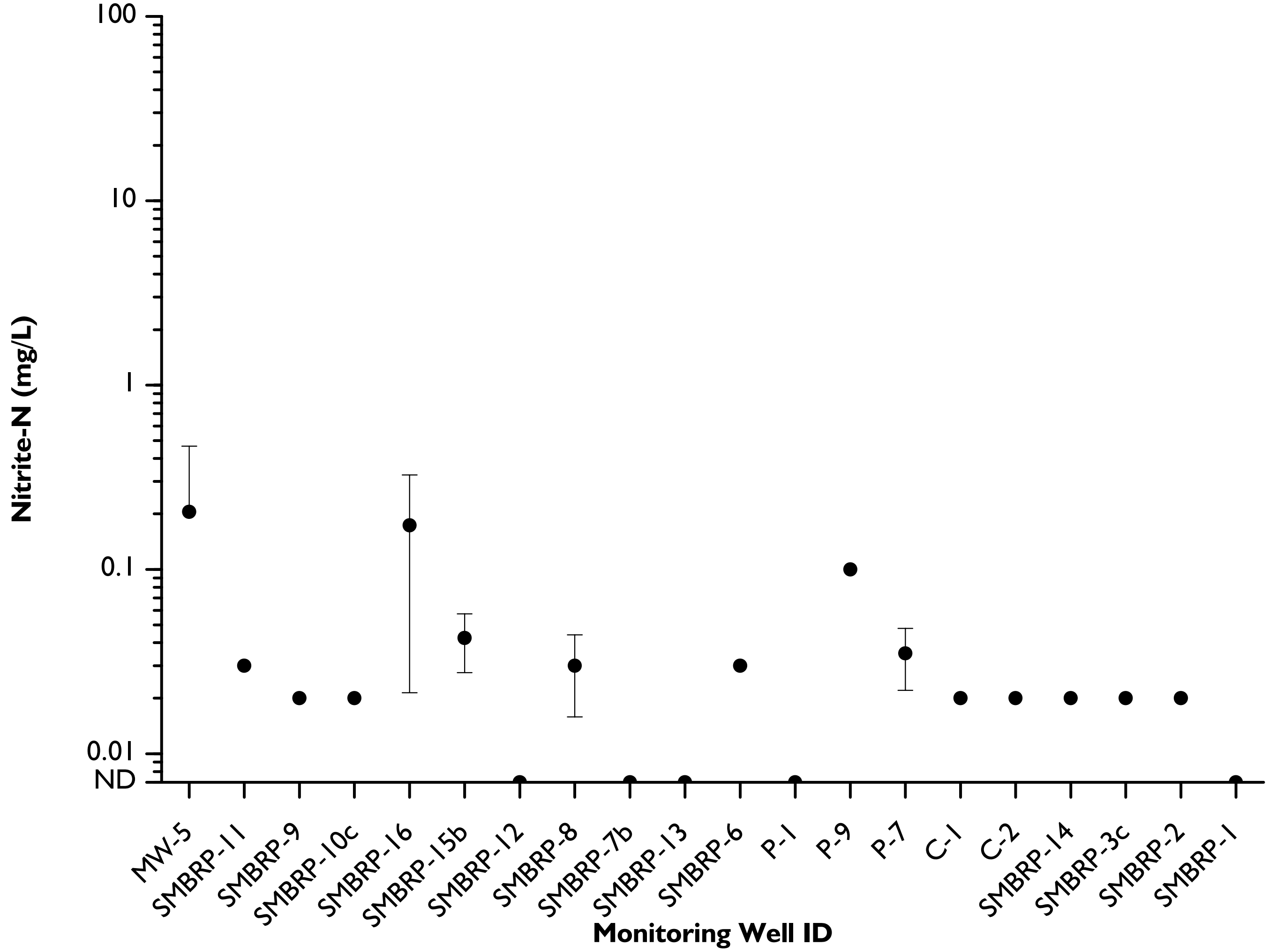

FIGURE 27: NITRITE-N AVERAGE CONCENTRATIONS (mg/L) FOR ALL MONITORING WELLS
City of Malibu, CA

Source: Laboratory reports from Pat-Chem Laboratories, Inc., 2003 and 2004.
Path: o:\proj-01\1269-w-malibu\reports\final\figures\AnalyteAvgStdev.opj
Date: 5-11-04 anm

STONE ENVIRONMENTAL INC

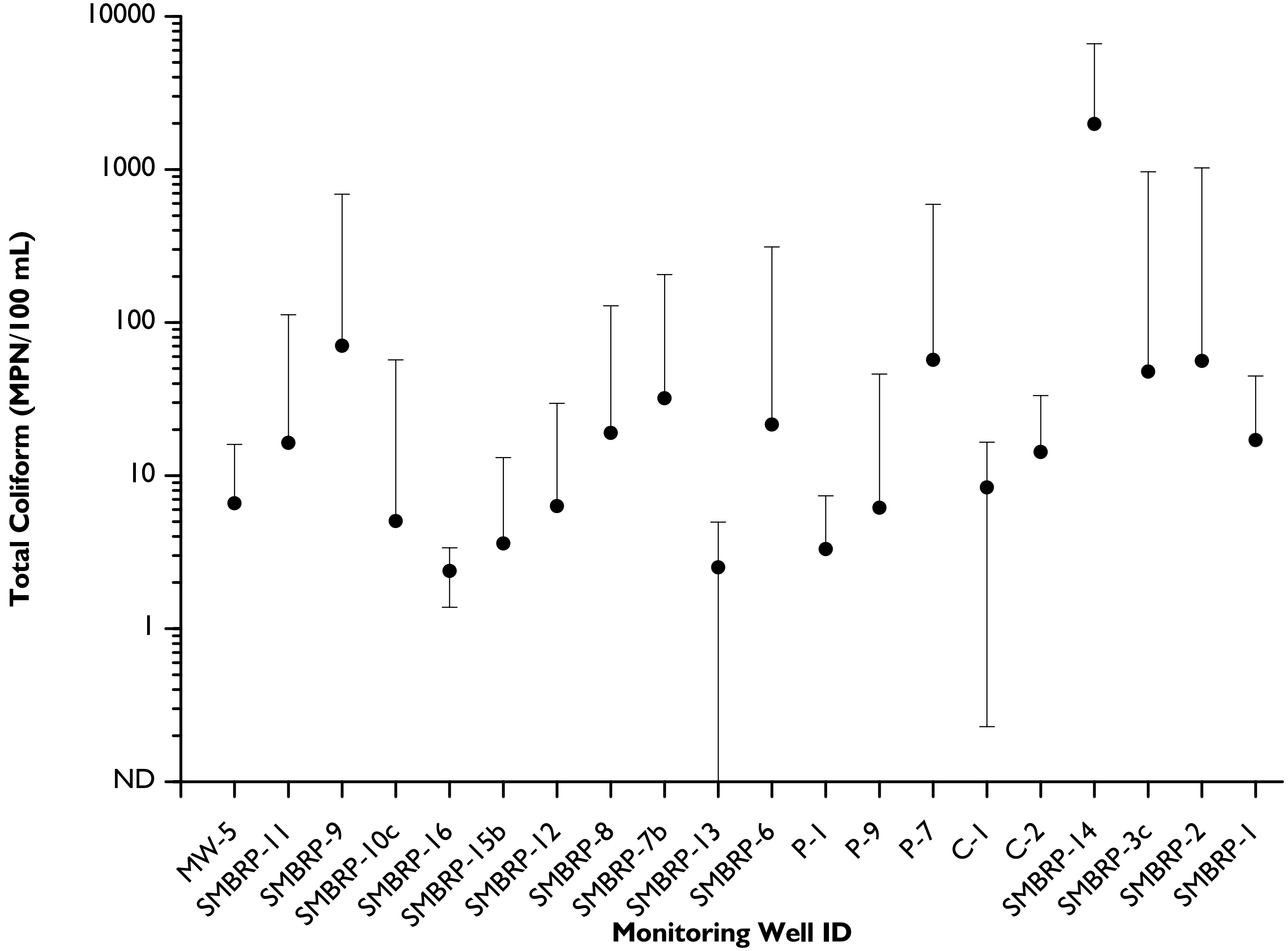

FIGURE 28: TOTAL COLIFORM GEOMETRIC MEAN CONCENTRATIONS (MPN/100 mL) FOR ALL MONITORING WELLS
City of Malibu, CA

Source: Laboratory reports from Pat-Chem Laboratories, Inc., 2003 and 2004.
Notes: Error bars indicate +/- one standard deviation from the geometric mean
Path: o:\proj-01\1269-w-malibu\reports\final\figures\AnalyteAvgStdev.opj
Date: 5-11-04 anm

STONE ENVIRONMENTAL INC

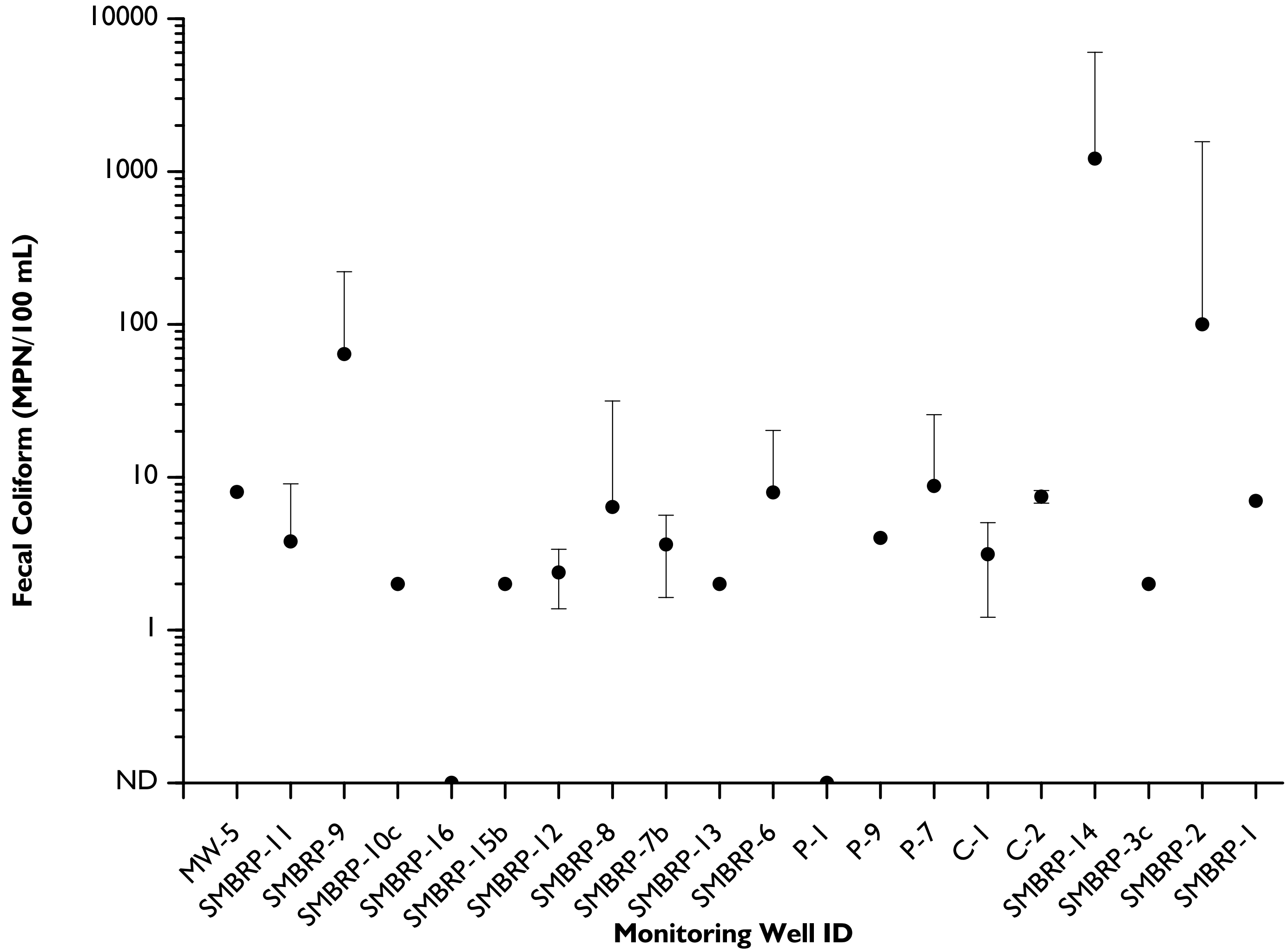

FIGURE 29: FECAL COLIFORM GEOMETRIC MEAN CONCENTRATIONS (MPN/100 ML) FOR ALL MONITORING WELLS
City of Malibu, CA

Source: Laboratory reports from Pat-Chem Laboratories, Inc., 2003 and 2004.
Notes: Error bars indicate +/- one standard deviation from the geometric mean
Path: o:\proj-01\1269-w-malibu\reports\final\figures\AnalyteAvgStdev.opj
Date: 5-11-04 anm

STONE ENVIRONMENTAL INC

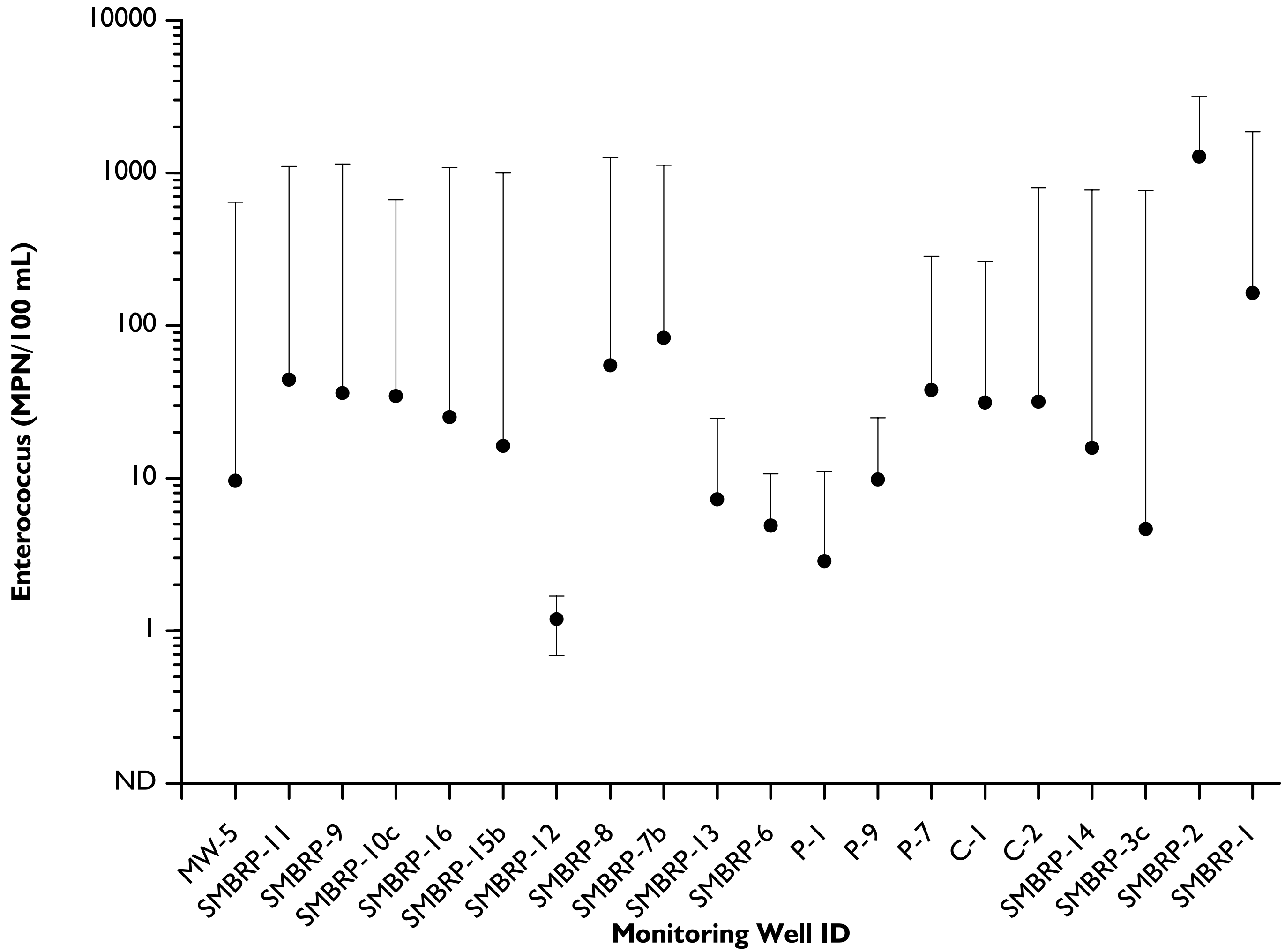

FIGURE 30: ENTEROCOCCUS GEOMETRIC MEAN CONCENTRATIONS (MPN/100 ML) FOR ALL MONITORING WELLS
City of Malibu, CA

Source: Laboratory reports from Pat-Chem Laboratories, Inc., 2003 and 2004.
Notes: Error bars indicate +/- one standard deviation from the geometric mean
Path: o:\proj-01\1269-w-malibu\reports\final\figures\AnalyteAvgStdev.opj
Date: 5-11-04 anm

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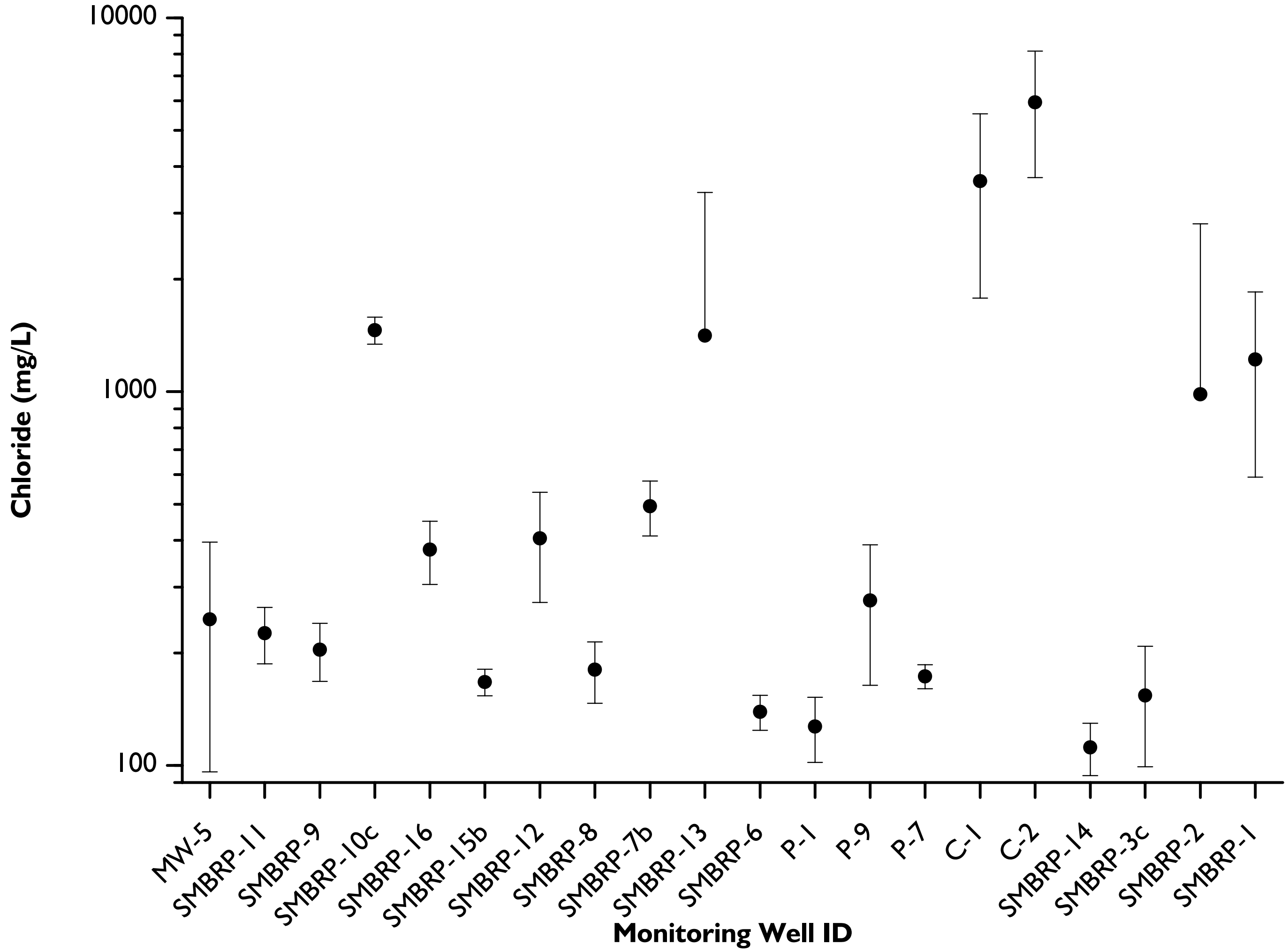

FIGURE XX: CHLORIDE AVERAGE CONCENTRATIONS (mg/L) FOR ALL MONITORING WELLS
City of Malibu, CA

Source: Laboratory reports from Pat-Chem Laboratories, Inc., 2003 and 2004.
Path: o:\proj-01\1269-w-malibu\reports\final\figures\AnalyteAvgStdev.opj
Date: 5-11-04 anm

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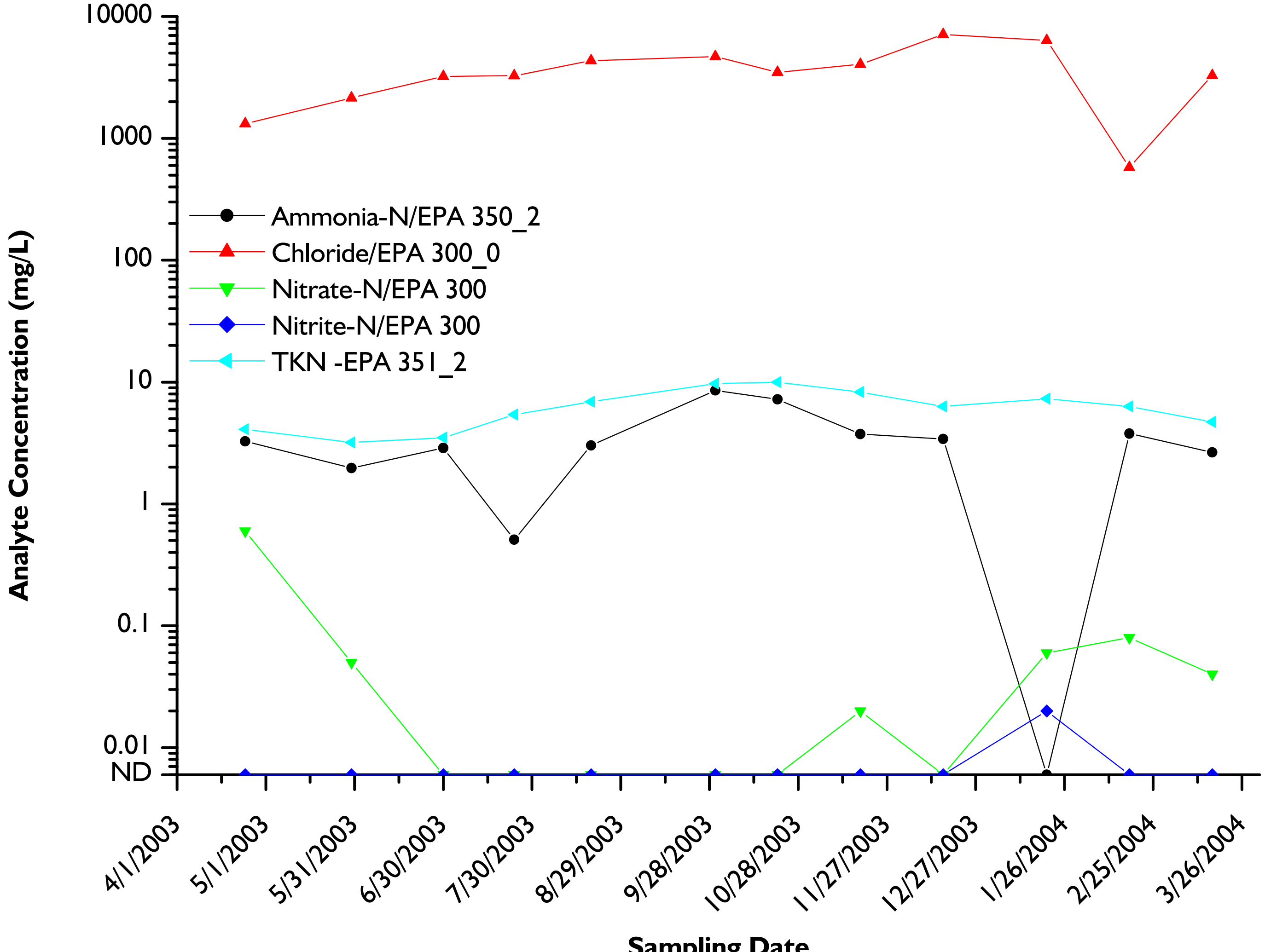

FIGURE 32: INORGANIC ANALYSES, WELL C-1
City of Malibu, CA

Source: Laboratory reports from Pat-Chem Laboratories, Inc., 2003 and 2004.
Path: o:\proj-01\1269-w-malibu\data\welldata\AnalyticalResults\Figures\AllAnalyticalFigures.opj
Date: 3-31-04 anm

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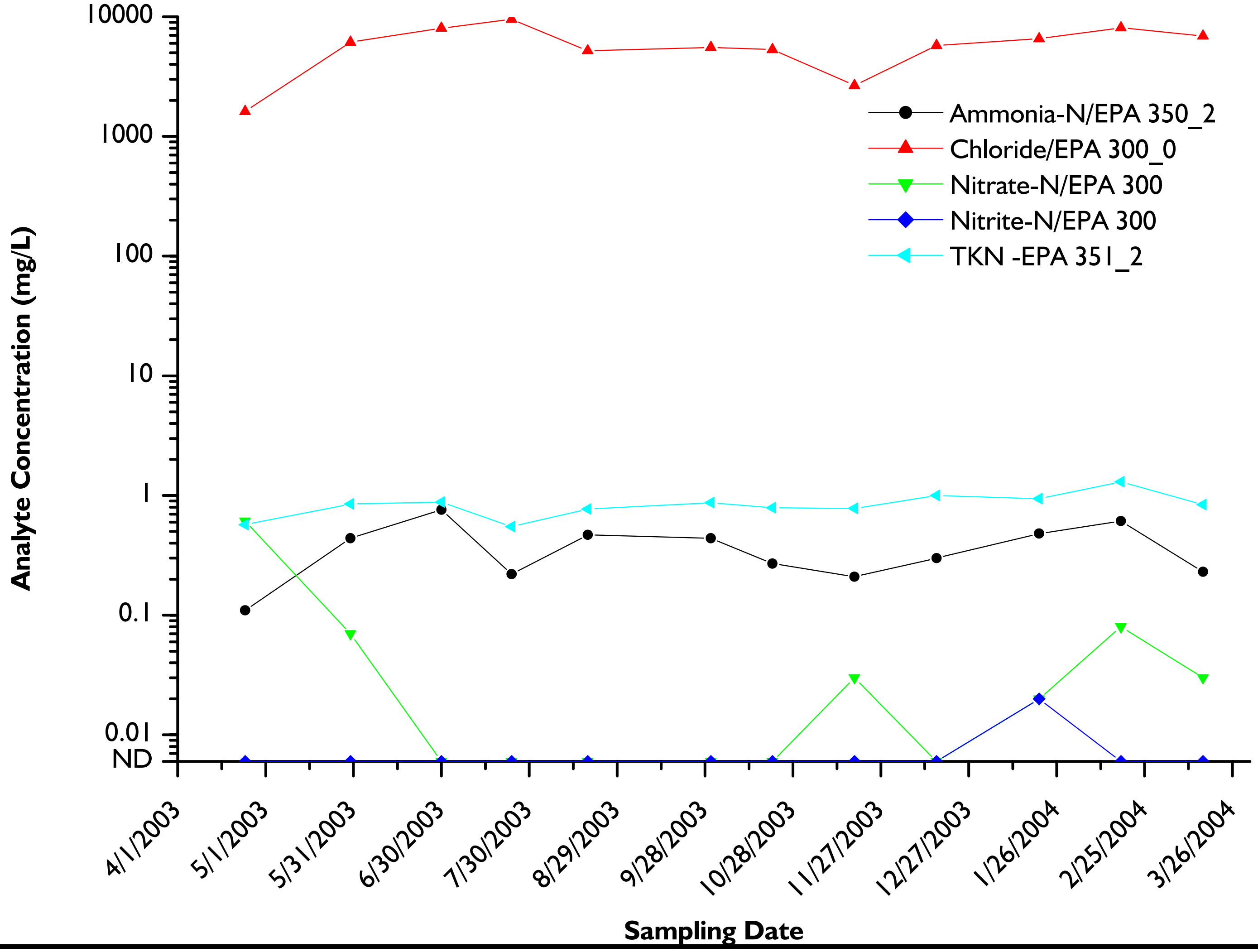

FIGURE 33: INORGANIC ANALYSES, WELL C-2
City of Malibu, CA

Source: Laboratory reports from Pat-Chem Laboratories, Inc., 2003 and 2004.
Path: o:\proj-01\1269-w-malibu\data\welldata\AnalyticalResults\Figures\AllAnalyticalFigures.opj
Date: 3-31-04 anm

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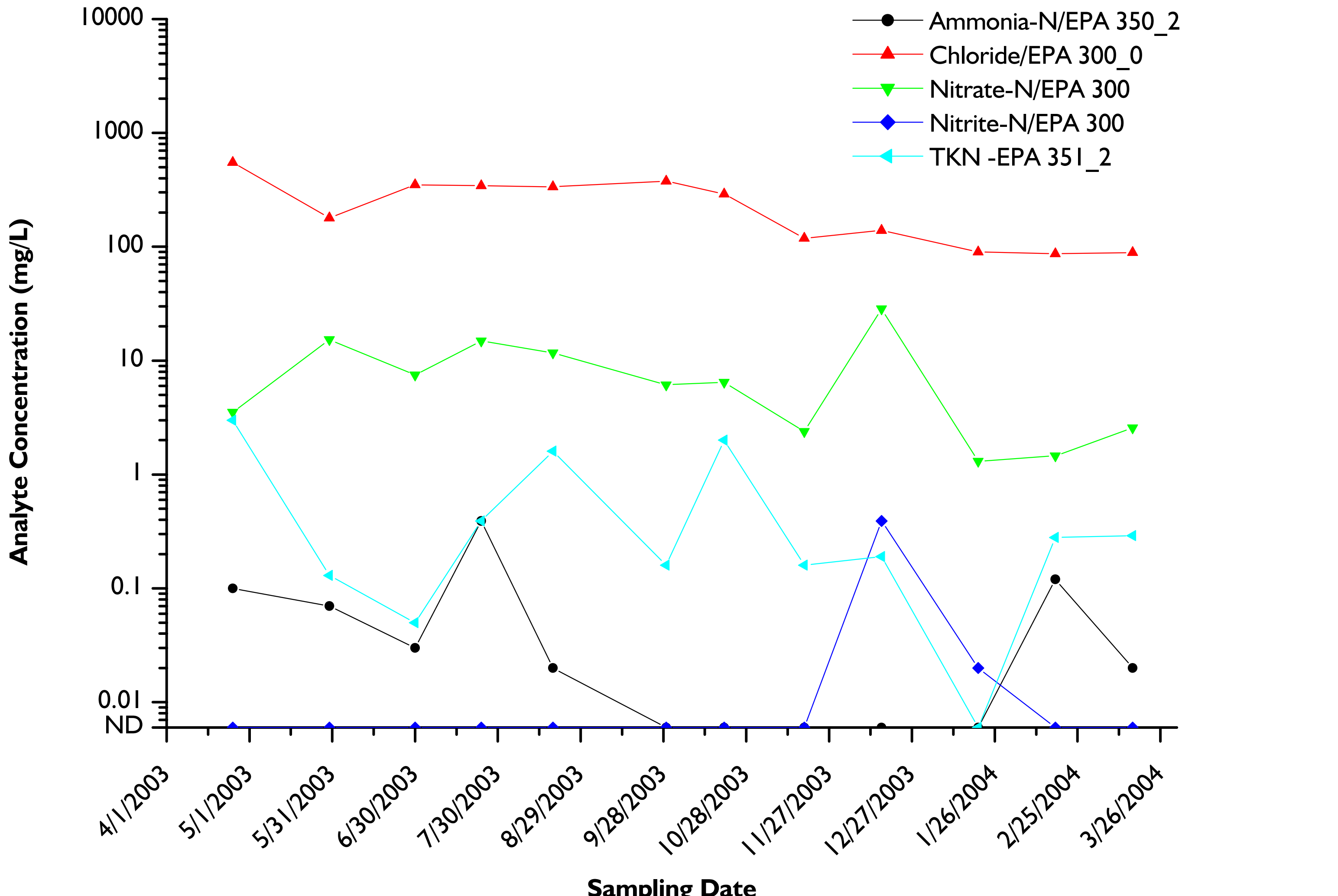

FIGURE 34: INORGANIC ANALYSES, WELL MW-5
City of Malibu, CA

Source: Laboratory reports from Pat-Chem Laboratories, Inc., 2003 and 2004.
Path: o:\proj-01\1269-w-malibu\data\welldata\AnalyticalResults\Figures\AllAnalyticalFigures.opj
Date: 3-31-04 anm

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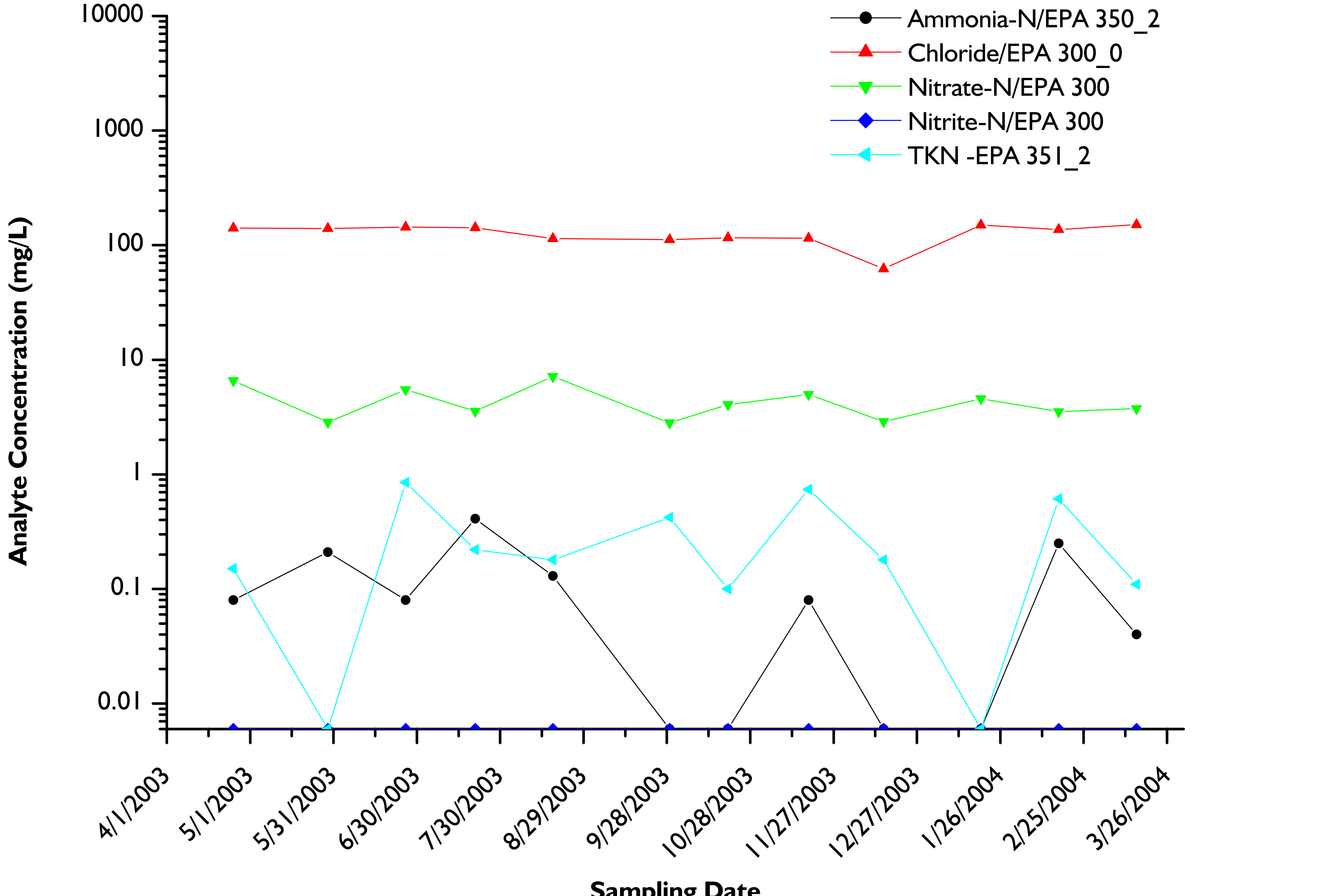

FIGURE 35: INORGANIC ANALYSES, WELL P-1

City of Malibu, CA

Source: Laboratory reports from Pat-Chem Laboratories, Inc., 2003 and 2004.
Path: o:\proj-01\1269-w-malibu\data\welldata\AnalyticalResults\Figures\AllAnalyticalFigures.opj
Date: 3-31-04 anm

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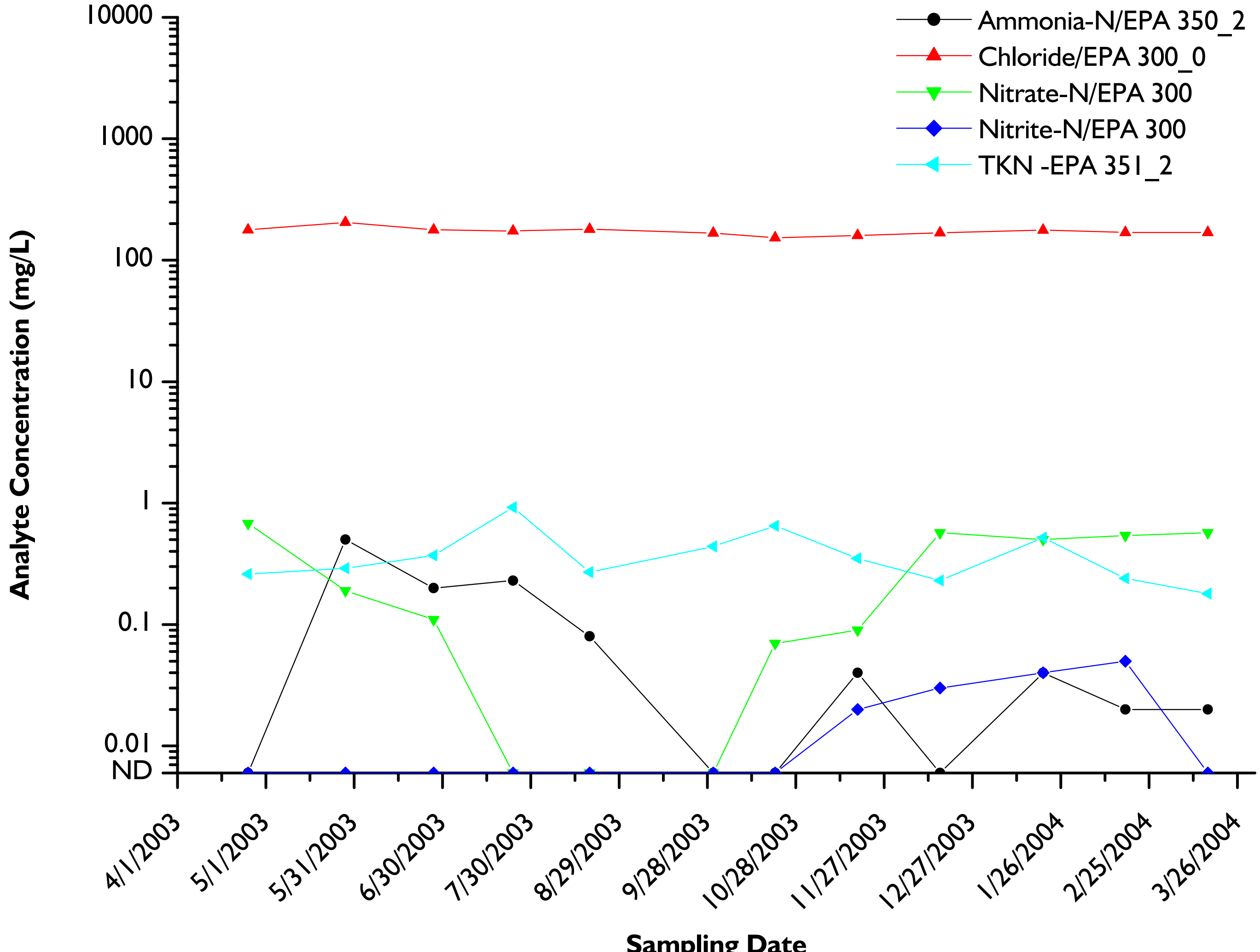

FIGURE 36: INORGANIC ANALYSES, WELL P-7
City of Malibu, CA

Source: Laboratory reports from Pat-Chem Laboratories, Inc., 2003 and 2004.
Path: o:\proj-01\1269-w-malibu\data\welldata\AnalyticalResults\Figures\AllAnalyticalFigures.opj
Date: 3-31-04 anm

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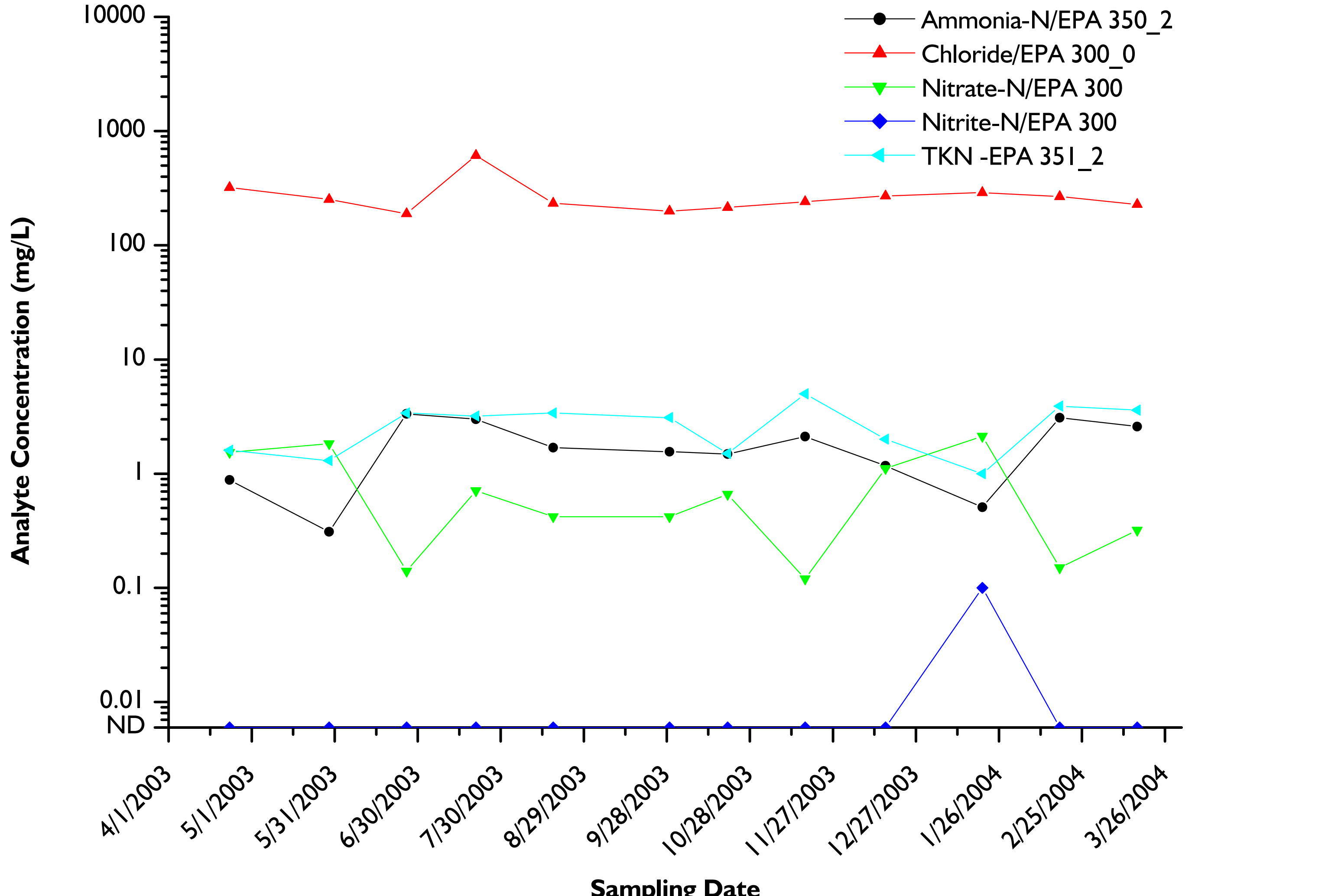

FIGURE 37: INORGANIC ANALYSES, WELL P-9
City of Malibu, CA

Source: Laboratory reports from Pat-Chem Laboratories, Inc., 2003 and 2004.
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Date: 3-31-04 anm

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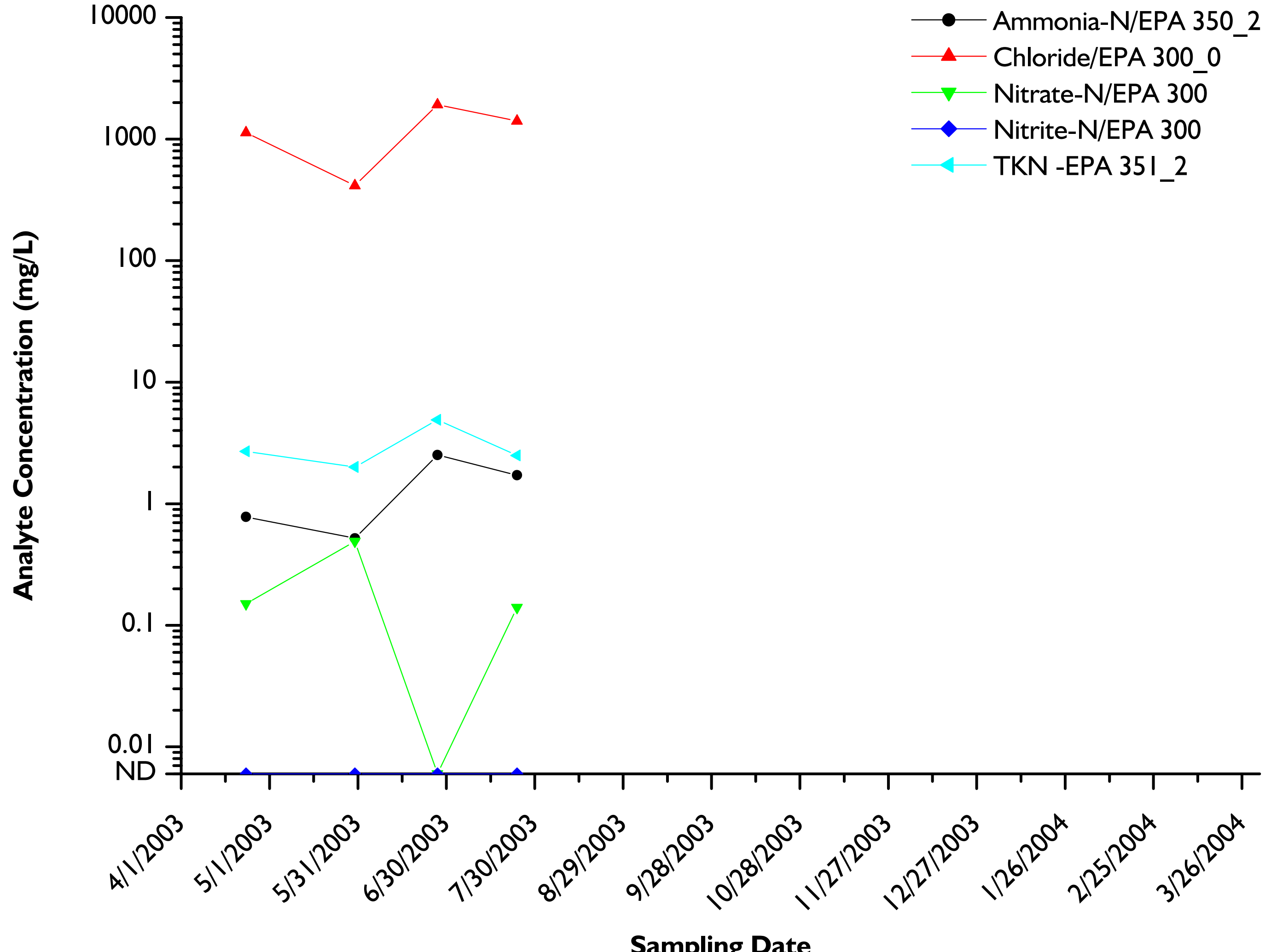

FIGURE 38: INORGANIC ANALYSES, WELL SMBRP-1
City of Malibu, CA

Source: Laboratory reports from Pat-Chem Laboratories, Inc., 2003 and 2004.
Path: o:\proj-01\1269-w-malibu\data\welldata\AnalyticalResults\Figures\AllAnalyticalFigures.opj
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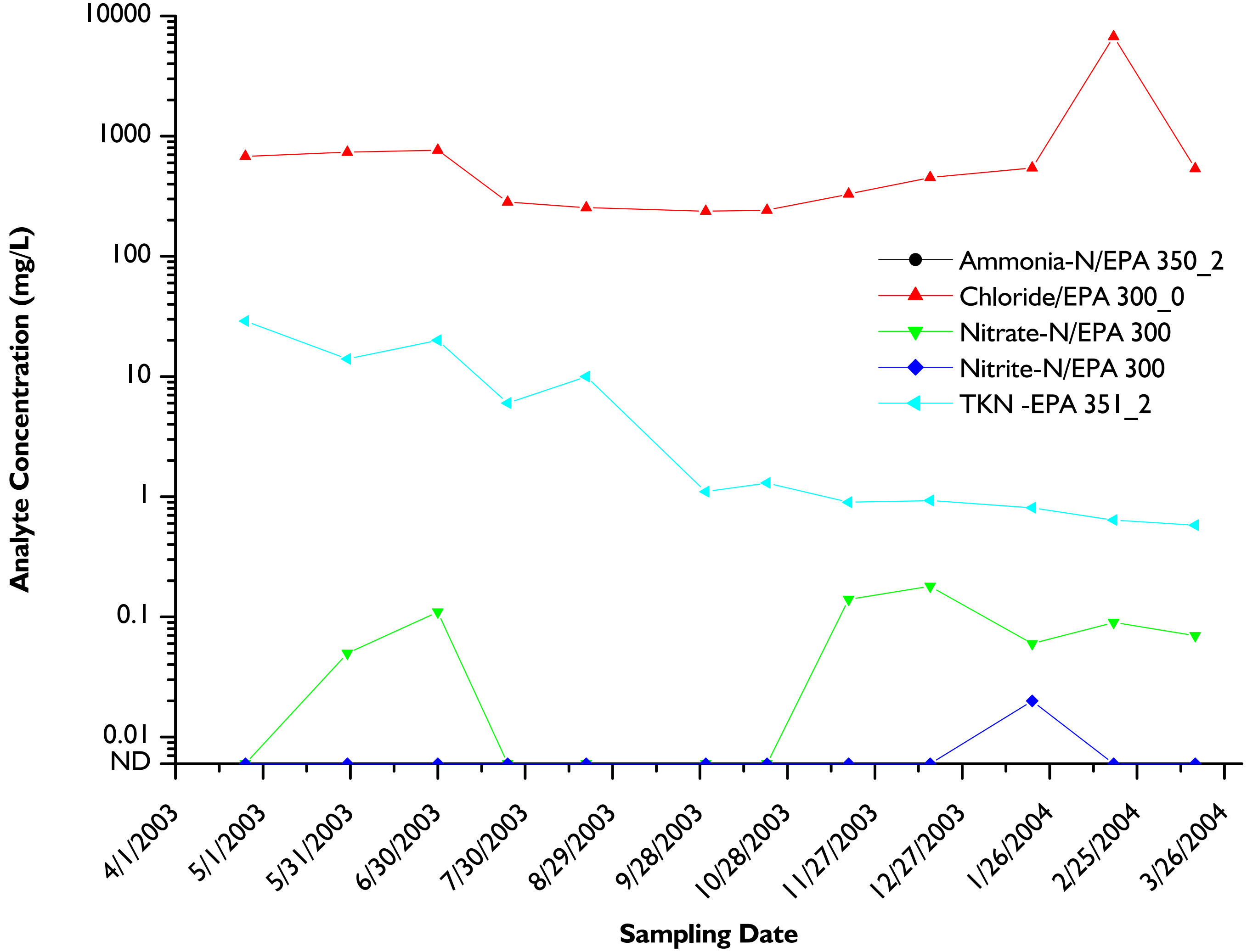

FIGURE 39: INORGANIC ANALYSES, WELL SMBRP-2
City of Malibu, CA

Source: Laboratory reports from Pat-Chem Laboratories, Inc., 2003 and 2004.
Path: o:\proj-01\1269-w-malibu\data\welldata\AnalyticalResults\Figures\AllAnalyticalFigures.opj
Date: 3-31-04 anm

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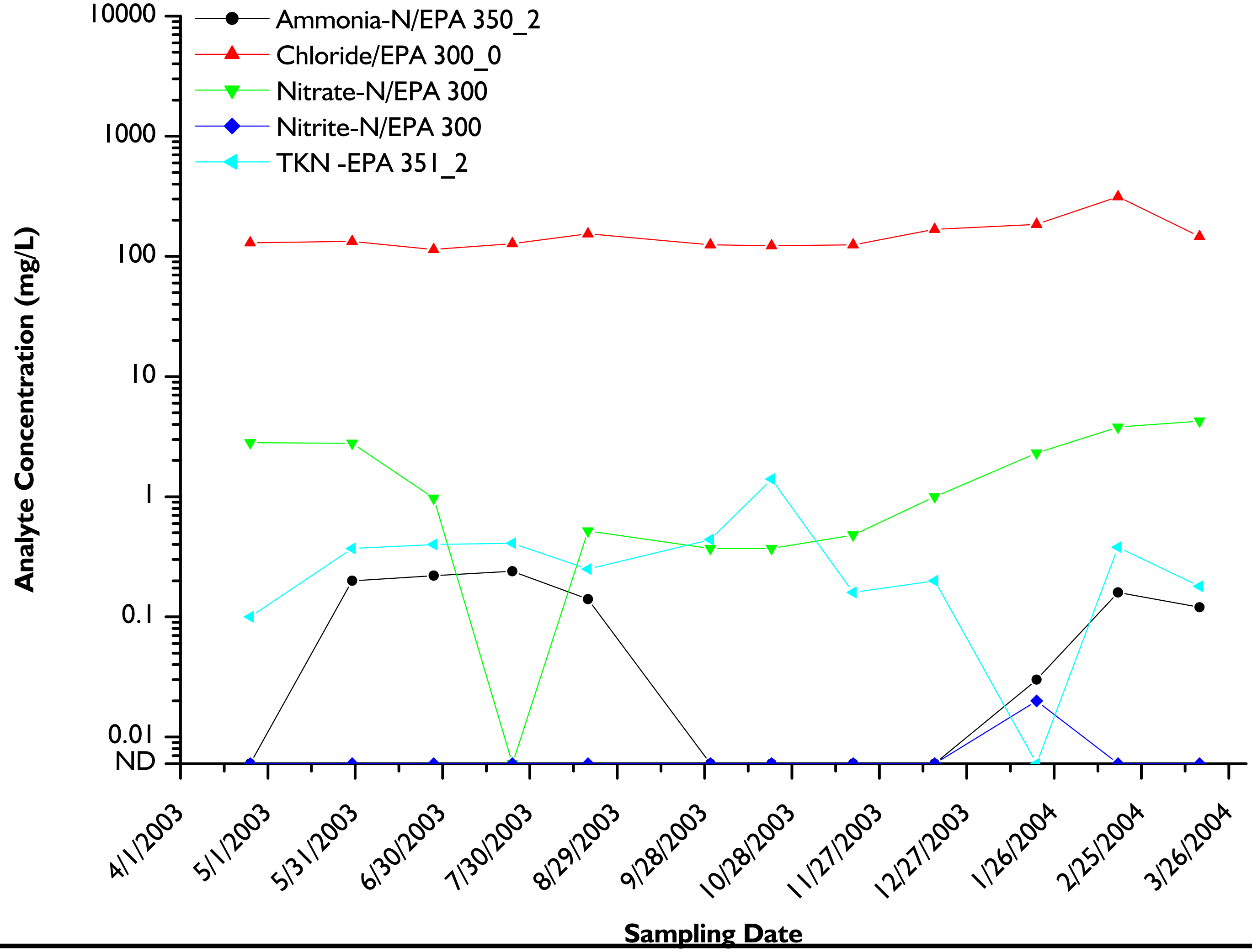

FIGURE 40: INORGANIC ANALYSES, WELL SMBRP-3c
City of Malibu, CA

Source: Laboratory reports from Pat-Chem Laboratories, Inc., 2003 and 2004.
Path: o:\proj-01\1269-w-malibu\data\welldata\AnalyticalResults\Figures\AllAnalyticalFigures.opj
Date: 3-31-04 anm

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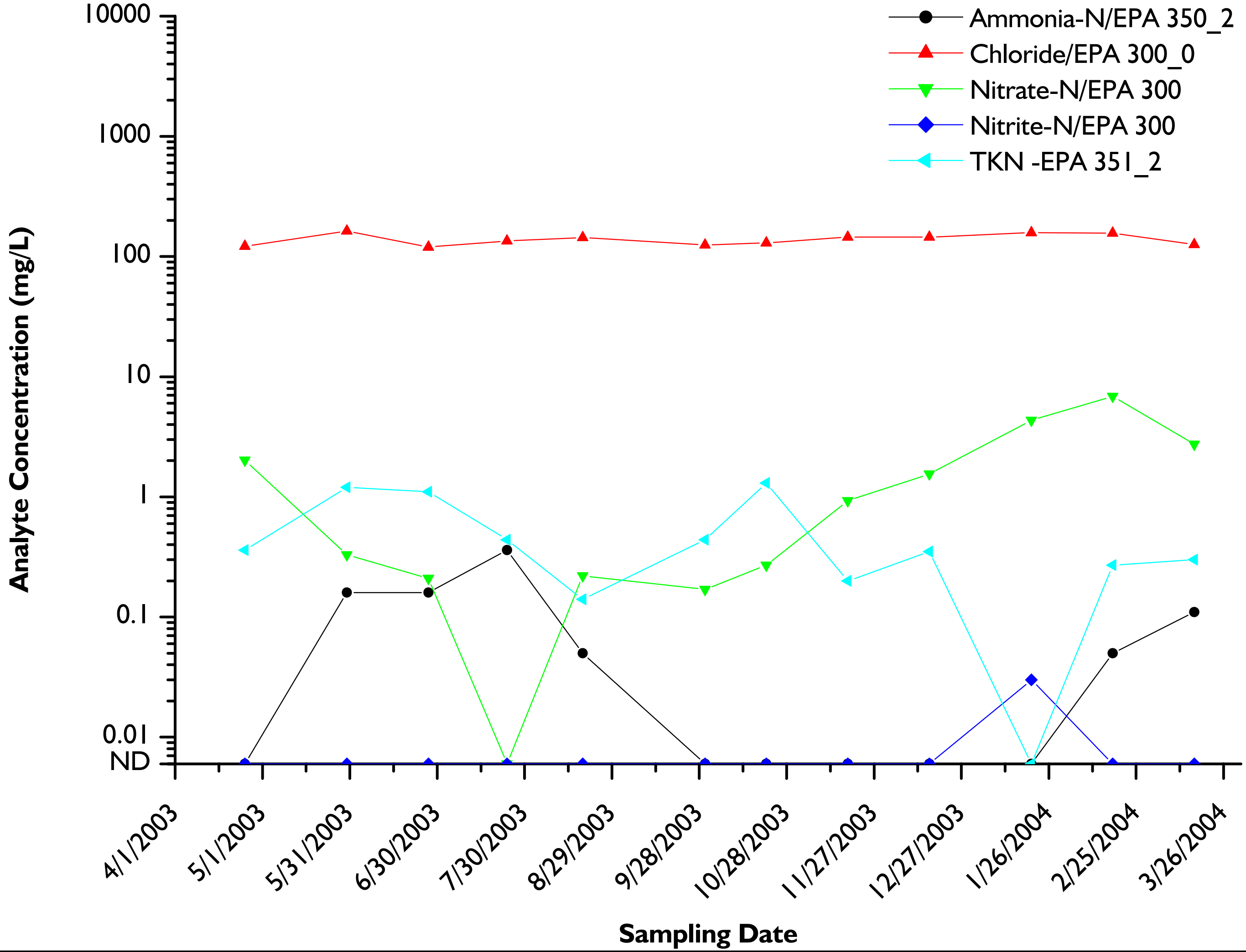

FIGURE 41: INORGANIC ANALYSES, WELL SMBRP-6
City of Malibu, CA

Source: Laboratory reports from Pat-Chem Laboratories, Inc., 2003 and 2004.
Path: o:\proj-01\1269-w-malibu\data\welldata\AnalyticalResults\Figures\AllAnalyticalFigures.opj
Date: 3-31-04 anm

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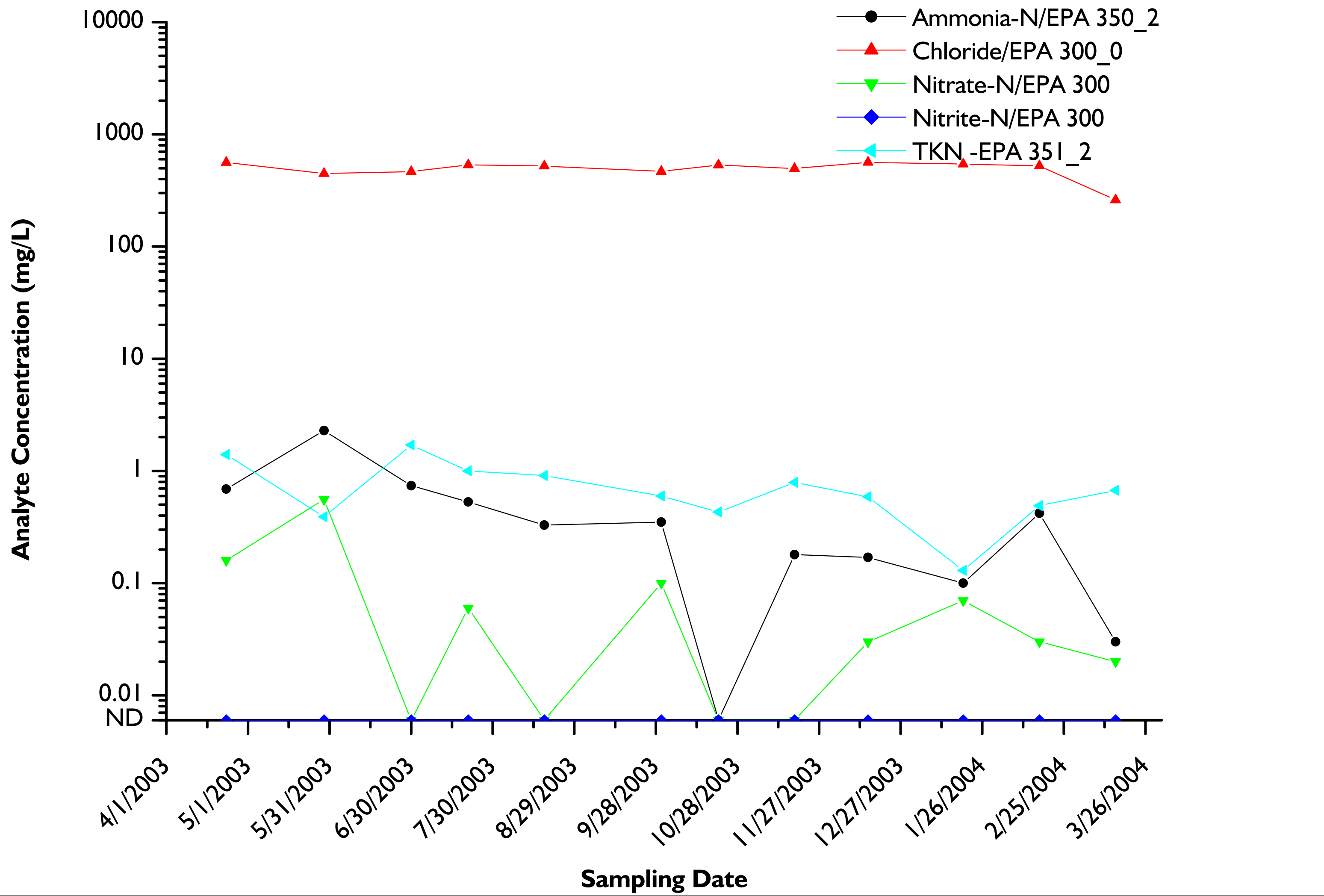

FIGURE 42: INORGANIC ANALYSES, WELL SMBRP-7b
City of Malibu, CA

Source: Laboratory reports from Pat-Chem Laboratories, Inc., 2003 and 2004.
Path: o:\proj-01\1269-w-malibu\data\welldata\AnalyticalResults\Figures\AllAnalyticalFigures.opj
Date: 3-31-04 anm

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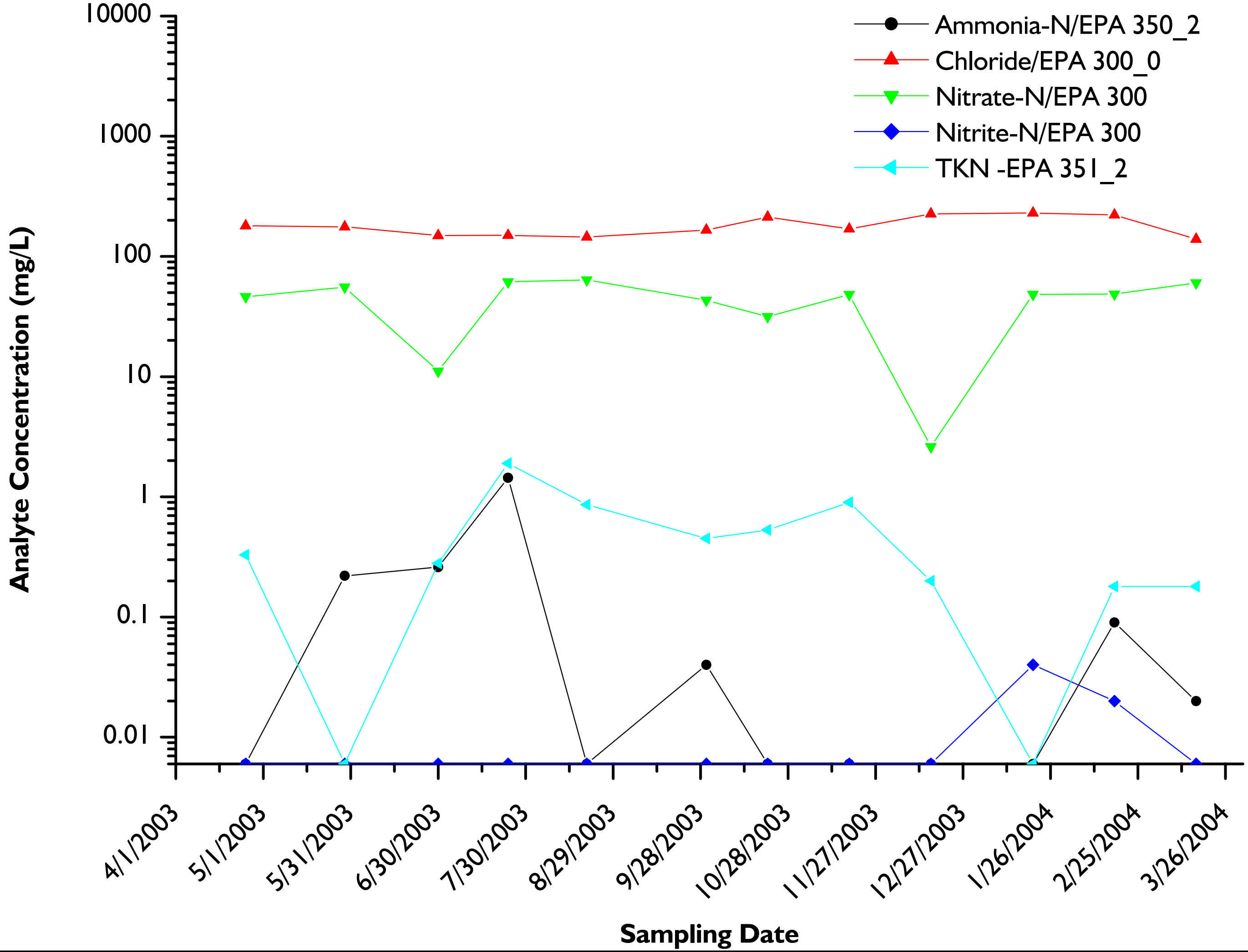

FIGURE 43: INORGANIC ANALYSES, WELL SMBRP-8
City of Malibu, CA

Source: Laboratory reports from Pat-Chem Laboratories, Inc., 2003 and 2004.
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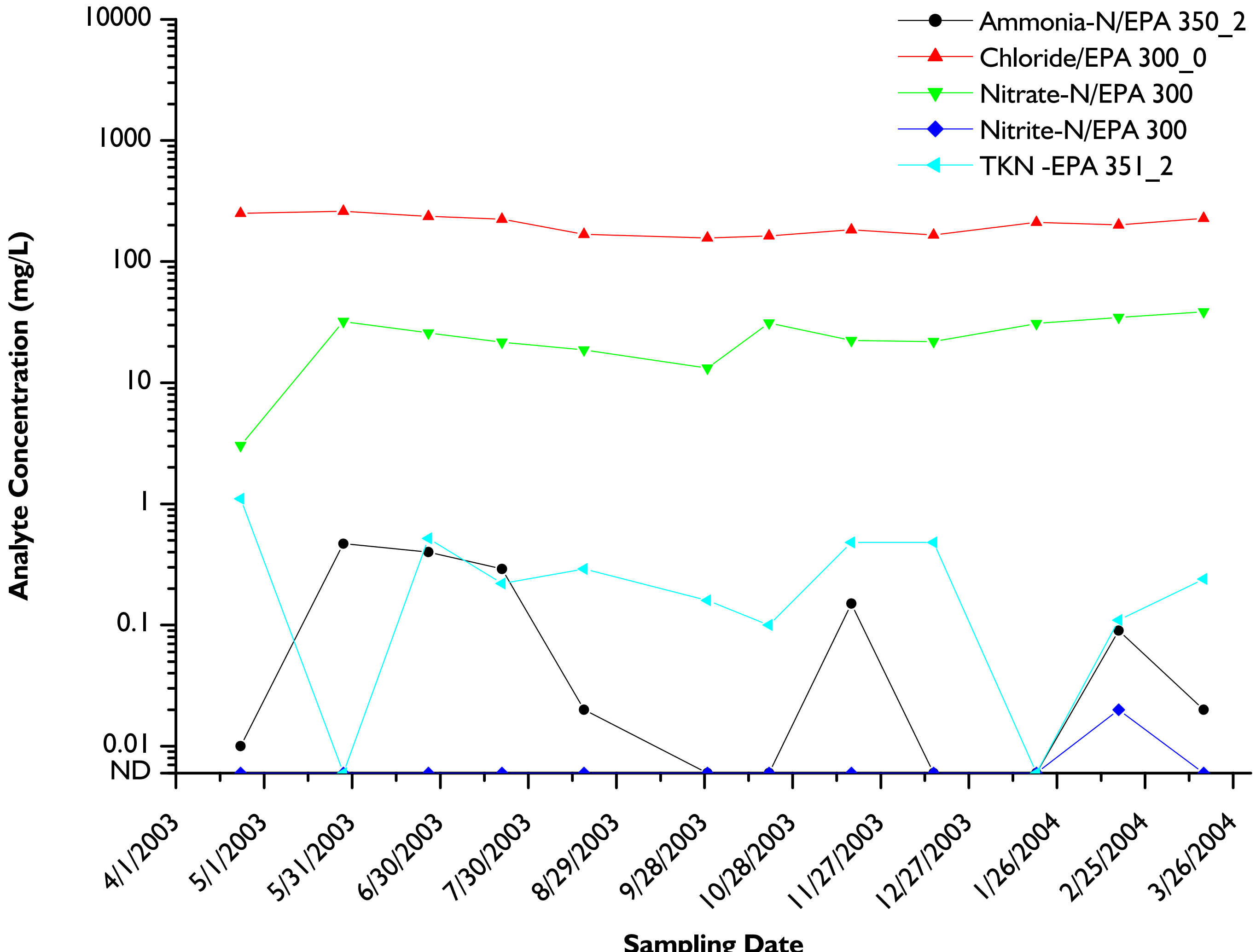

FIGURE 44: INORGANIC ANALYSES, WELL SMBRP-9
City of Malibu, CA

Source: Laboratory reports from Pat-Chem Laboratories, Inc., 2003 and 2004.
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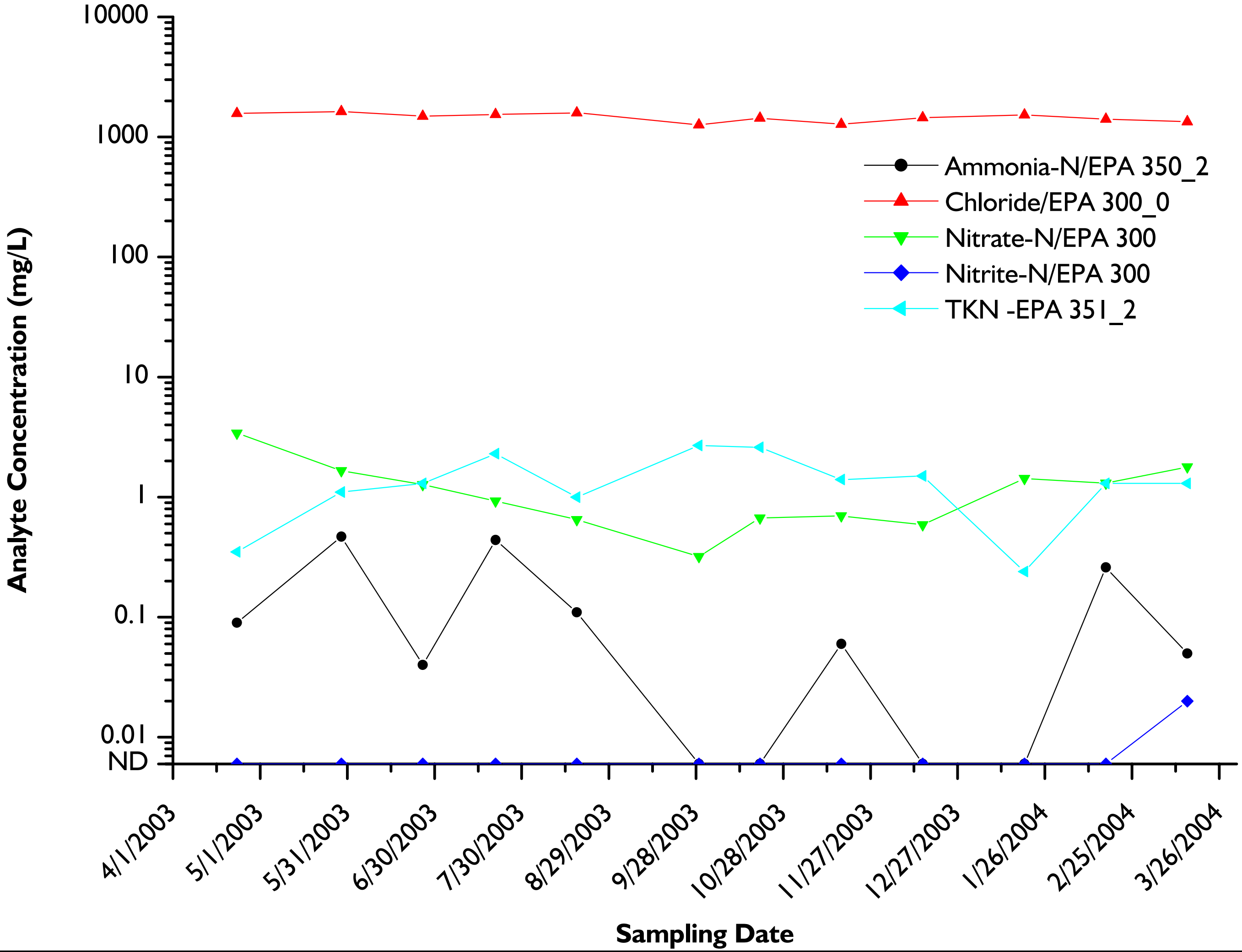

FIGURE 45: INORGANIC ANALYSES, WELL SMBRP-10c
City of Malibu, CA

Source: Laboratory reports from Pat-Chem Laboratories, Inc., 2003 and 2004.
Path: o:\proj-01\1269-w-malibu\data\welldata\AnalyticalResults\Figures\AllAnalyticalFigures.opj
Date: 3-31-04 anm

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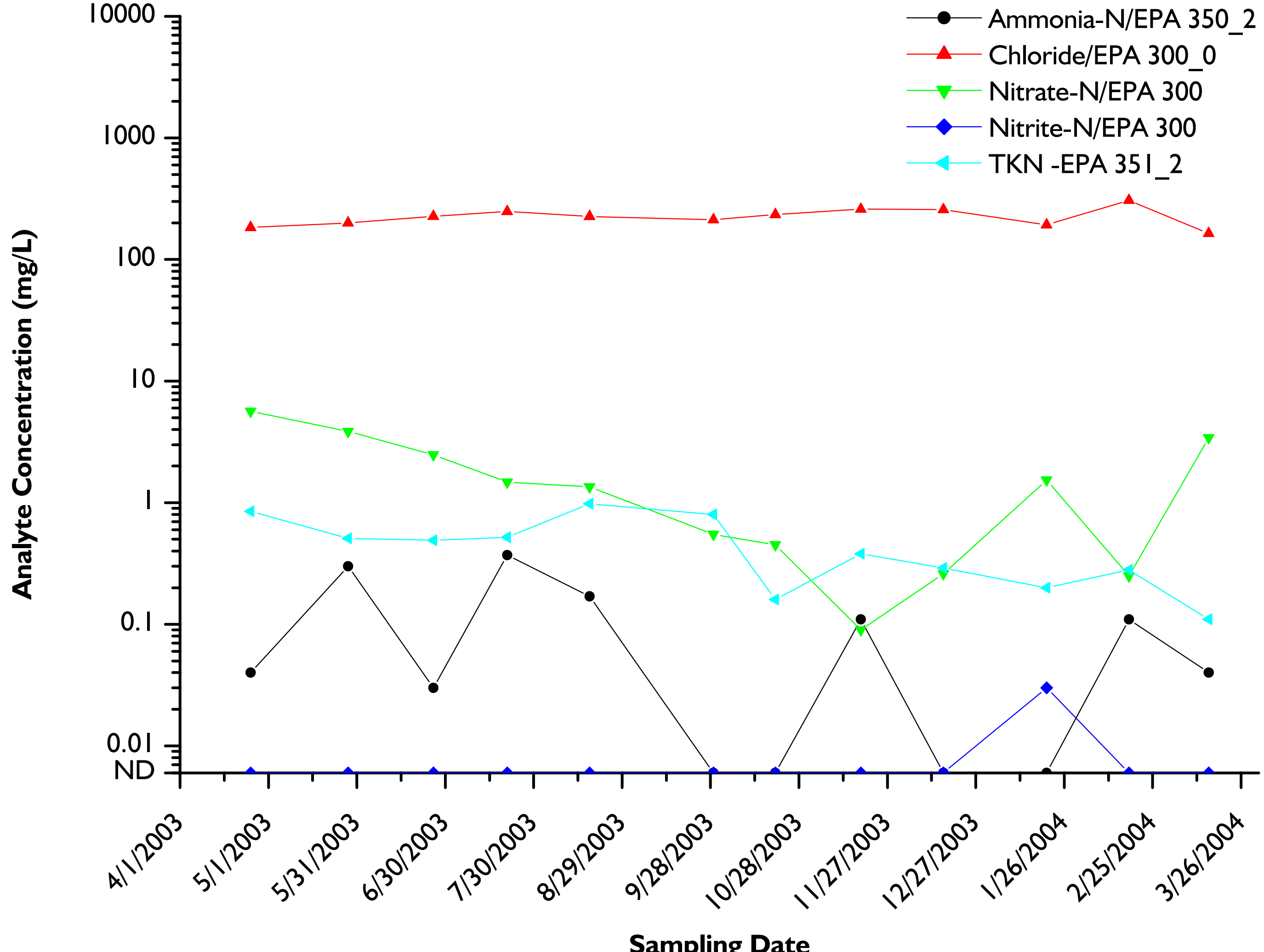

FIGURE 46: INORGANIC ANALYSES, WELL SMBRP-11
City of Malibu, CA

Source: Laboratory reports from Pat-Chem Laboratories, Inc., 2003 and 2004.
Path: o:\proj-01\1269-w-malibu\data\welldata\AnalyticalResults\Figures\AllAnalyticalFigures.opj
Date: 3-31-04 anm

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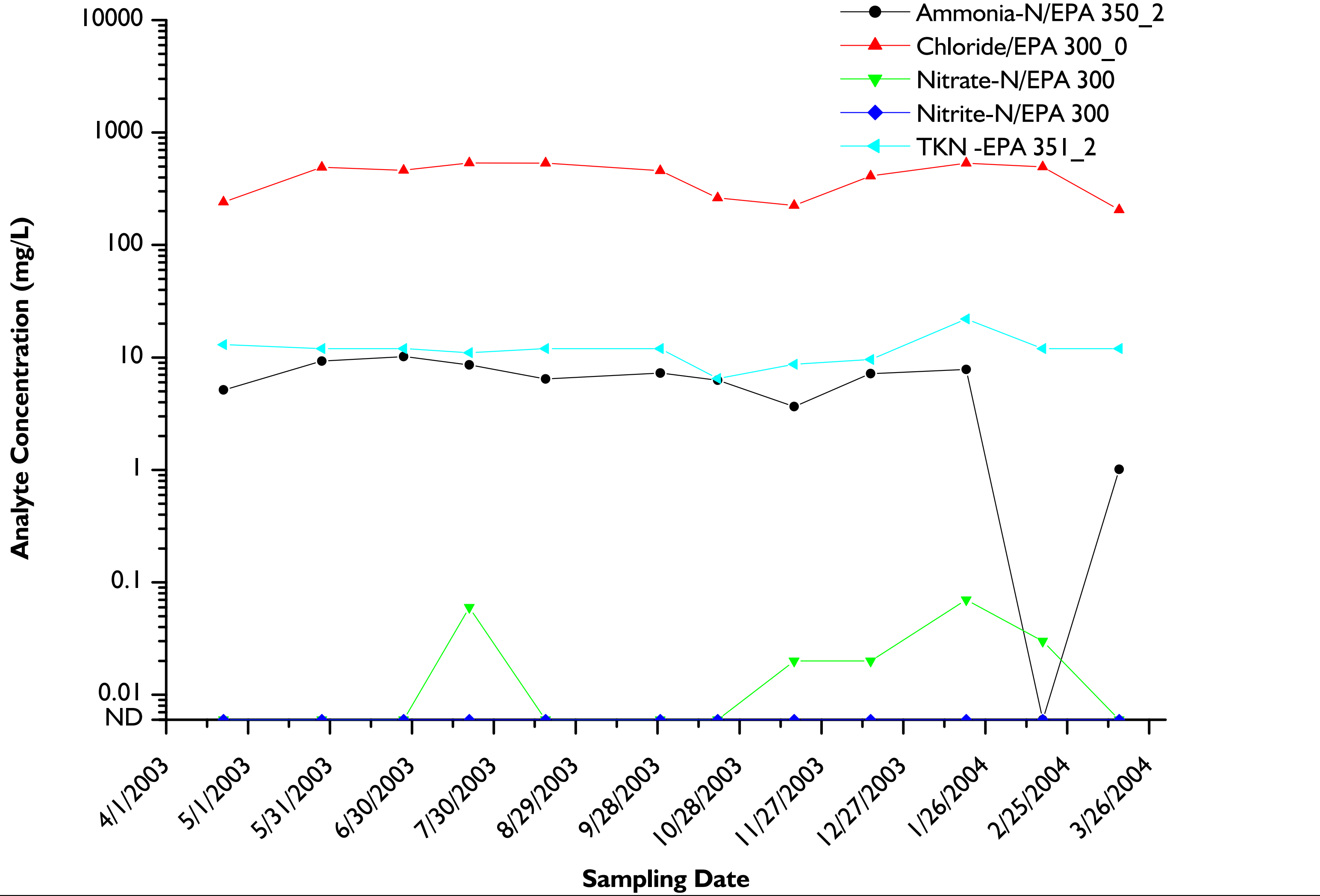

FIGURE 47: INORGANIC ANALYSES, WELL SMBRP-12
City of Malibu, CA

Source: Laboratory reports from Pat-Chem Laboratories, Inc., 2003 and 2004.
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Date: 3-31-04 anm

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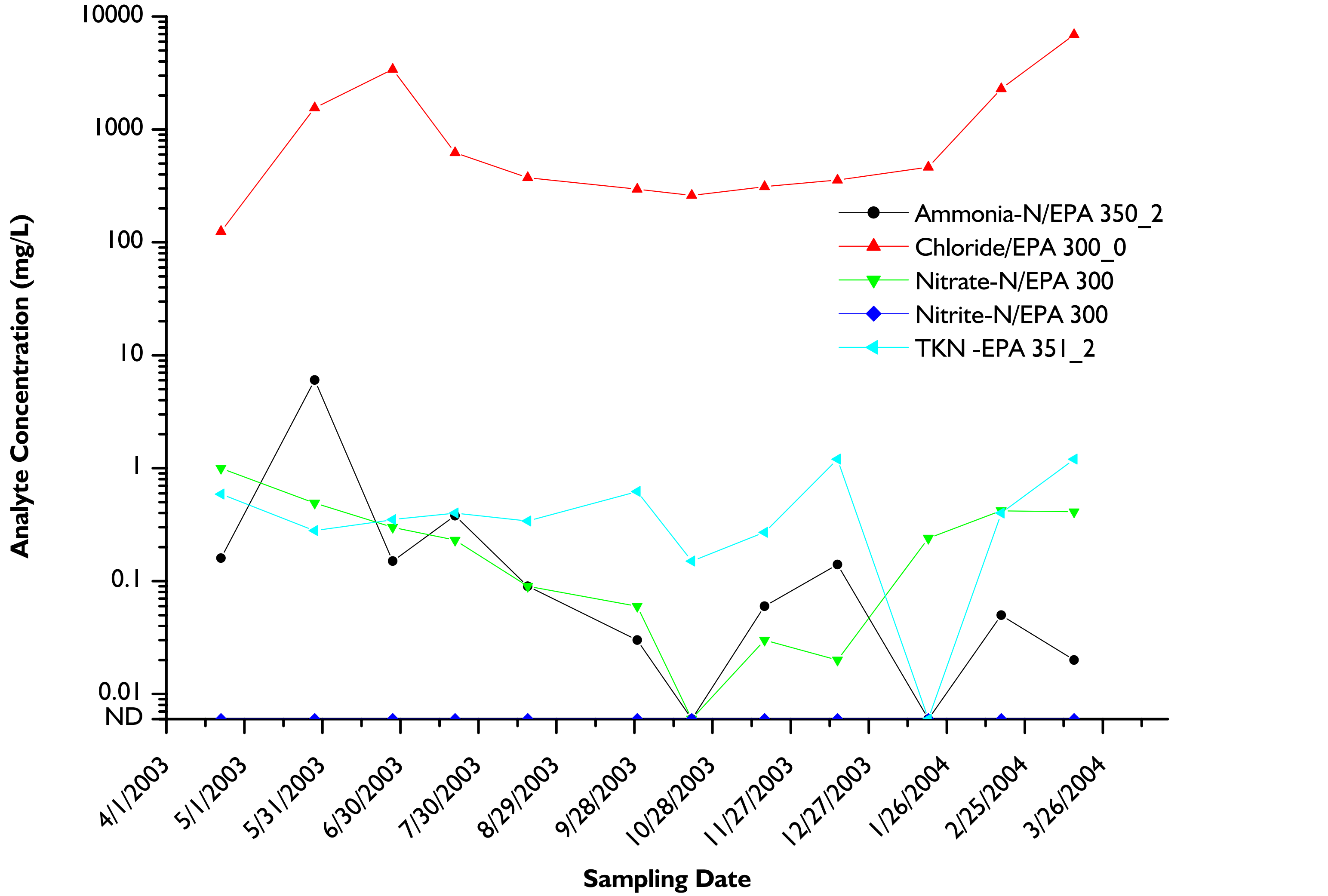

FIGURE 48: INORGANIC ANALYSES, WELL SMBRP-13
City of Malibu, CA

Source: Laboratory reports from Pat-Chem Laboratories, Inc., 2003 and 2004.
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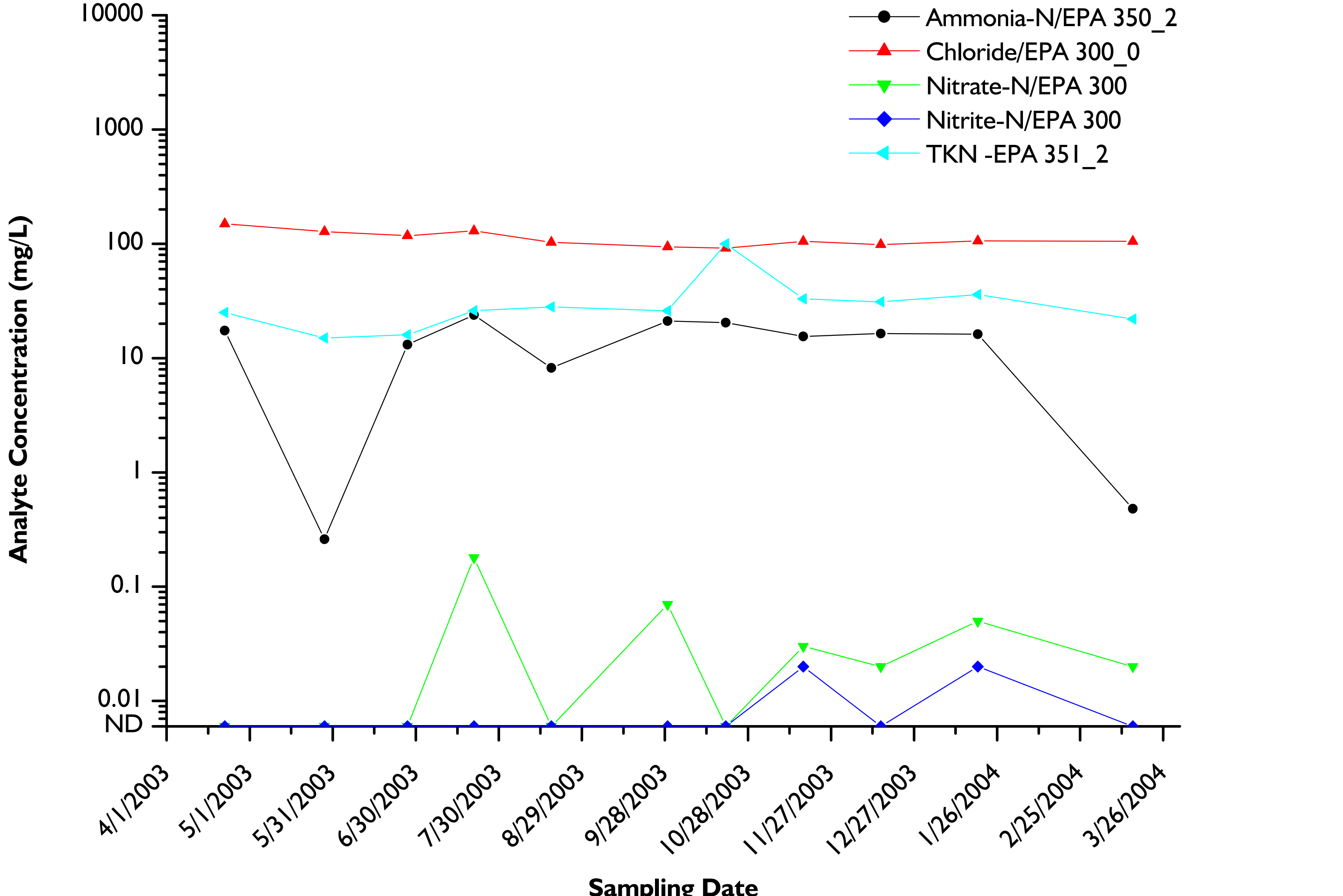

FIGURE 49: INORGANIC ANALYSES, WELL SMBRP-14
City of Malibu, CA

Source: Laboratory reports from Pat-Chem Laboratories, Inc., 2003 and 2004.
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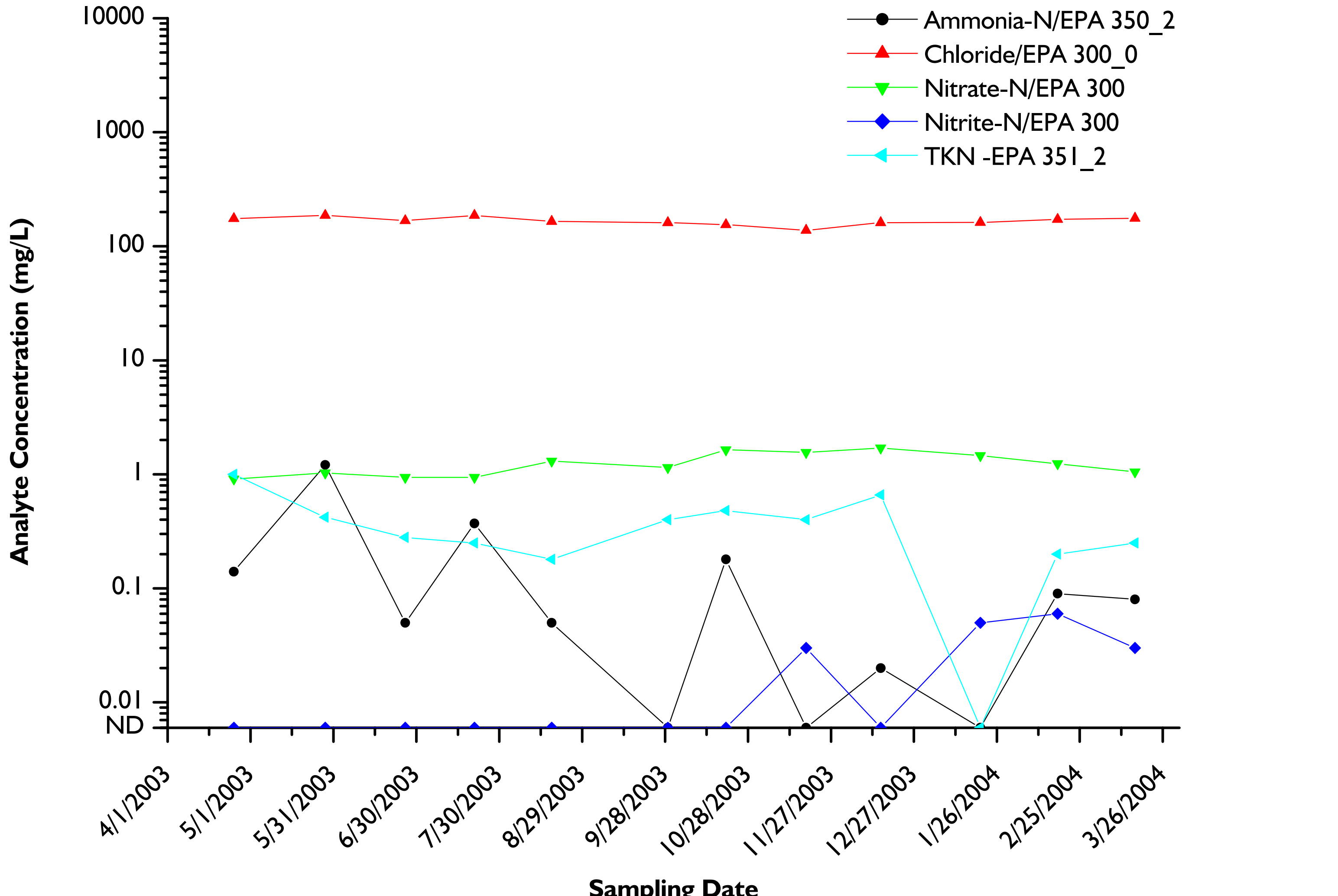

FIGURE 50: INORGANIC ANALYSES, WELL SMBRP-15b
City of Malibu, CA

Source: Laboratory reports from Pat-Chem Laboratories, Inc., 2003 and 2004.
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Date: 3-31-04 anm

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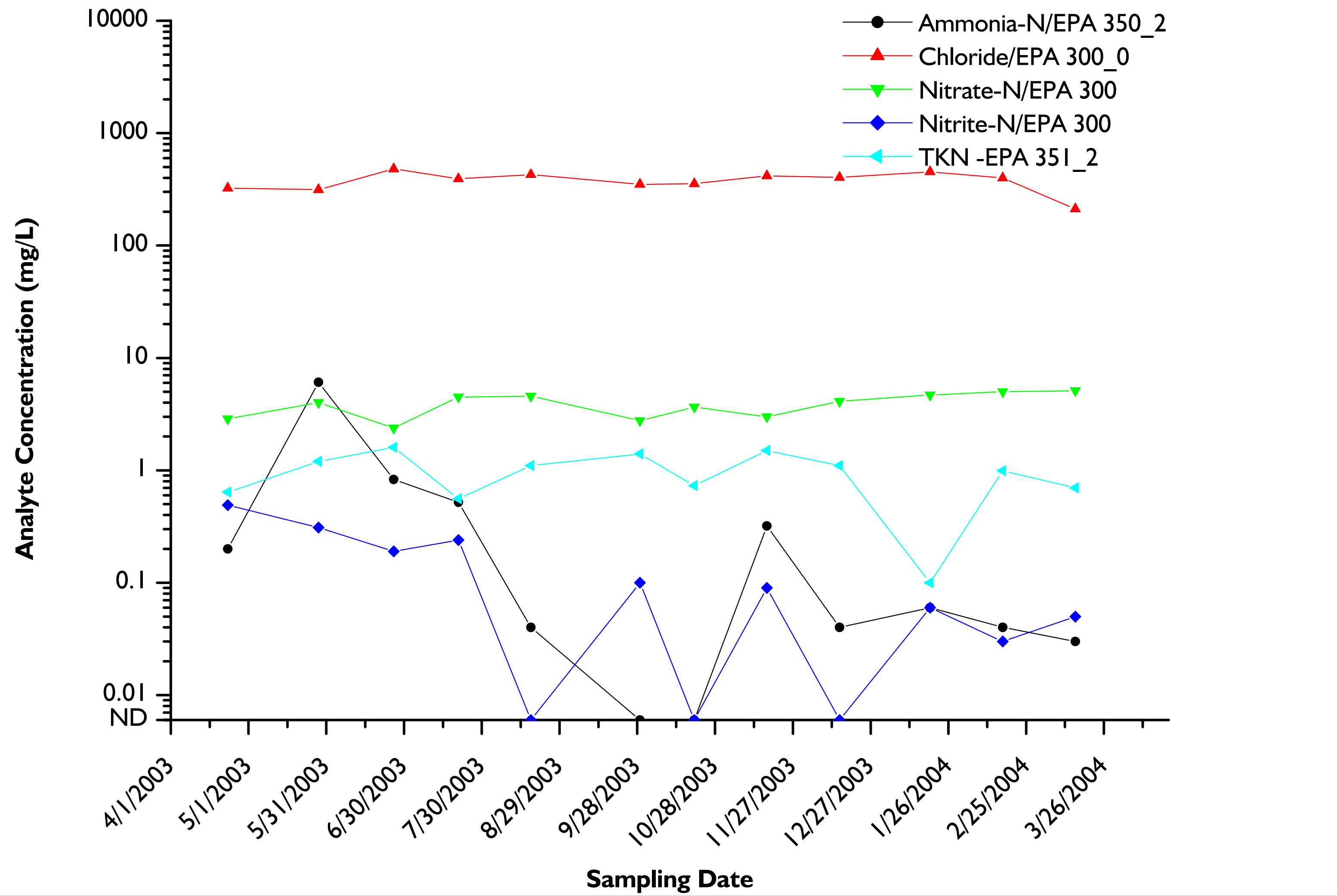

FIGURE 51: INORGANIC ANALYSES, WELL SMBRP-16
City of Malibu, CA

Source: Laboratory reports from Pat-Chem Laboratories, Inc., 2003 and 2004.
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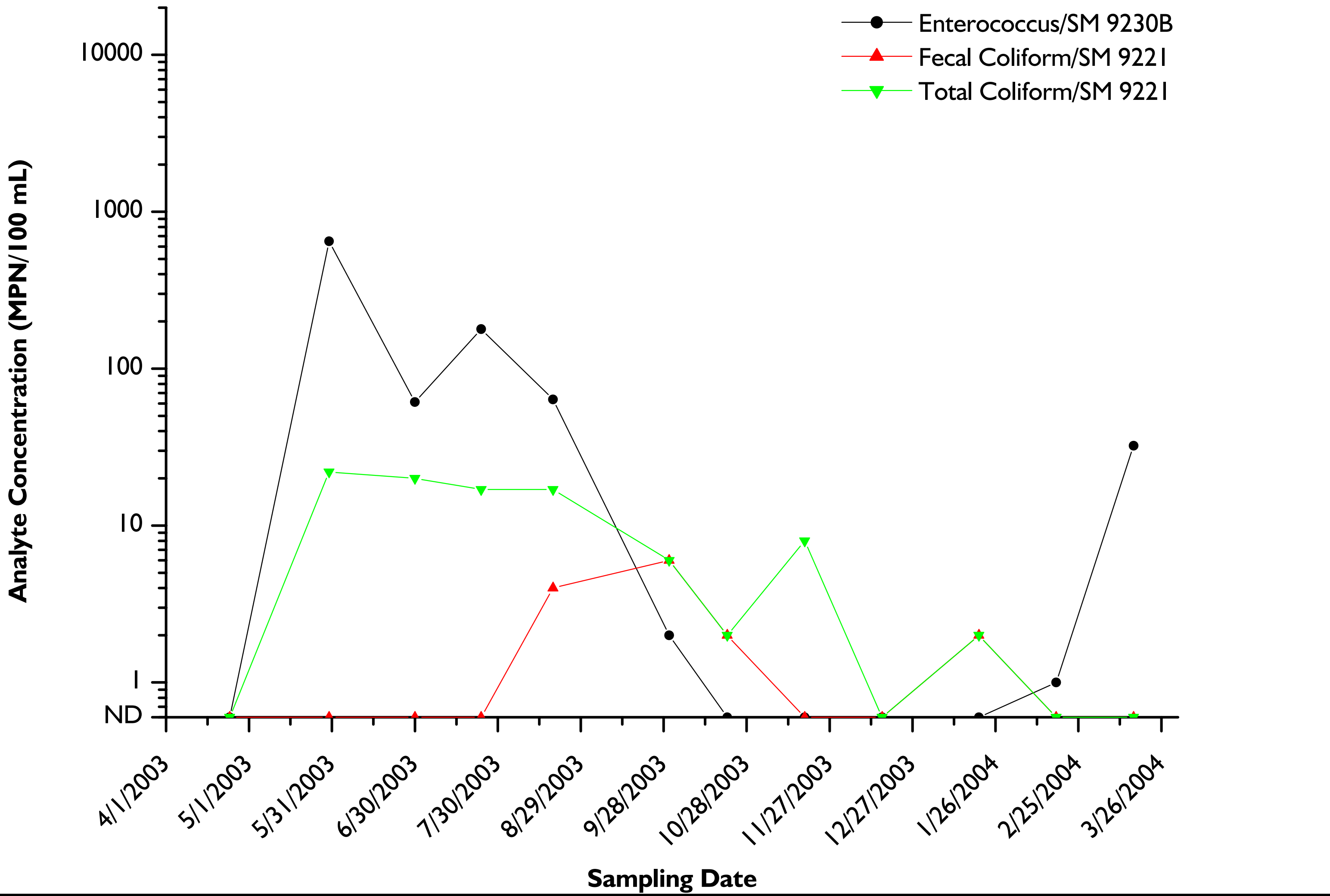

FIGURE 52: PATHOGEN COUNTS, WELL C-1
City of Malibu, CA

Source: Laboratory reports from Pat-Chem Laboratories, Inc., 2003 and 2004.
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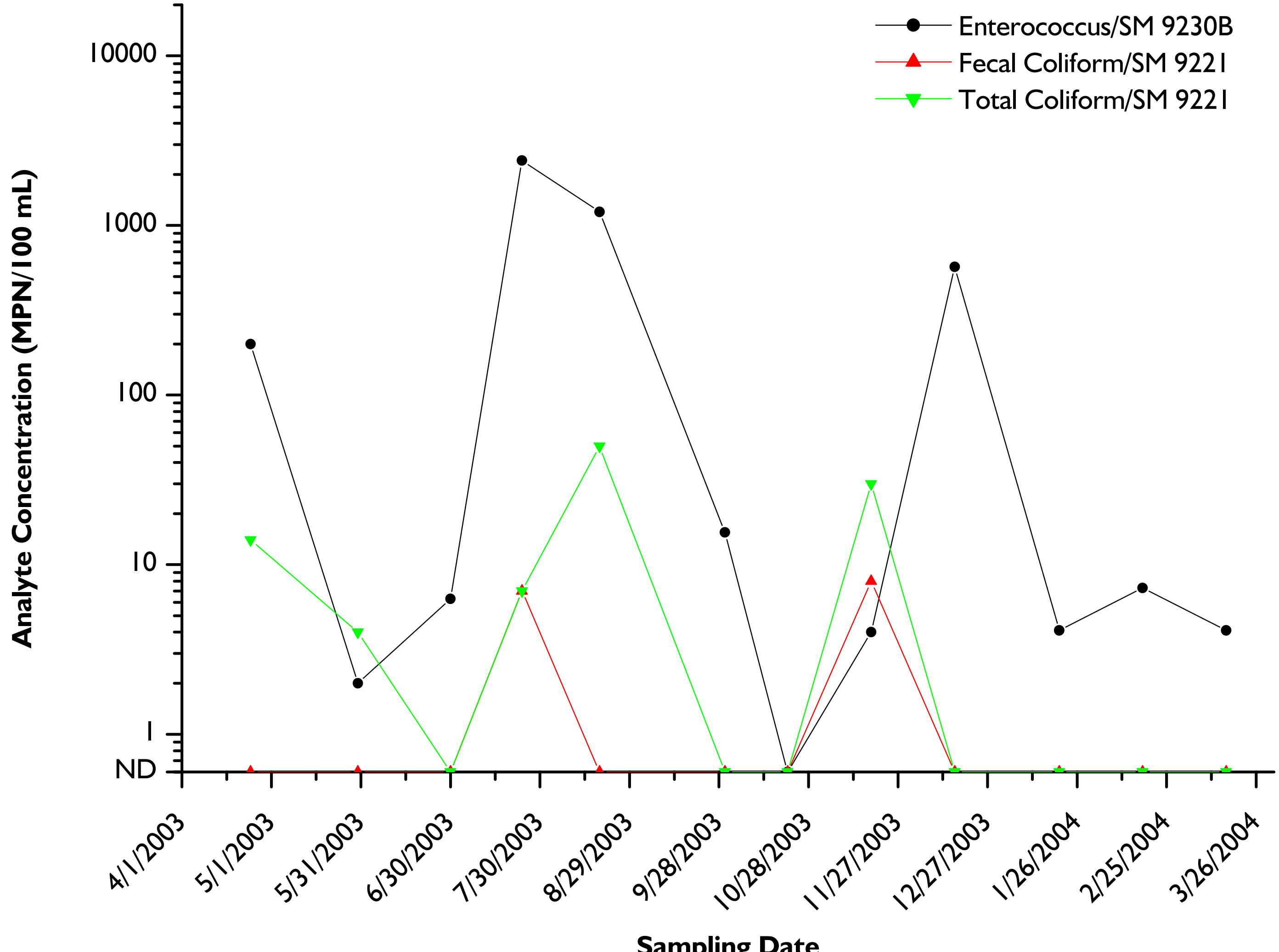

FIGURE 53: PATHOGEN COUNTS, WELL C-2
City of Malibu, CA

Source: Laboratory reports from Pat-Chem Laboratories, Inc., 2003 and 2004.
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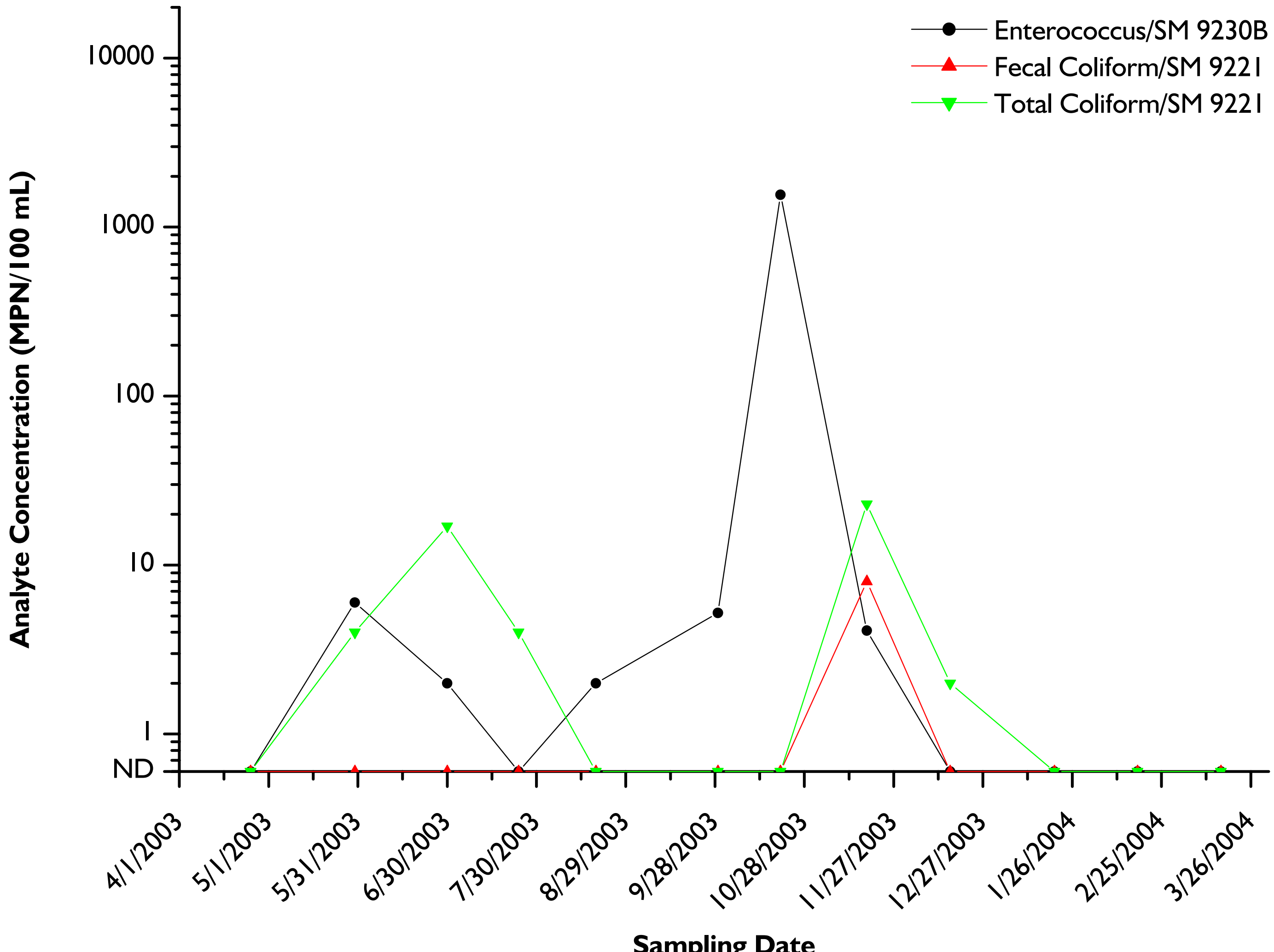

FIGURE 54: PATHOGEN COUNTS, WELL MW-5

City of Malibu, CA

Source: Laboratory reports from Pat-Chem Laboratories, Inc., 2003 and 2004.

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Date: 3-31-04 anm

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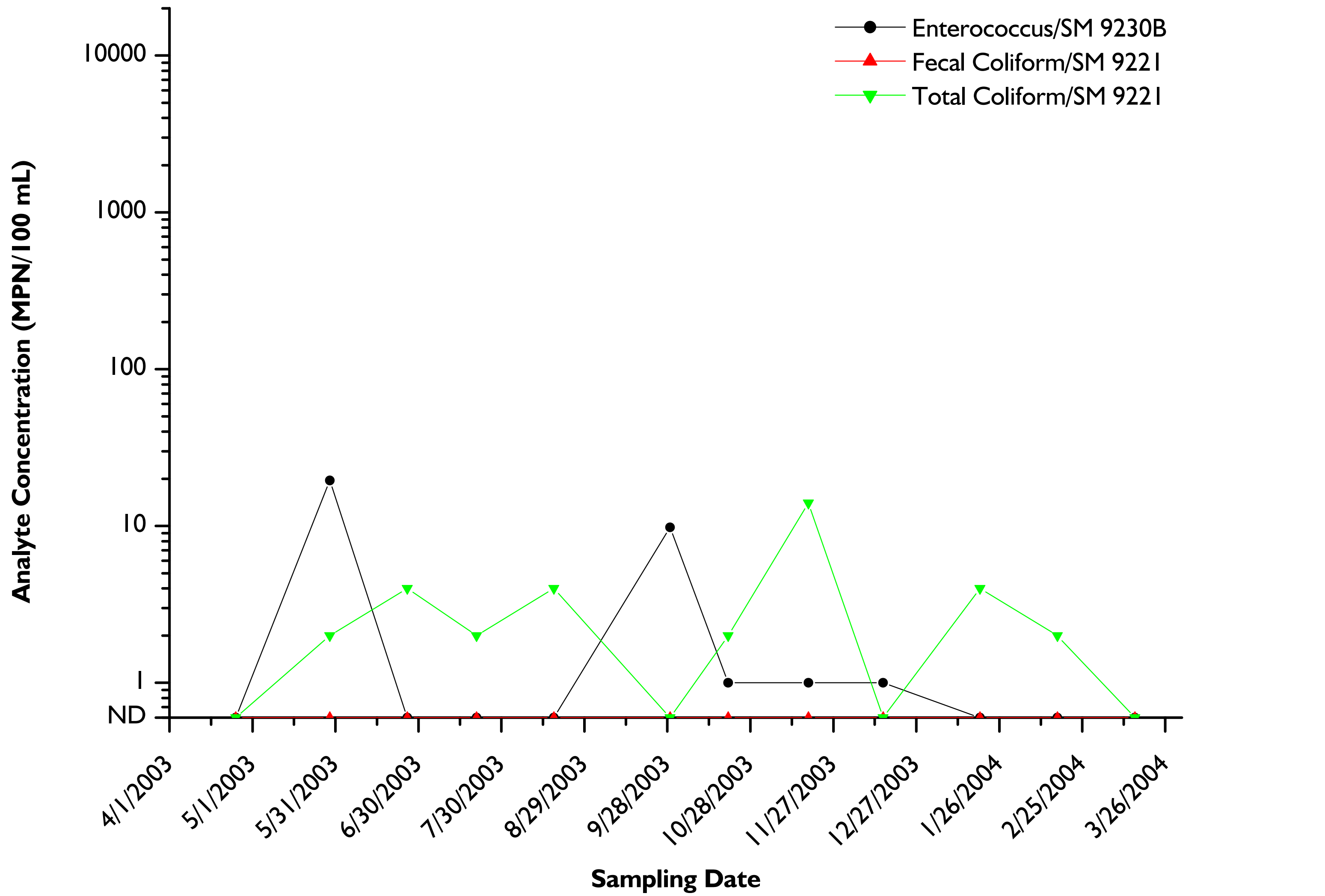

FIGURE 55: PATHOGEN COUNTS, WELL P-1
City of Malibu, CA

Source: Laboratory reports from Pat-Chem Laboratories, Inc., 2003 and 2004.
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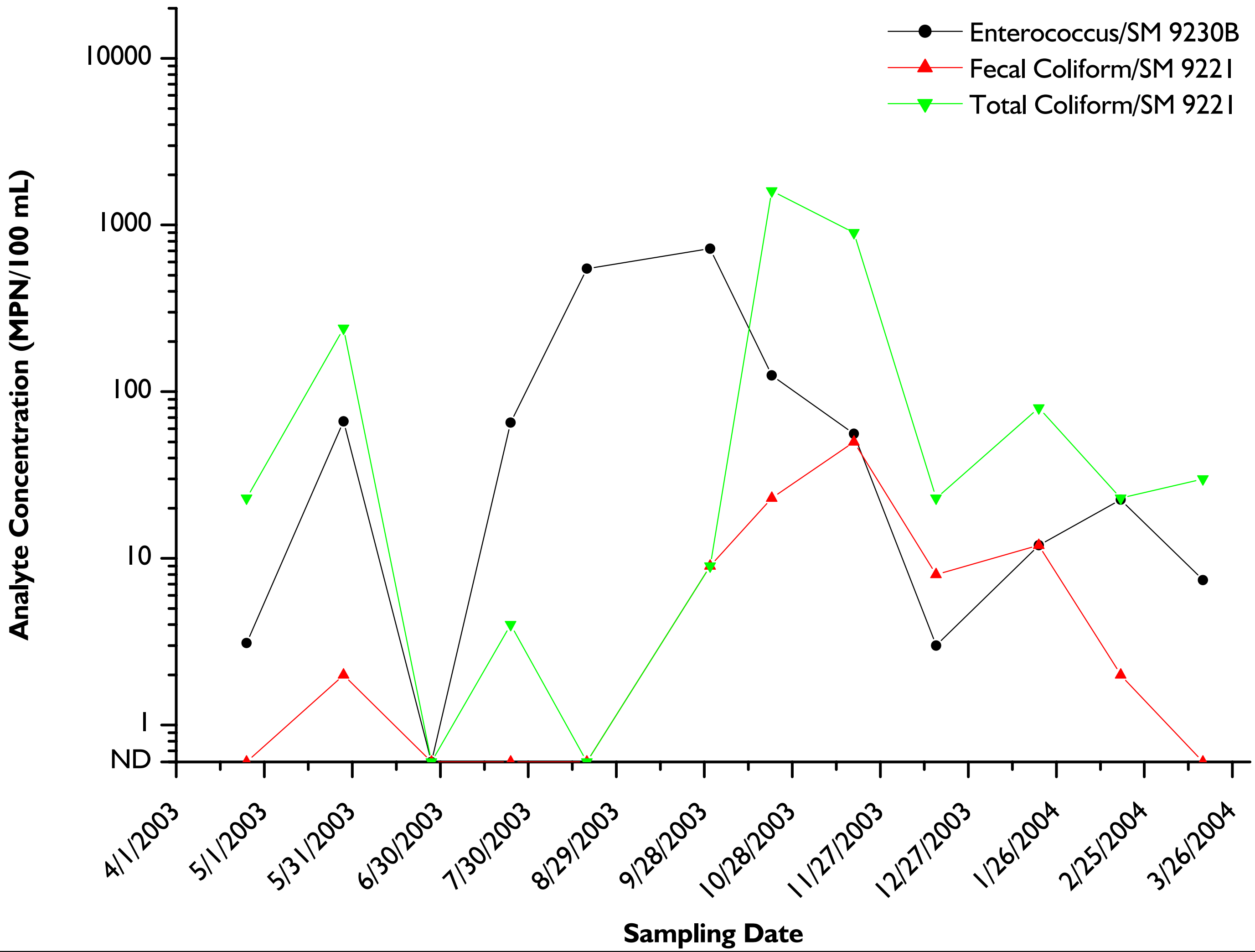

FIGURE 56: PATHOGEN COUNTS, WELL P-7
City of Malibu, CA

Source: Laboratory reports from Pat-Chem Laboratories, Inc., 2003 and 2004.
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Date: 3-31-04 anm

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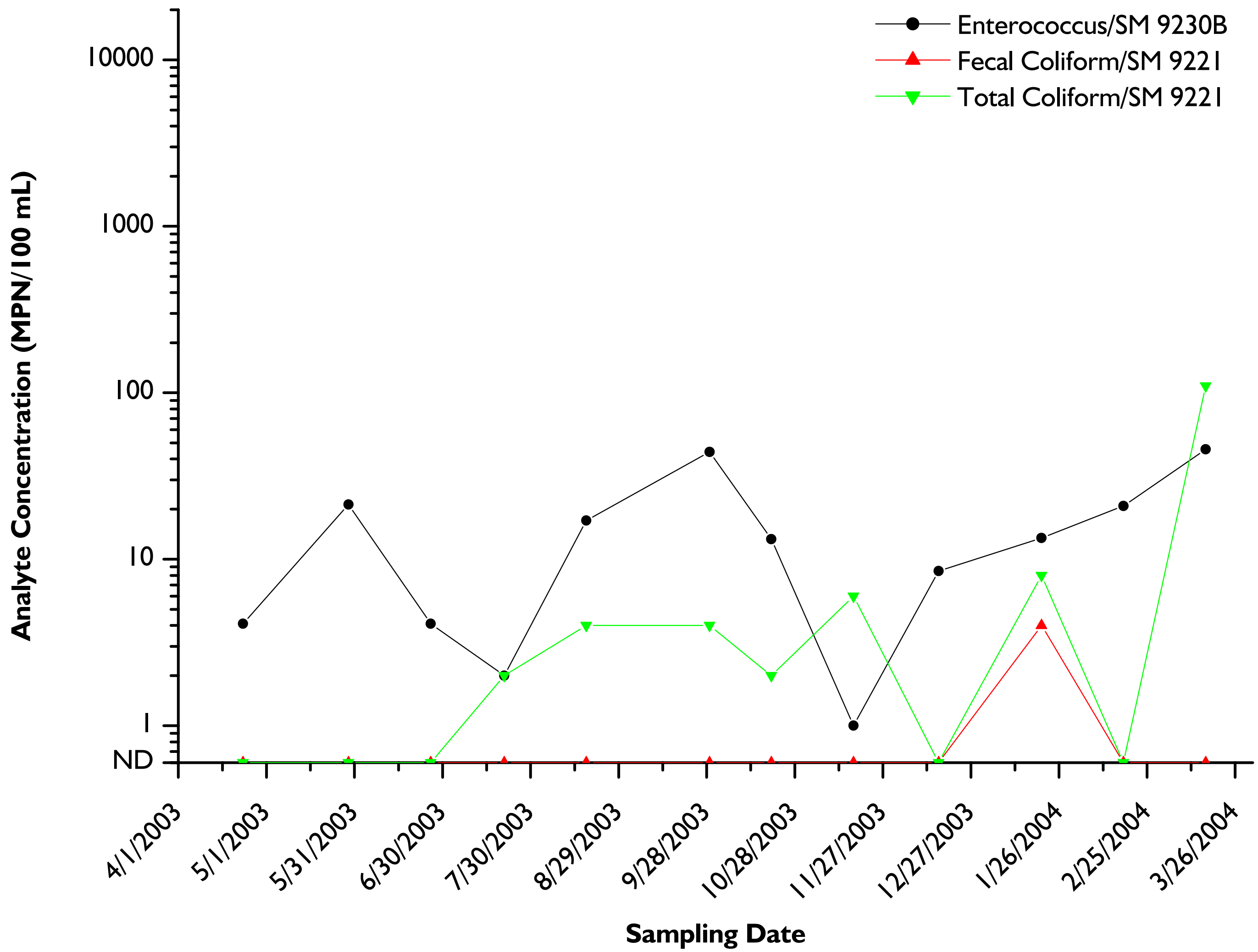

FIGURE 57: PATHOGEN COUNTS, WELL P-9
City of Malibu, CA

Source: Laboratory reports from Pat-Chem Laboratories, Inc., 2003 and 2004.
Path: o:\proj-01\1269-w-malibu\data\welldata\AnalyticalResults\Figures\AllAnalyticalFigures.opj
Date: 3-31-04 anm

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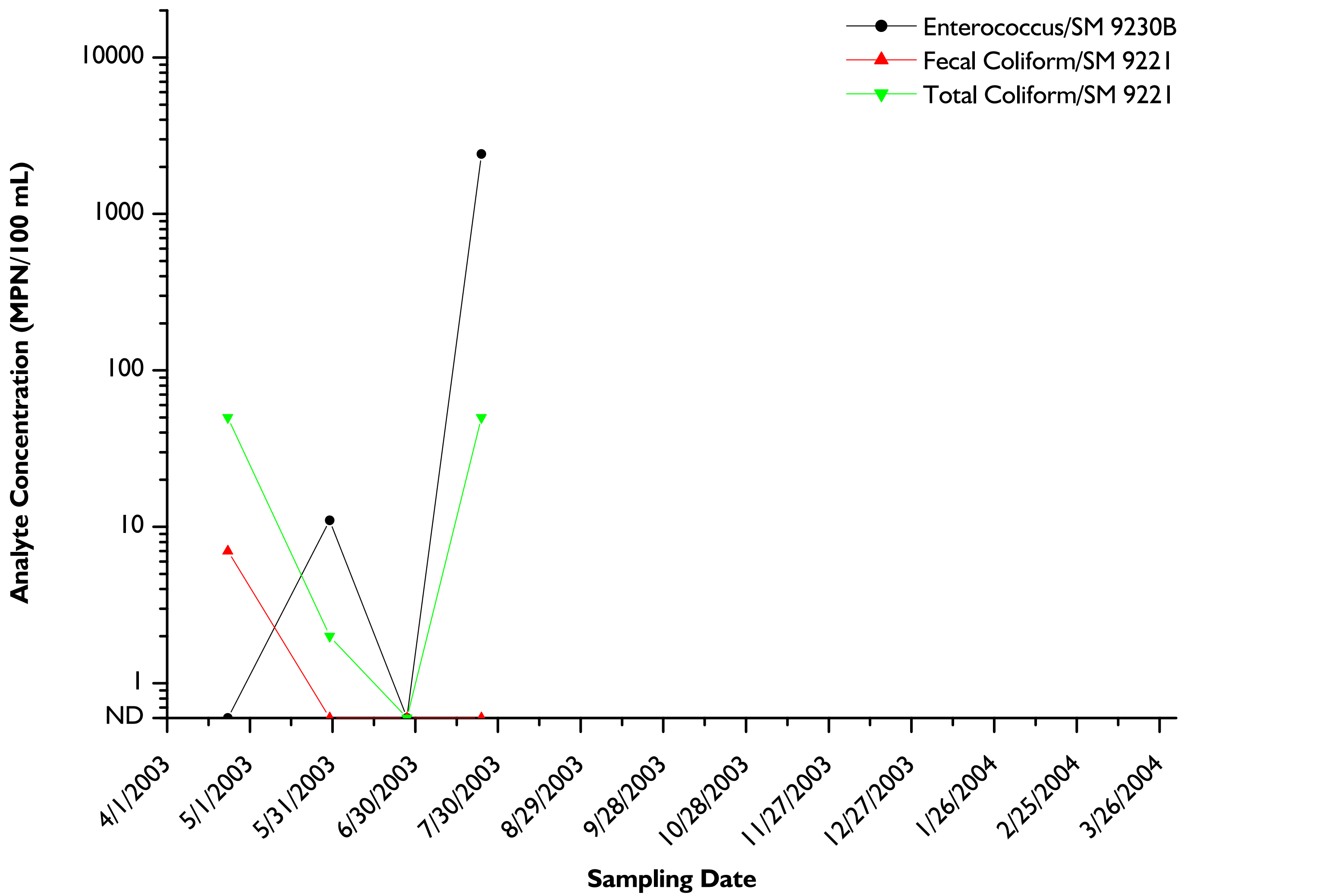

FIGURE 58: PATHOGEN COUNTS, WELL SMBRP-1
City of Malibu, CA

Source: Laboratory reports from Pat-Chem Laboratories, Inc., 2003 and 2004.
Path: o:\proj-01\1269-w-malibu\data\welldata\AnalyticalResults\Figures\AllAnalyticalFigures.opj
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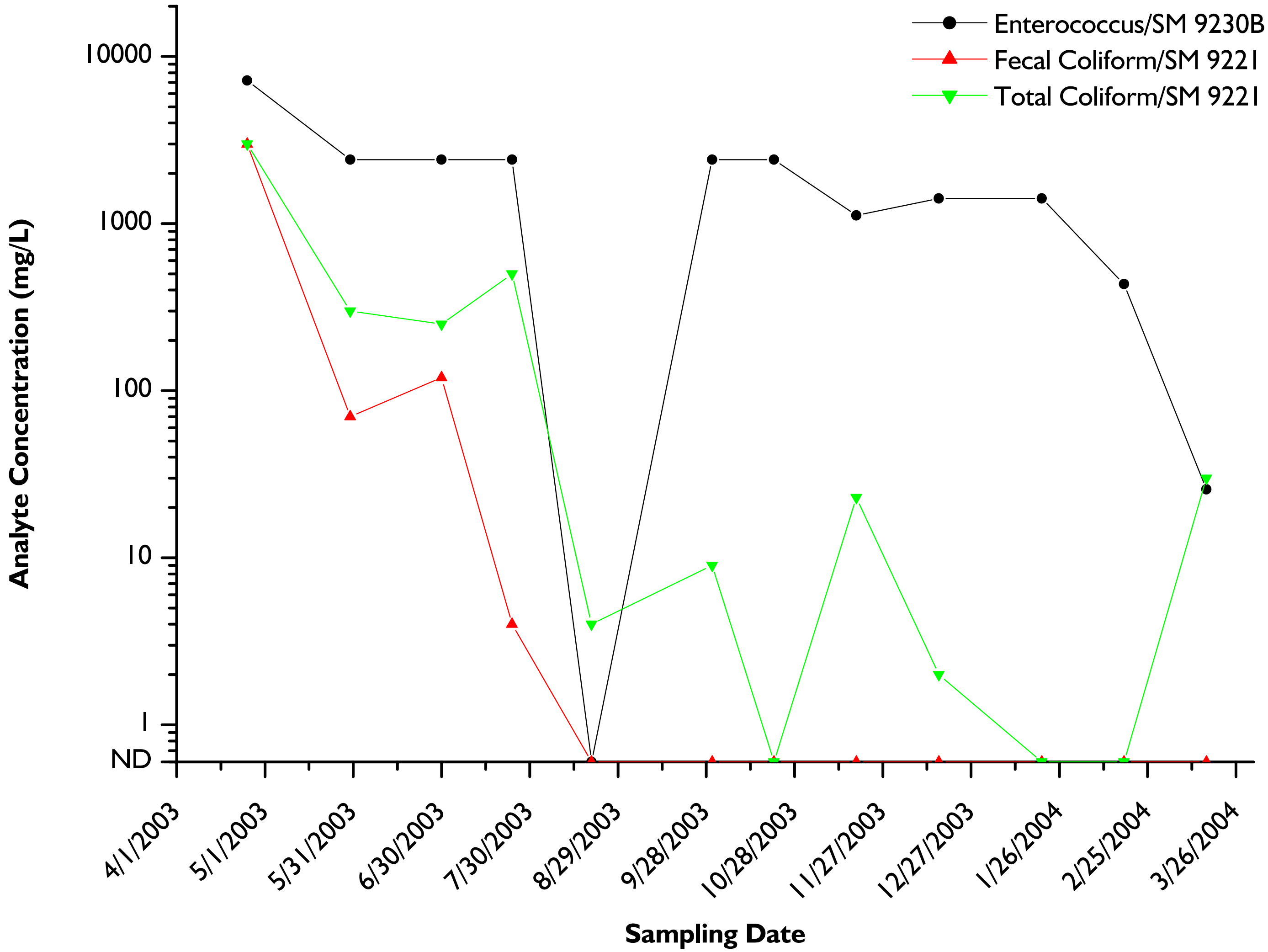

FIGURE 59: PATHOGEN COUNTS, WELL SMBRP-2
City of Malibu, CA

Source: Laboratory reports from Pat-Chem Laboratories, Inc., 2003 and 2004.
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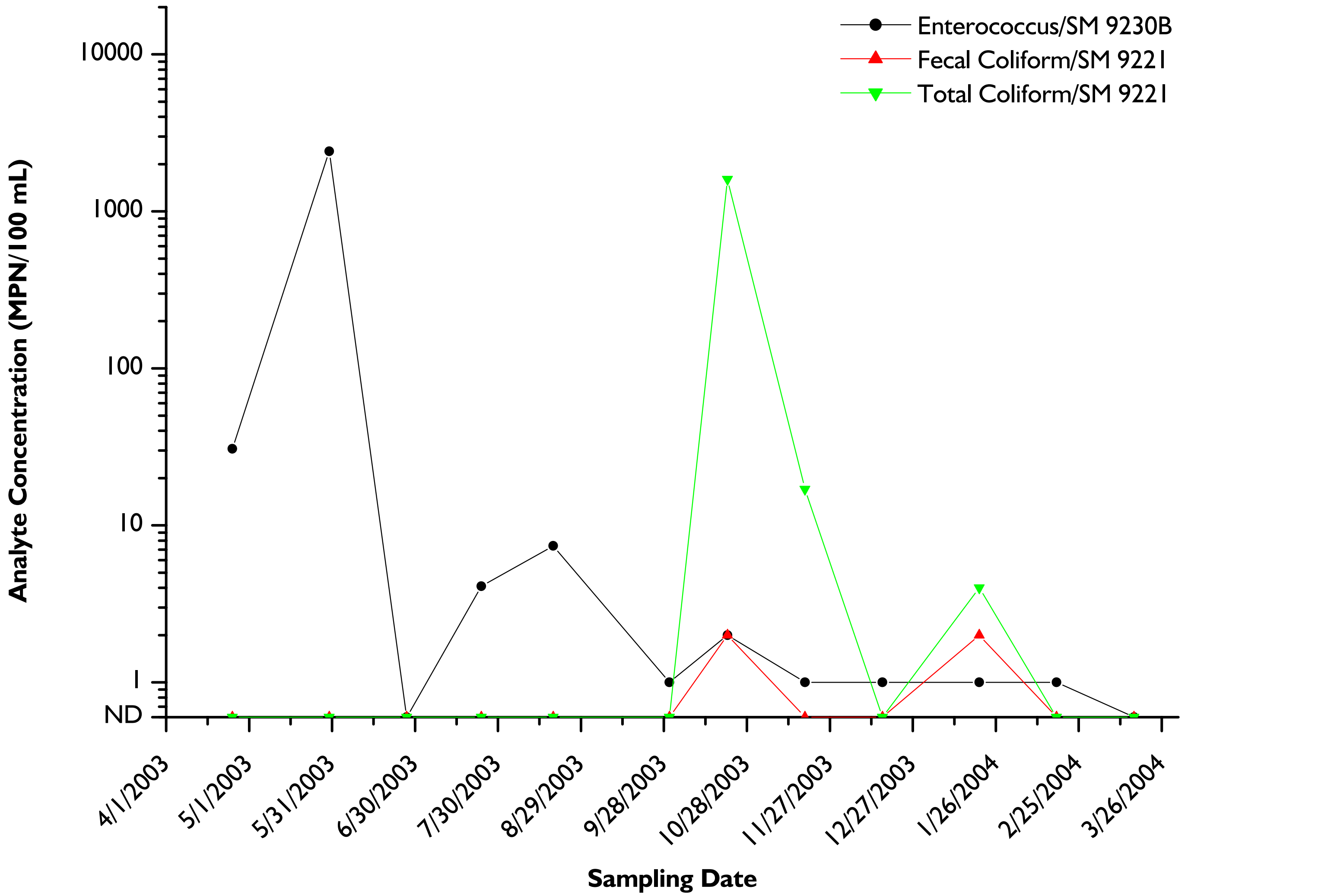

FIGURE 60: PATHOGEN COUNTS, WELL SMBRP-3c
City of Malibu, CA

Source: Laboratory reports from Pat-Chem Laboratories, Inc., 2003 and 2004.
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Date: 3-31-04 anm

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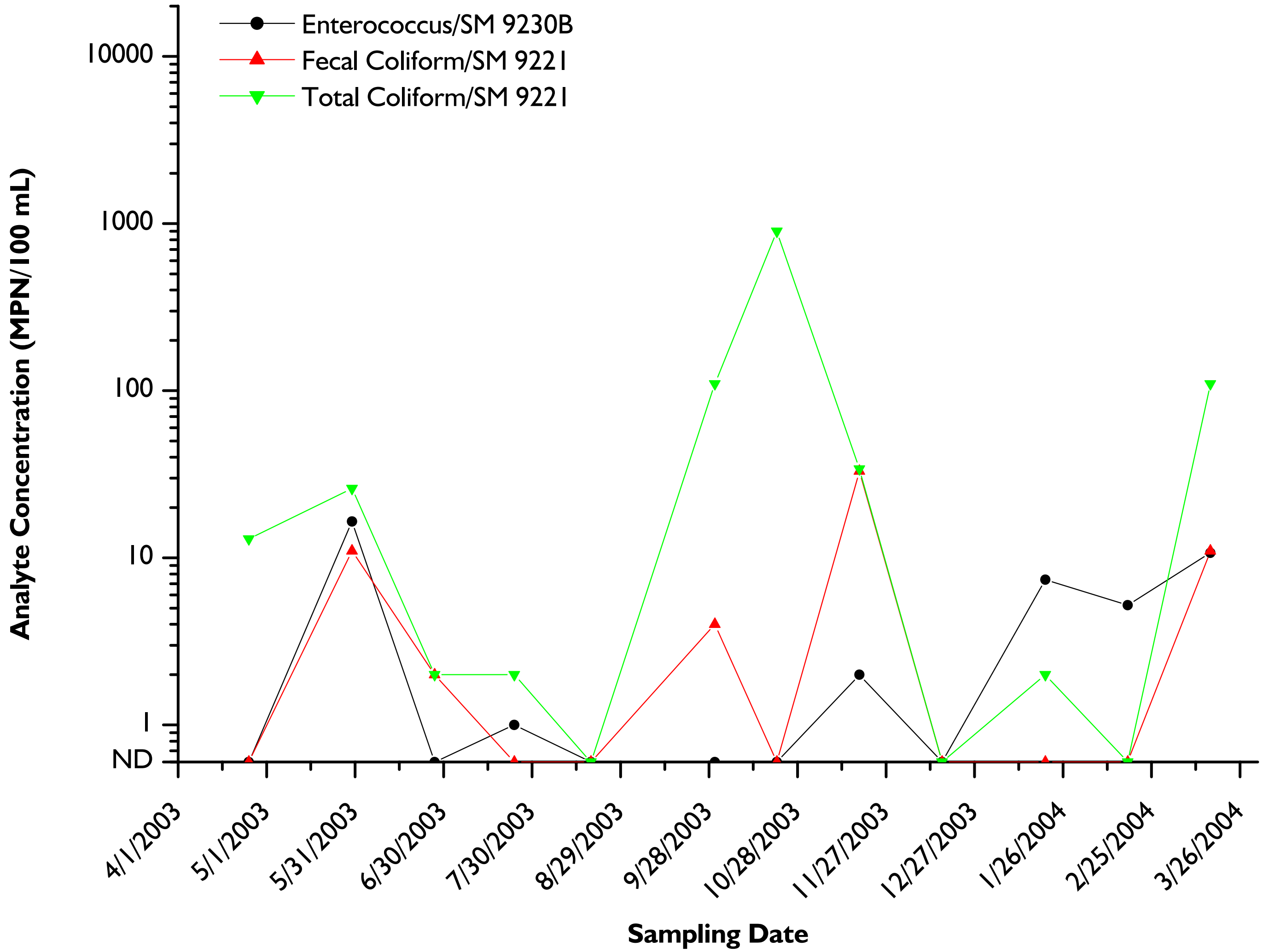

FIGURE 61: PATHOGEN COUNTS, WELL SMBRP-6

City of Malibu, CA

Source: Laboratory reports from Pat-Chem Laboratories, Inc., 2003 and 2004.

Path: o:\proj-01\1269-w-malibu\data\welldata\AnalyticalResults\Figures\AllAnalyticalFigures.opj

Date: 3-31-04 anm

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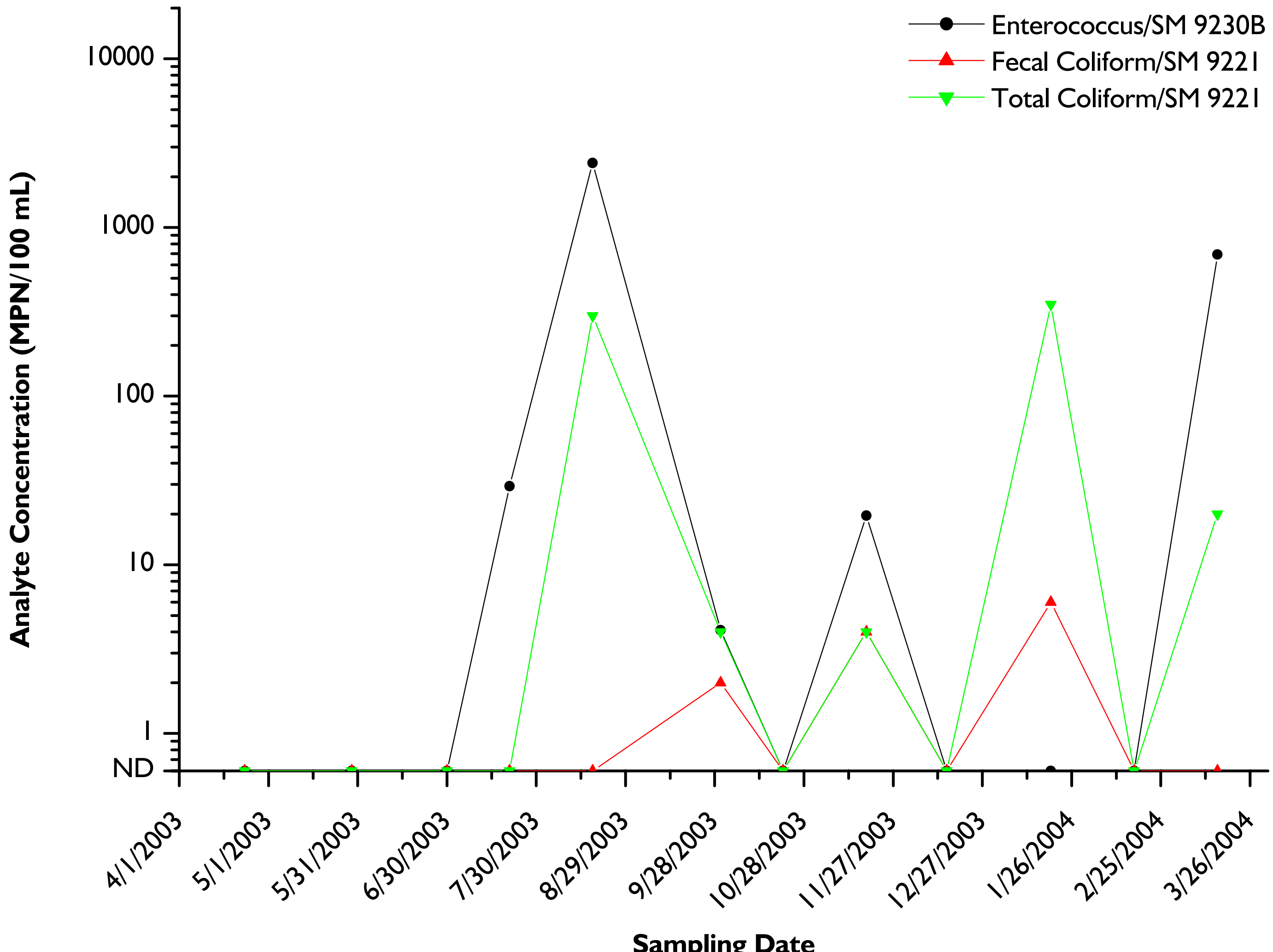

FIGURE 62: PATHOGEN COUNTS, WELL SMBRP-7b
City of Malibu, CA

Source: Laboratory reports from Pat-Chem Laboratories, Inc., 2003 and 2004.
Path: o:\proj-01\1269-w-malibu\data\welldata\AnalyticalResults\Figures\AllAnalyticalFigures.opj
Date: 3-31-04 anm

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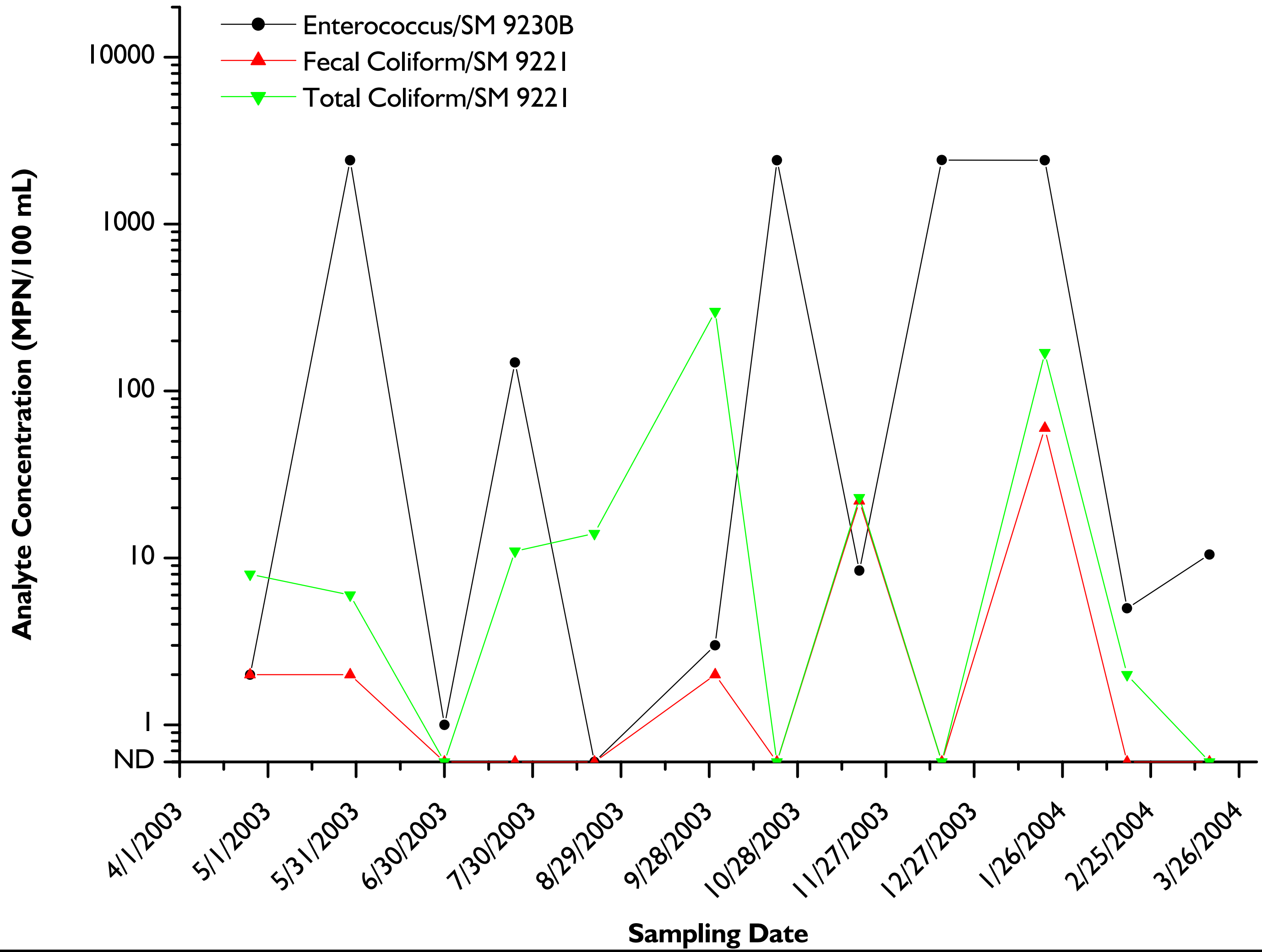

FIGURE 63: PATHOGEN COUNTS, WELL SMBRP-8
City of Malibu, CA

Source: Laboratory reports from Pat-Chem Laboratories, Inc., 2003 and 2004.
Path: o:\proj-01\1269-w-malibu\data\welldata\AnalyticalResults\Figures\AllAnalyticalFigures.opj
Date: 3-31-04 anm

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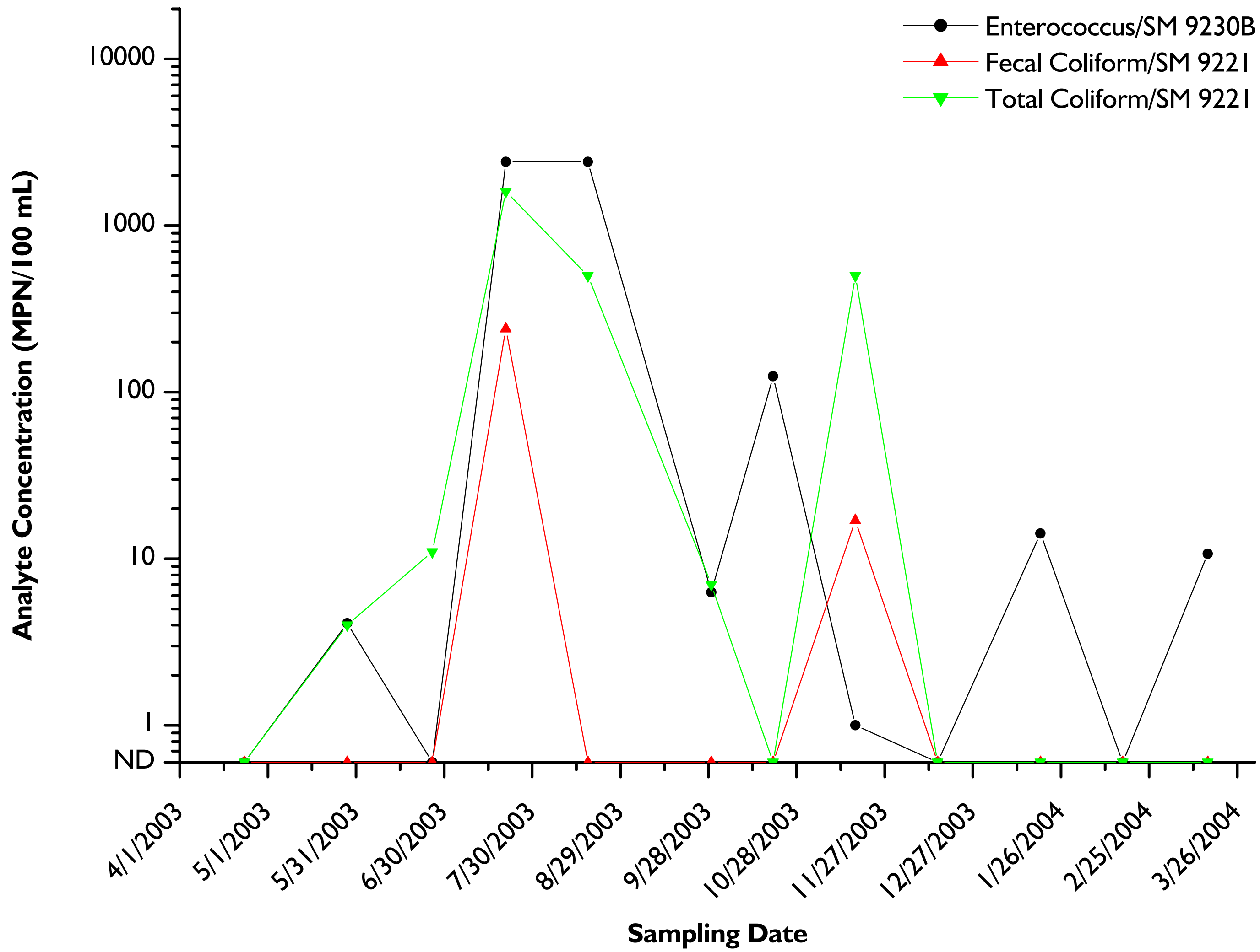

FIGURE 64: PATHOGEN COUNTS, WELL SMBRP-9
City of Malibu, CA

Source: Laboratory reports from Pat-Chem Laboratories, Inc., 2003 and 2004.
Path: o:\proj-01\1269-w-malibu\data\welldata\AnalyticalResults\Figures\AllAnalyticalFigures.opj
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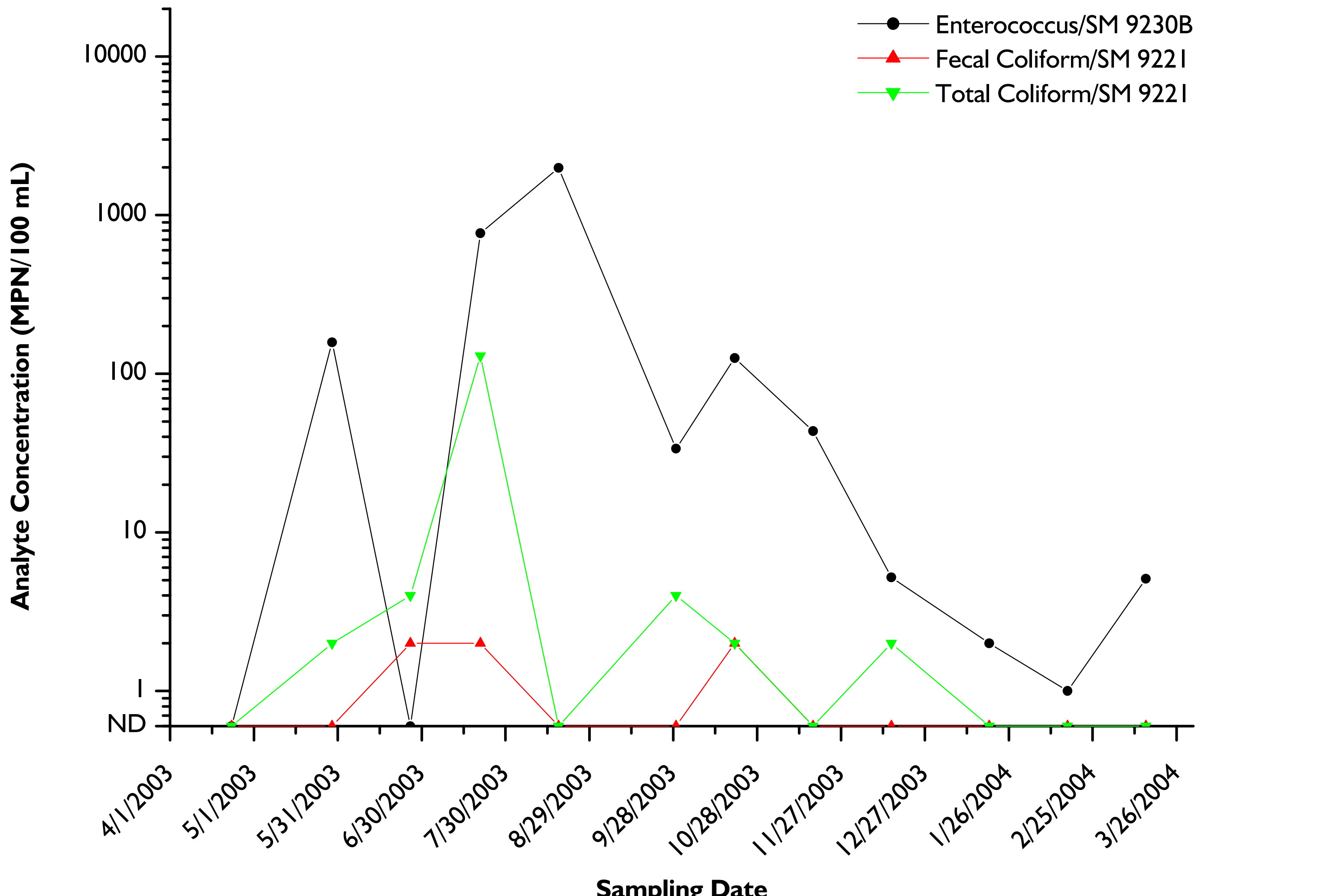

FIGURE 65: PATHOGEN COUNTS, WELL SMBRP-10c
City of Malibu, CA

Source: Laboratory reports from Pat-Chem Laboratories, Inc., 2003 and 2004.
Path: o:\proj-01\1269-w-malibu\data\welldata\AnalyticalResults\Figures\AllAnalyticalFigures.opj
Date: 3-31-04 anm

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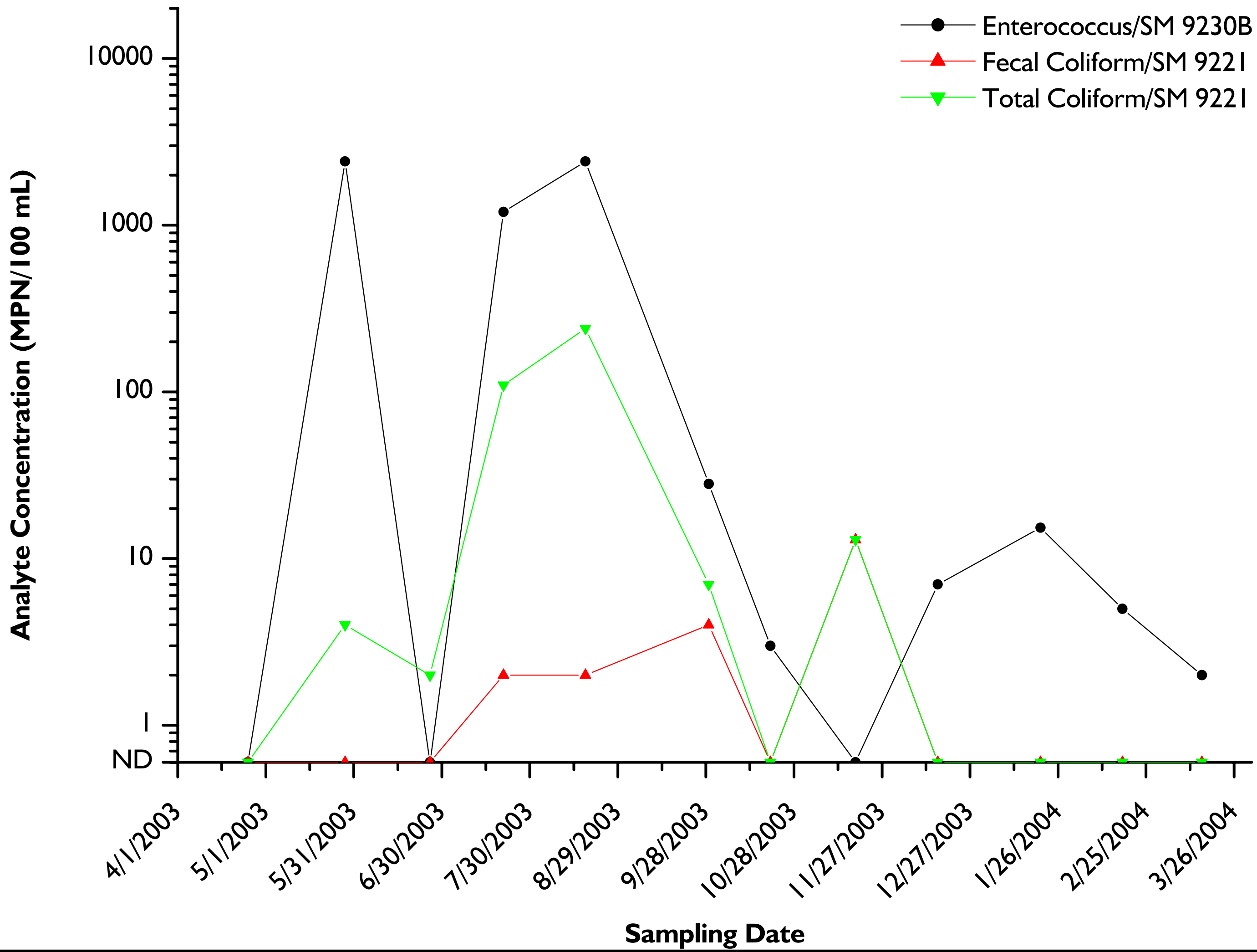

FIGURE 66: PATHOGEN COUNTS, WELL SMBRP-11
City of Malibu, CA

Source: Laboratory reports from Pat-Chem Laboratories, Inc., 2003 and 2004.
Path: o:\proj-01\1269-w-malibu\data\welldata\AnalyticalResults\Figures\AllAnalyticalFigures.opj
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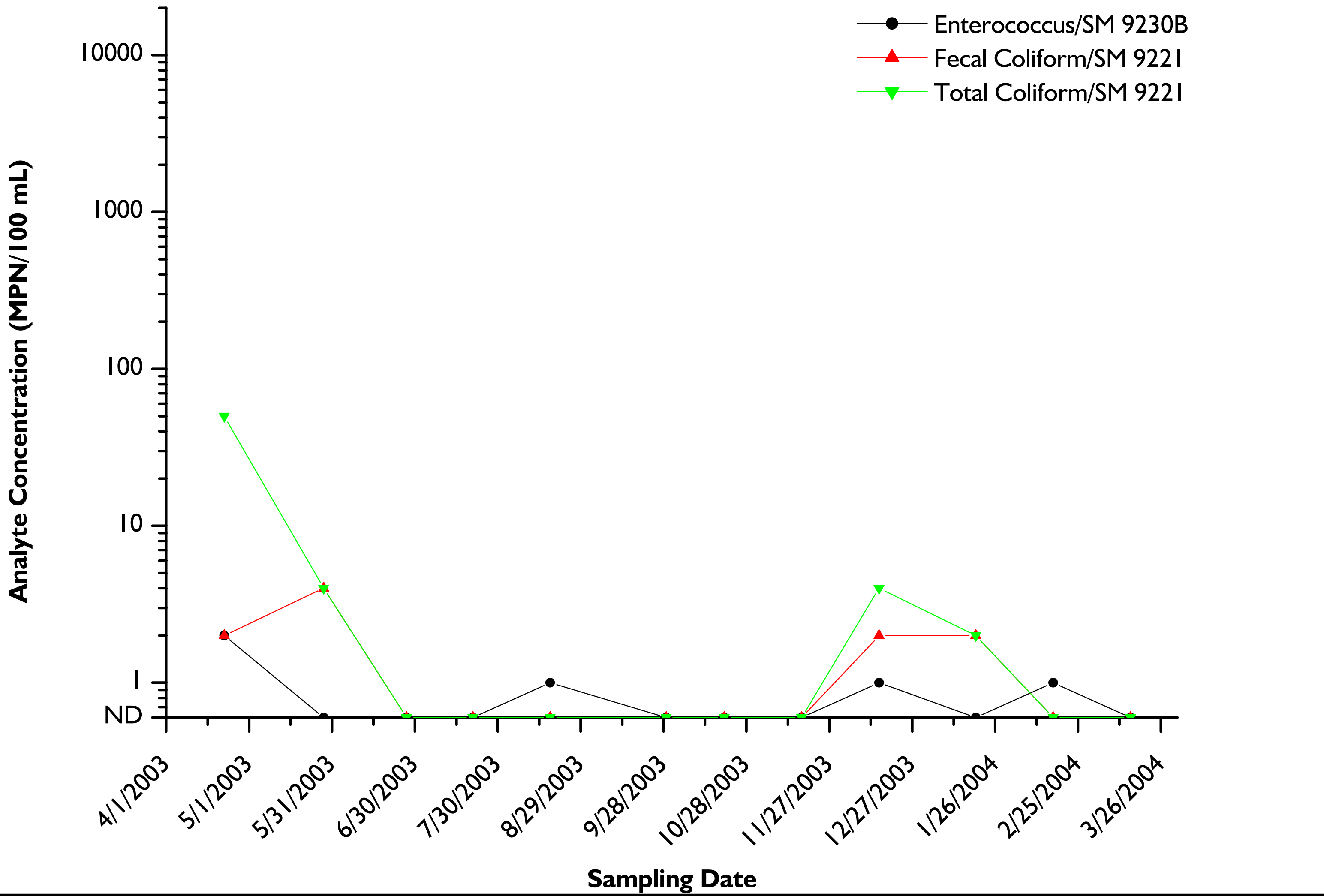

FIGURE 67: PATHOGEN COUNTS, WELL SMBRP-12
City of Malibu, CA

Source: Laboratory reports from Pat-Chem Laboratories, Inc., 2003 and 2004.
Path: o:\proj-01\1269-w-malibu\data\welldata\AnalyticalResults\Figures\AllAnalyticalFigures.opj
Date: 3-31-04 anm

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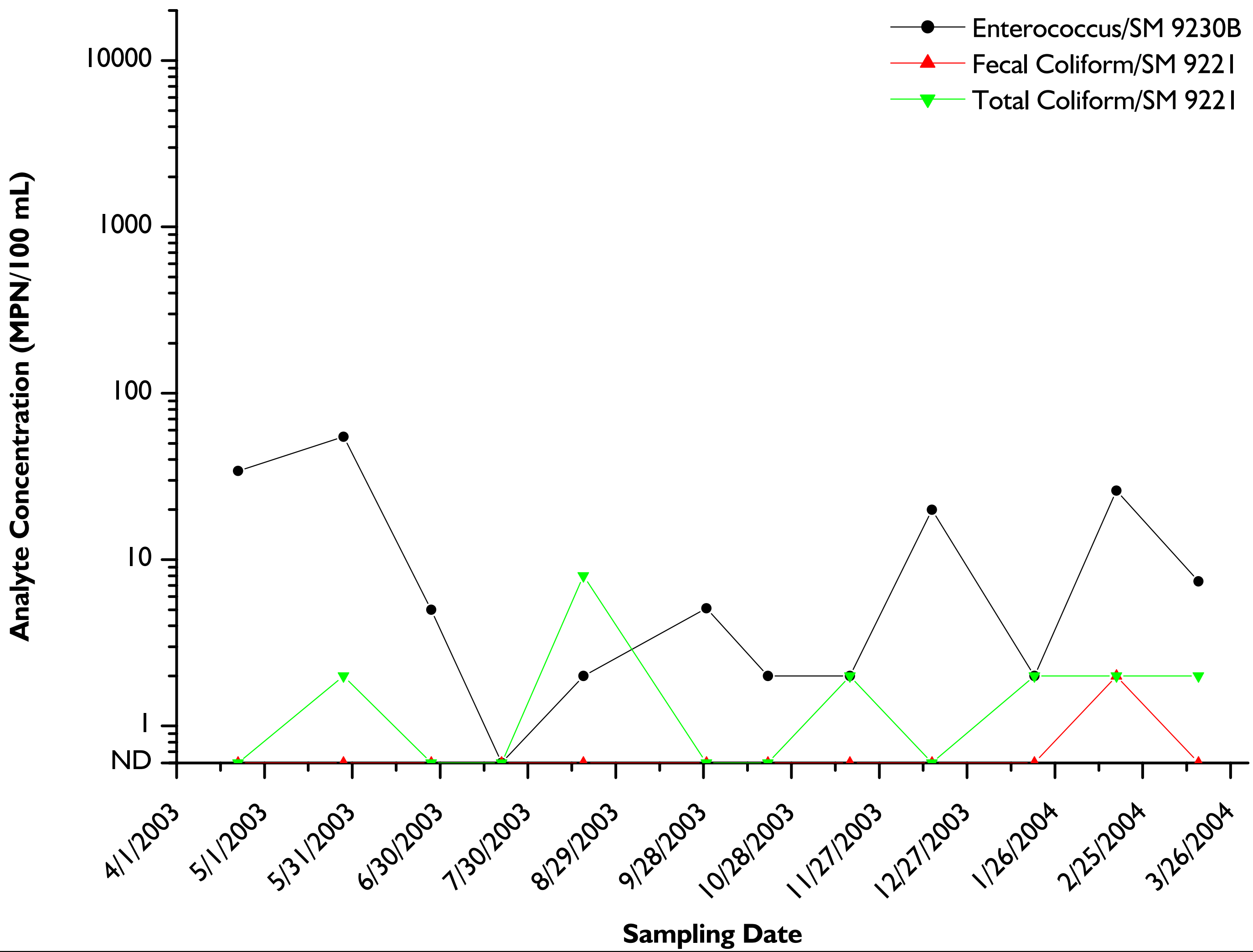

FIGURE 68: PATHOGEN COUNTS, WELL SMBRP-13
City of Malibu, CA

Source: Laboratory reports from Pat-Chem Laboratories, Inc., 2003 and 2004.
Path: o:\proj-01\1269-w-malibu\data\welldata\AnalyticalResults\Figures\AllAnalyticalFigures.opj
Date: 3-31-04 anm

STONE ENVIRONMENTAL INC

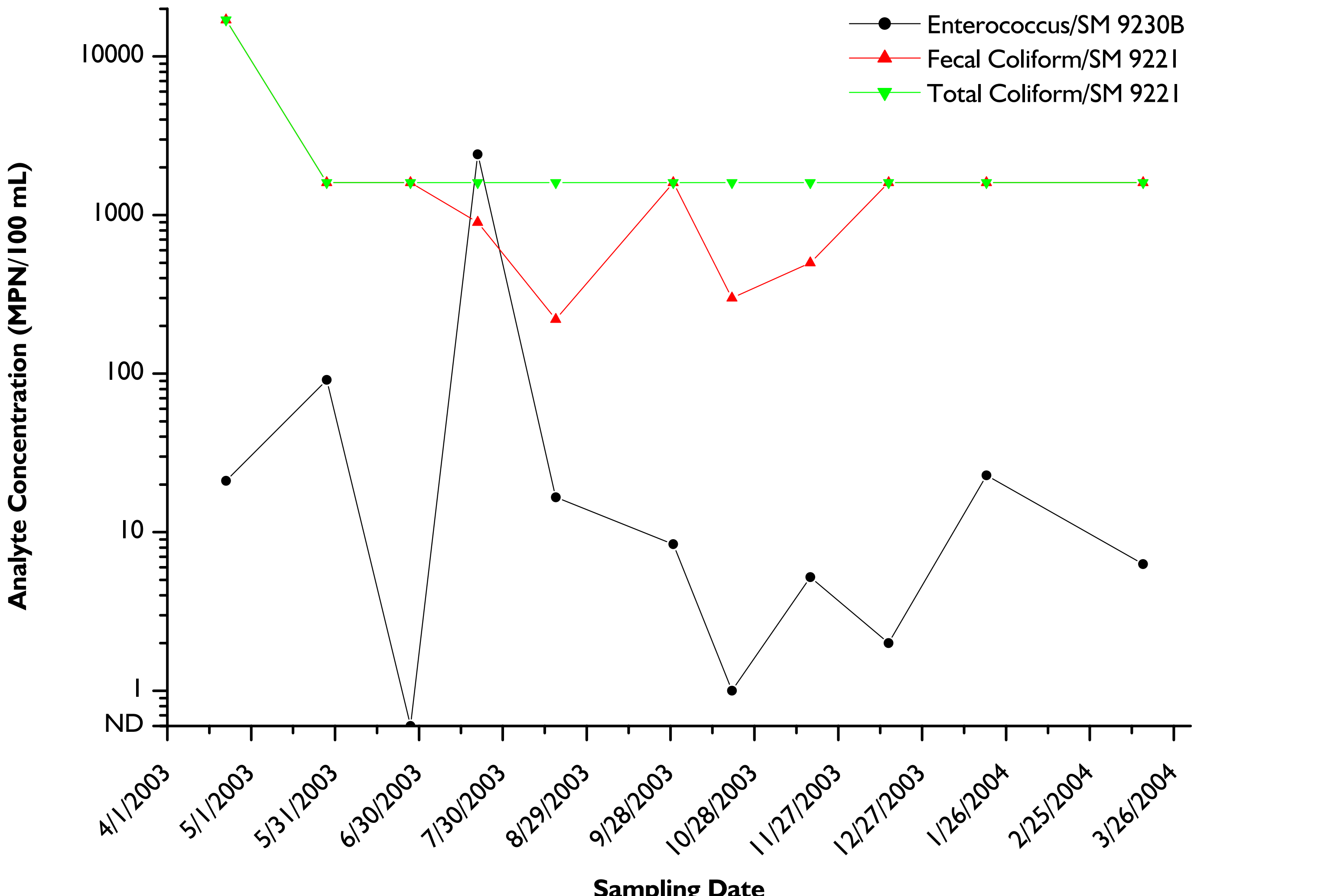

FIGURE 69: PATHOGEN COUNTS, WELL SMBRP-14
City of Malibu, CA

Source: Laboratory reports from Pat-Chem Laboratories, Inc., 2003 and 2004.
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Date: 3-31-04 anm

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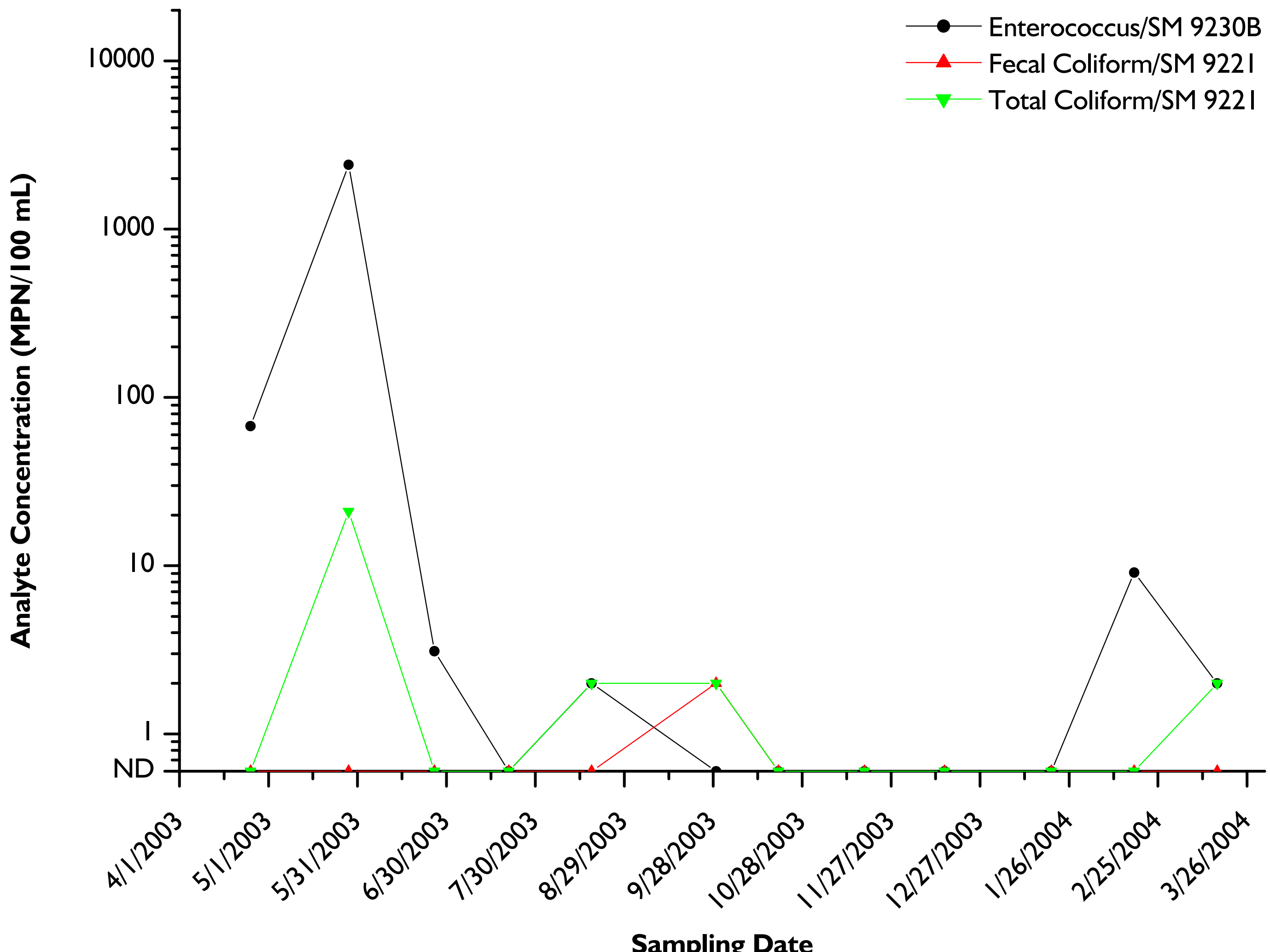

FIGURE 70: PATHOGEN COUNTS, WELL SMBRP-15b
City of Malibu, CA

Source: Laboratory reports from Pat-Chem Laboratories, Inc., 2003 and 2004.
Path: o:\proj-01\1269-w-malibu\data\welldata\AnalyticalResults\Figures\AllAnalyticalFigures.opj
Date: 3-31-04 anm

STONE ENVIRONMENTAL INC

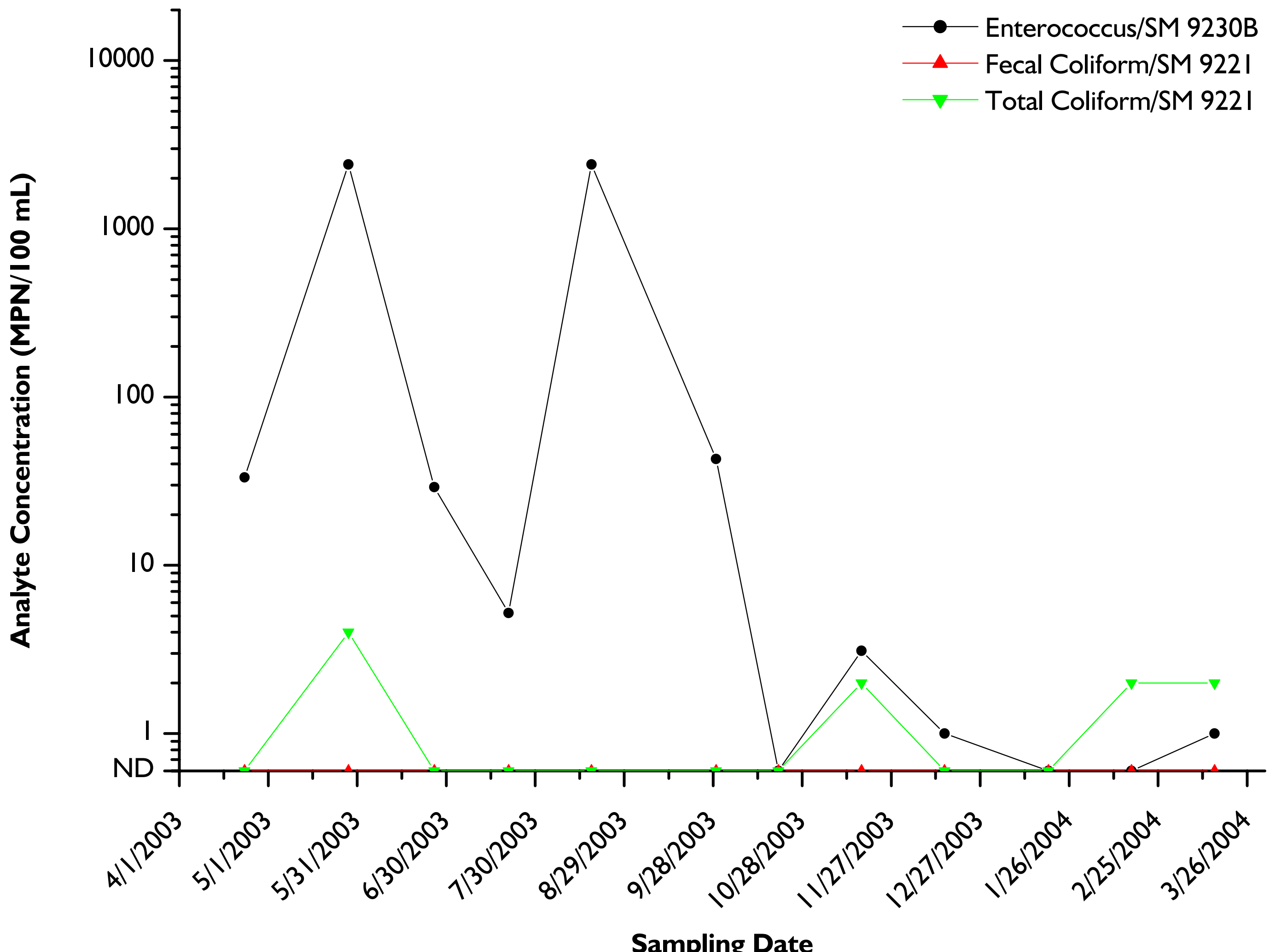

FIGURE 71: PATHOGEN COUNTS, WELL SMBRP-16
City of Malibu, CA

Source: Laboratory reports from Pat-Chem Laboratories, Inc., 2003 and 2004.
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Date: 3-31-04 anm

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MAP 1: STUDY AREA

Risk Assessment of Decentralized Wastewater Treatment Systems in High Priority Areas

City of Malibu, California

0 2.5 5 10 15 Miles

Source: Roads & Political Boundaries, TIGER FILES, U.S. Bureau of the Census;
Streams, Digitized by SEI from Aerial Imagery, AirPhoto USA, November 2000;
Study Area Boundary, SEI.

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MAP 2: STUDY AREA BASE MAP WITH 1-METER SATELLITE IMAGERY AND PARCEL BOUNDARIES

Risk Assessment of Decentralized Wastewater Treatment Systems in High Priority Areas
in the City of Malibu, California

0 0.25 0.5
Miles

Source: Satellite Imagery Data, AirPhoto USA, November 2000;
Parcel Boundaries, City of Malibu, CA; Study Area Boundary, SEI.

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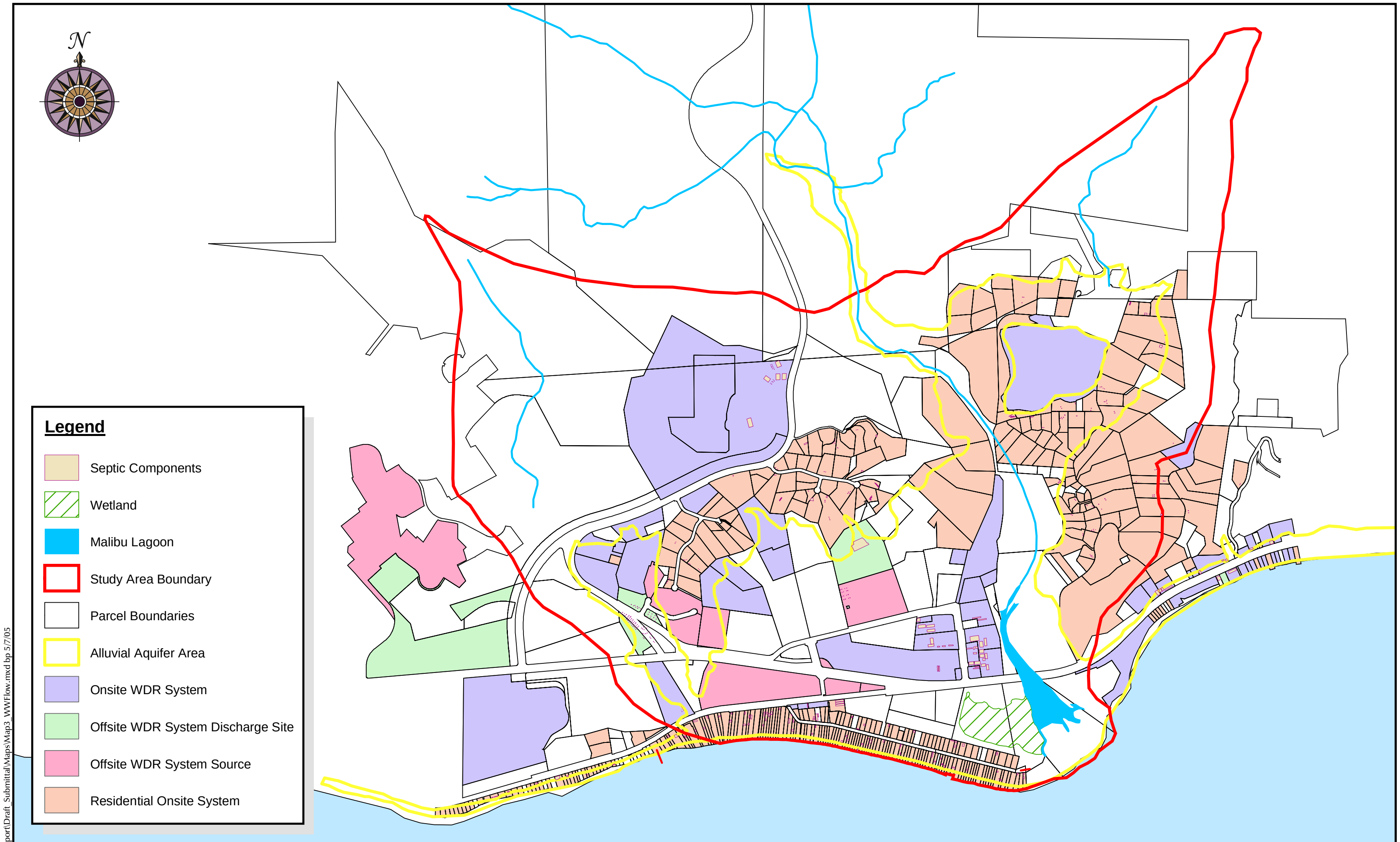

MAP 3: WASTEWATER FLOW-SOURCES AND DISCHARGE LOCATIONS

Risk Assessment of Decentralized Wastewater Treatment Systems in High Priority Areas

City of Malibu, California

0 0.25 0.5 Miles

Source: Parcels Boundaries, LA County; Study Area Boundary, SEI; Borings from City of Malibu files;
Well locations from various Geological studies in Malibu, CA (Complete list of references available from SEI)

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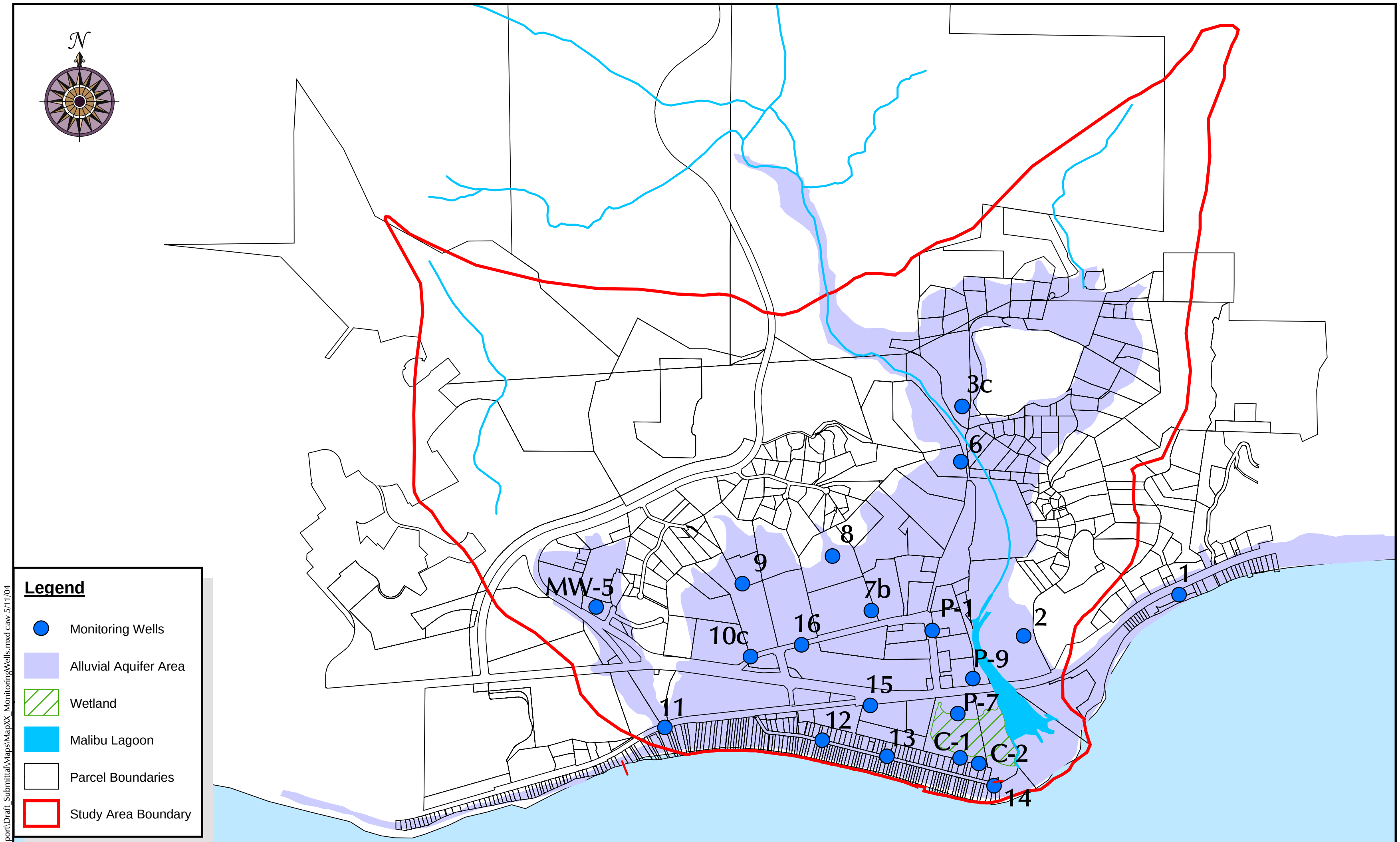

MAP 4: MONITORING WELL LOCATIONS FOR SAMPLING PROGRAM
Risk Assessment of Decentralized Wastewater Treatment Systems in High Priority Areas
City of Malibu, California

Source: Parcels Boundaries, LA County; Study Area Boundary, SEI; Borings from City of Malibu files;
Well locations from various Geological studies in Malibu, CA (Complete list of references available from SEI)

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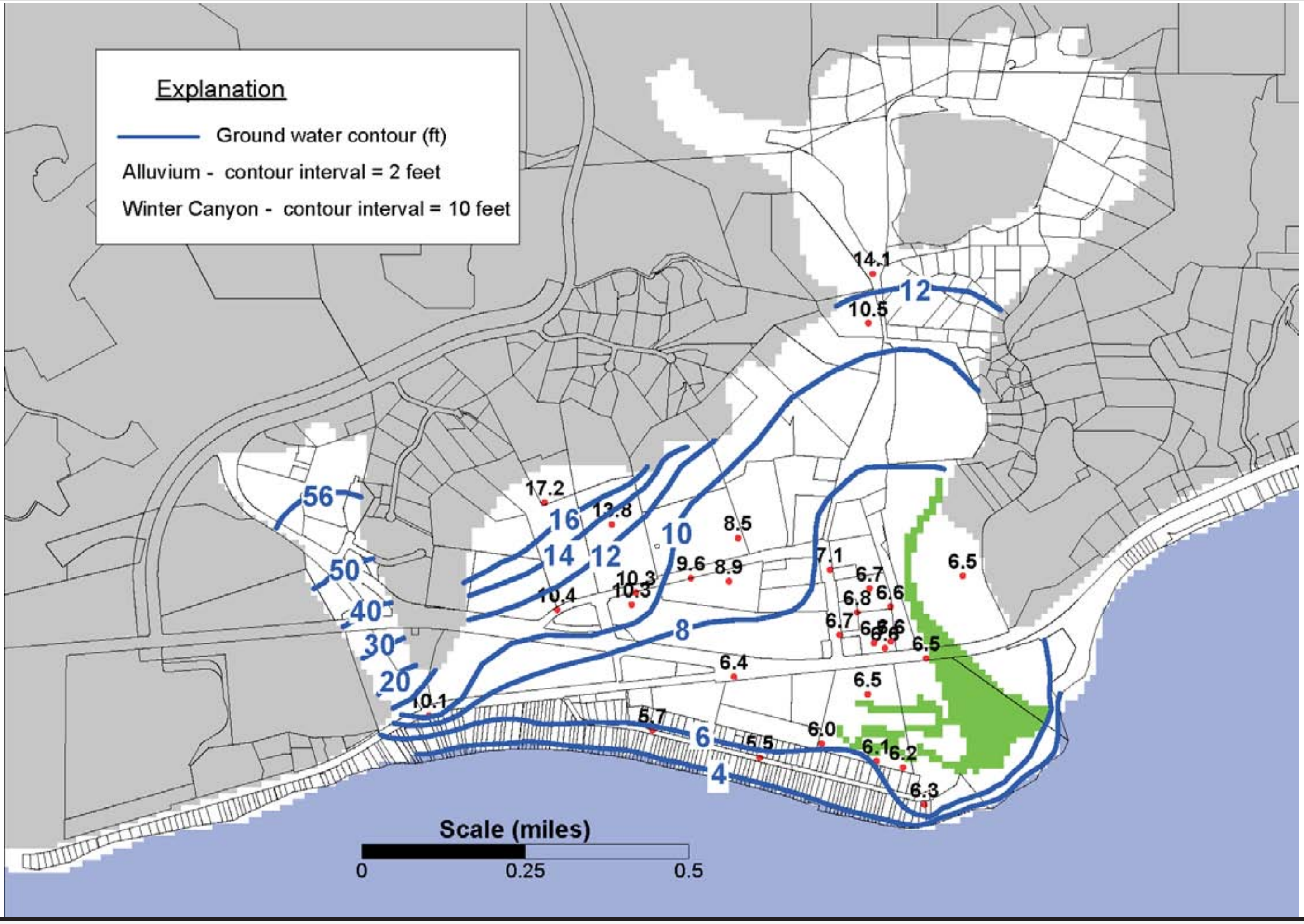
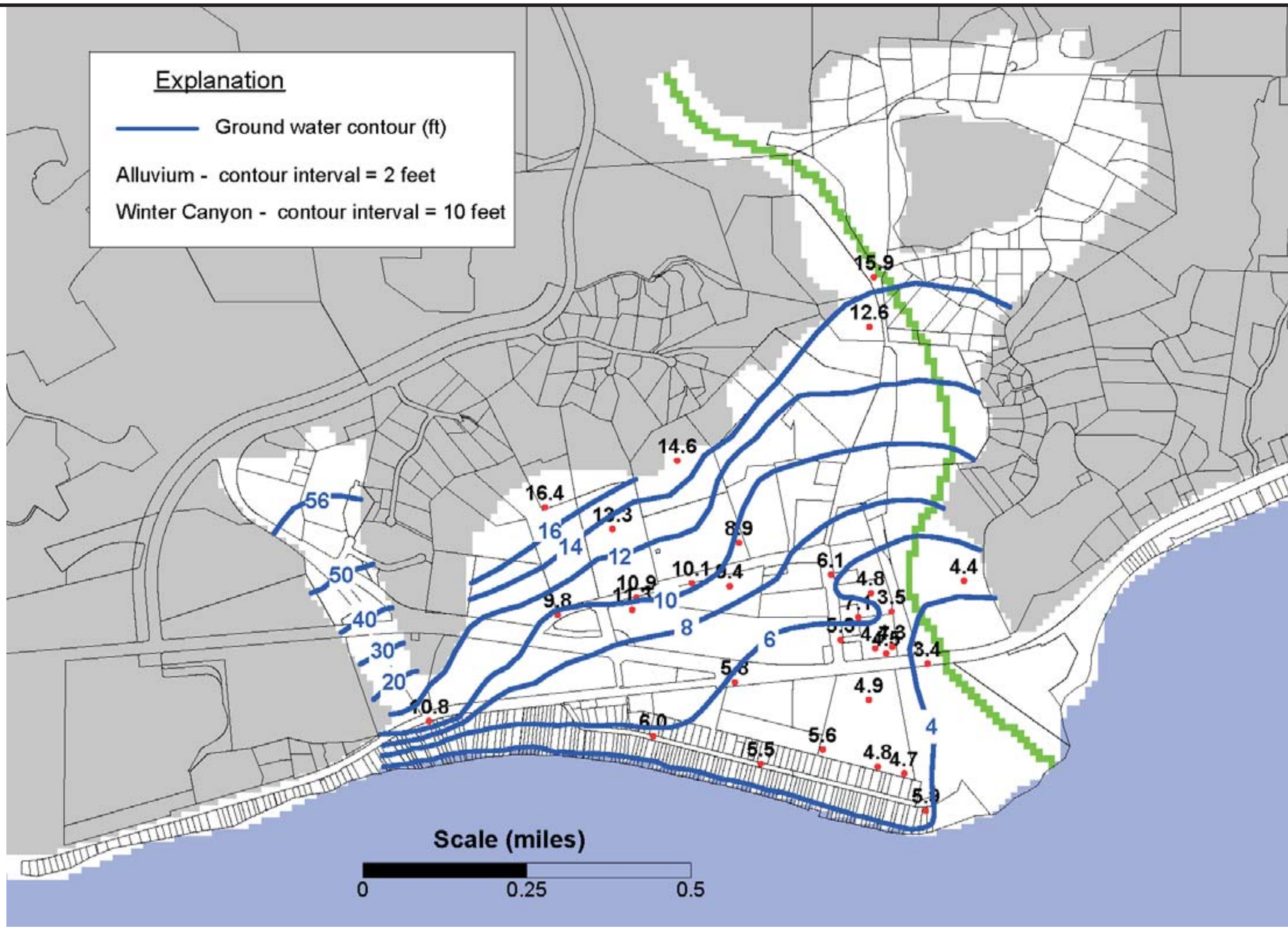


MAP 5: WATER LEVELS MEASURED ON SEPTEMBER 25, 2003--UNBREACHED LAGOON
Risk Assessment of Decentralized Wastewater Treatment Systems in High Priority Areas
City of Malibu, California

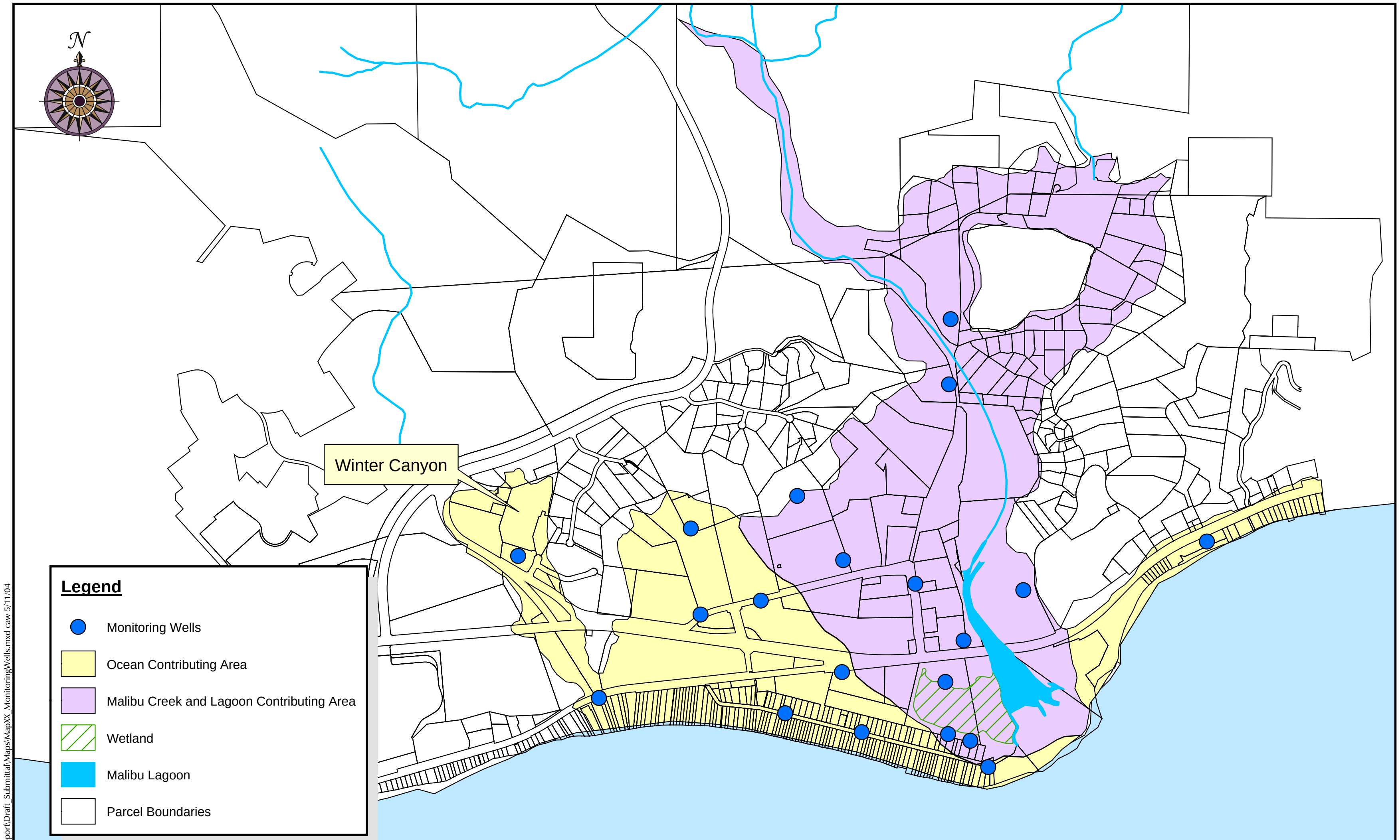
Source: Draft Model Report Figure 9, McDonald-Morrissey Associates Inc., 2004.
Path: O:\Proj-01\1269-W-Malibu\Reports\DraftSubmittal\Maps\Map4.cdr
Date/init: 5-14-04 anm



MAP 6: WATER LEVELS MEASURED ON MARCH 9, 2004--BREACHED LAGOON
Risk Assessment of Decentralized Wastewater Treatment Systems in High Priority Areas
City of Malibu, California

Source: Draft Model Report Figure 9, McDonald-Morrissey Associates Inc., 2004.
Path: O:\Proj-01\1269-W-Malibu\Reports\DraftSubmittal\Maps\Map4.cdr
Date/init: 5-14-04 anm

STONE ENVIRONMENTAL INC



MAP 7: CONTRIBUTING AREAS
Risk Assessment of Decentralized Wastewater Treatment Systems in High Priority Areas
City of Malibu, California

Source: Parcels Boundaries, LA County; Study Area Boundary, SEI; Borings from City of Malibu files;
Well locations from various Geological studies in Malibu, CA (Complete list of references available from SEI)

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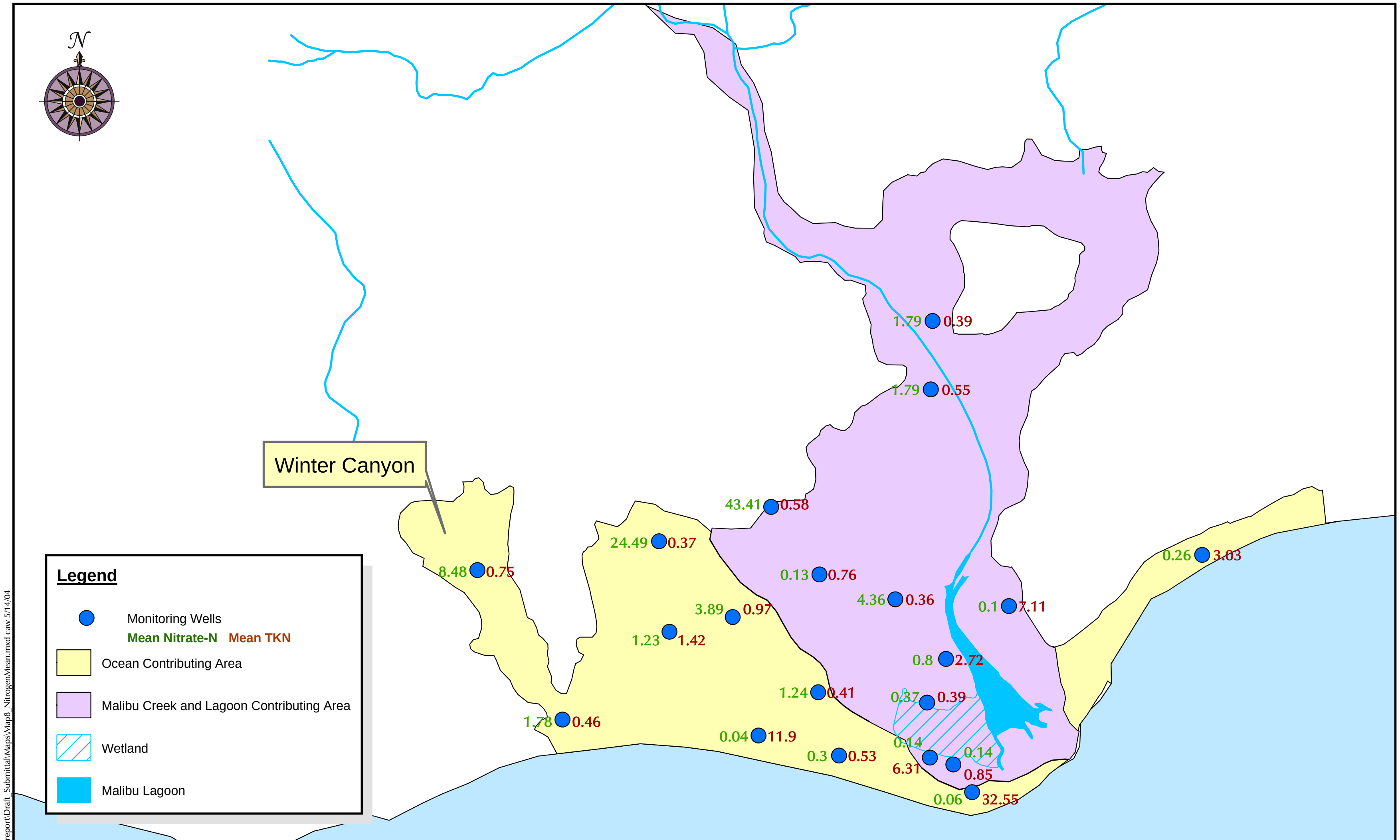

MAP 8: NITROGEN WATER QUALITY HIGHLIGHTS

Risk Assessment of Decentralized Wastewater Treatment Systems in High Priority Areas
City of Malibu, California

0 0.25 0.5
Miles

Source: Parcels Boundaries, LA County; Study Area Boundary, SEI; Borings from City of Malibu files;
Well locations from various Geological studies in Malibu, CA (Complete list of references available from SEI)

Stone Environmental Inc

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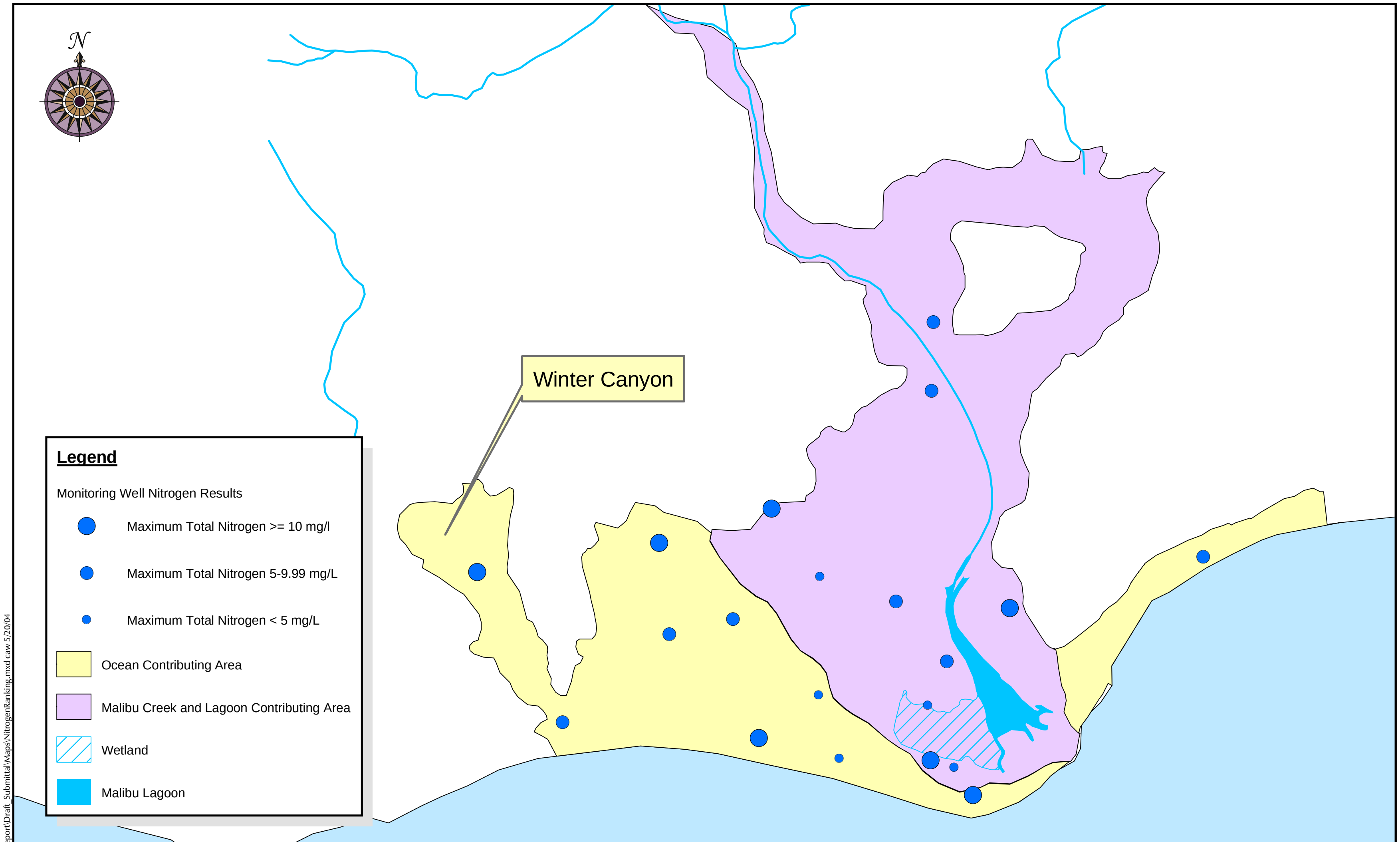

MAP 9: RANKING OF WATER QUALITY SAMPLING RESULTS FOR TOTAL NITROGEN

Risk Assessment of Decentralized Wastewater Treatment Systems in High Priority Areas

City of Malibu, California

0 0.25 0.5 Miles

Source: Parcels Boundaries, LA County; Study Area Boundary, SEI; Borings from City of Malibu files;
Well locations from various Geological studies in Malibu, CA (Complete list of references available from SEI)

STONE ENVIRONMENTAL INC

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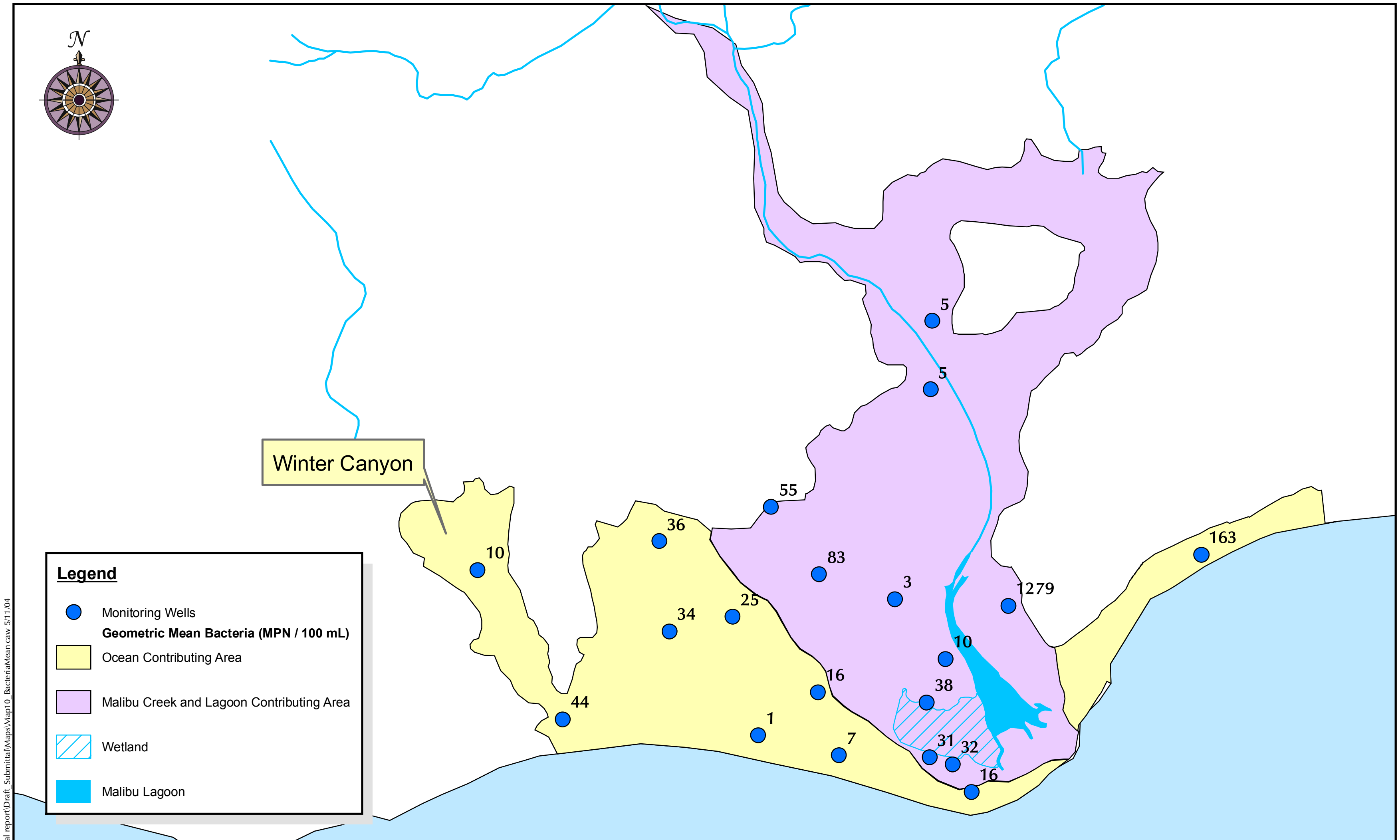
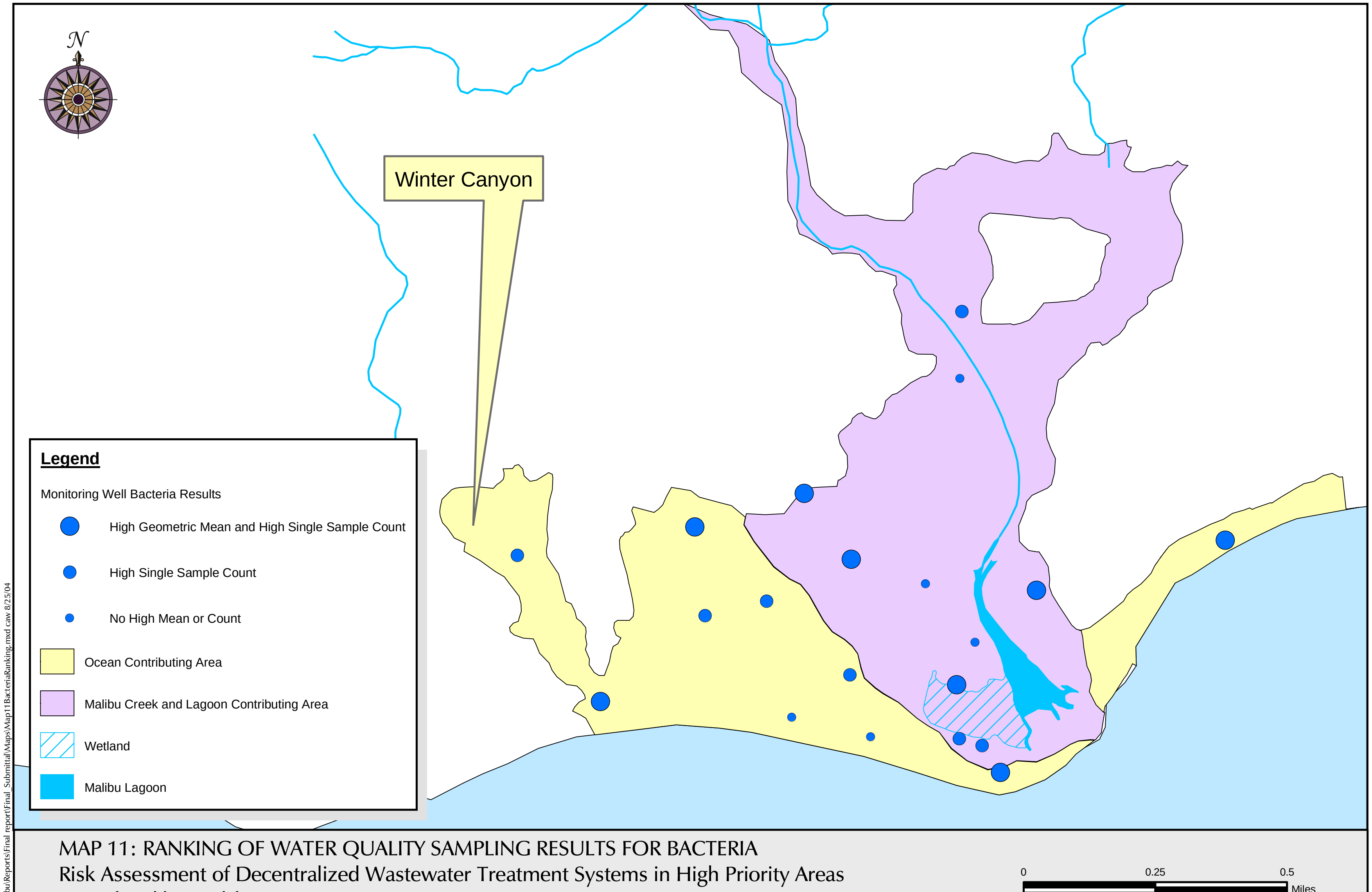


MAP 10 : BACTERIA WATER QUALITY HIGHLIGHTS - ENTEROCOCCUS
Risk Assessment of Decentralized Wastewater Treatment Systems in High Priority Areas
City of Malibu, California

0 0.25 0.5
Miles

Source: Parcels Boundaries, LA County; Study Area Boundary, SEI; Borings from City of Malibu files;
Well locations from various Geological studies in Malibu, CA (Complete list of references available from SEI)

STONE ENVIRONMENTAL INC



MAP 11: RANKING OF WATER QUALITY SAMPLING RESULTS FOR BACTERIA
Risk Assessment of Decentralized Wastewater Treatment Systems in High Priority Areas
City of Malibu, California

Source: Parcels Boundaries, LA County; Study Area Boundary, SEI; Borings from City of Malibu files;
Well locations from various Geological studies in Malibu, CA (Complete list of references available from SEI)

STONE ENVIRONMENTAL INC

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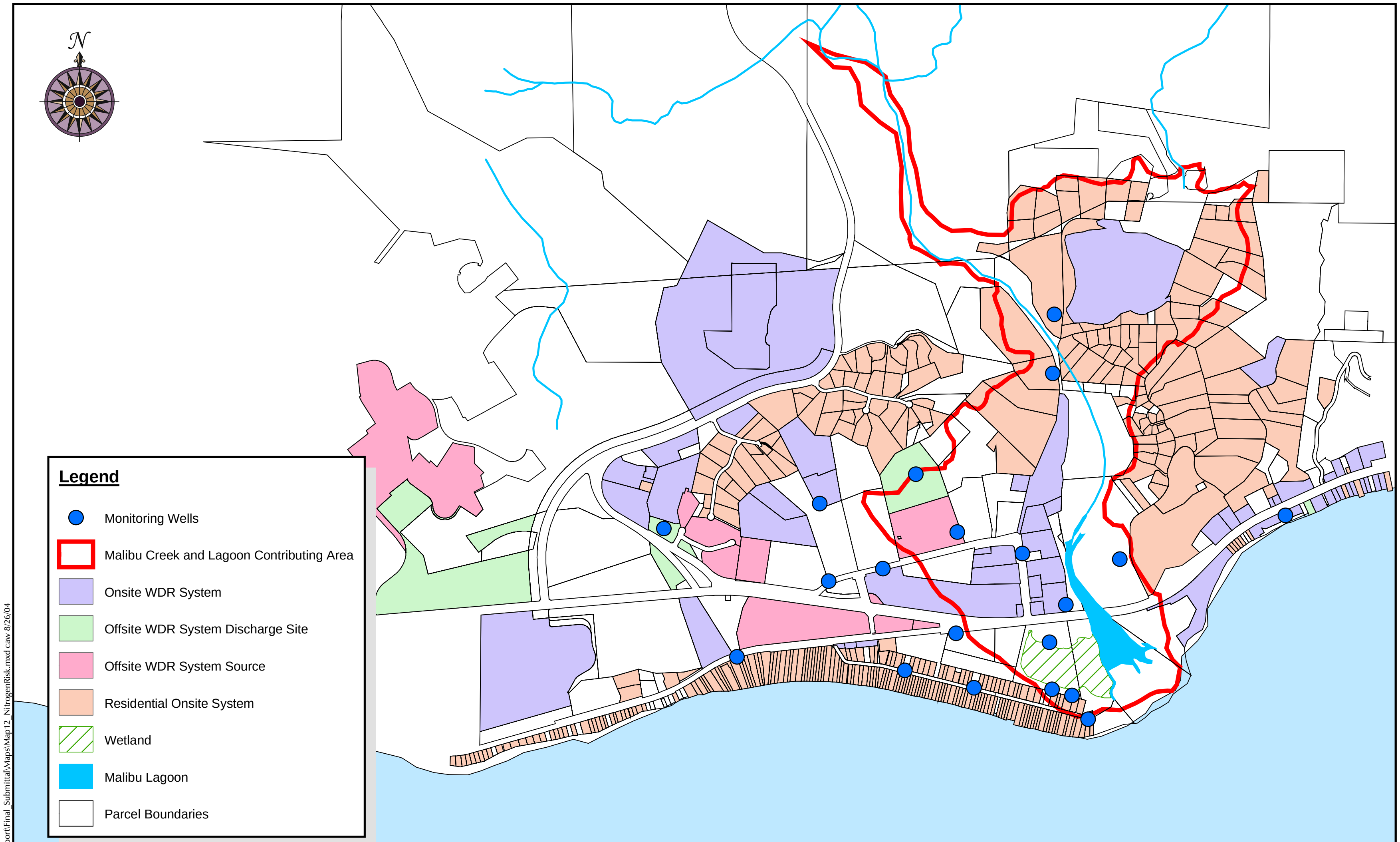

MAP 12: NITROGEN RISK ASSESSMENT - MALIBU CREEK AND LAGOON CONTRIBUTING AREA

Risk Assessment of Decentralized Wastewater Treatment Systems in High Priority Areas

City of Malibu, California

0 0.25 0.5 Miles

Source: Parcels Boundaries, LA County; Study Area Boundary, SEI; Borings from City of Malibu files;
Well locations from various Geological studies in Malibu, CA (Complete list of references available from SEI)

STONE ENVIRONMENTAL INC

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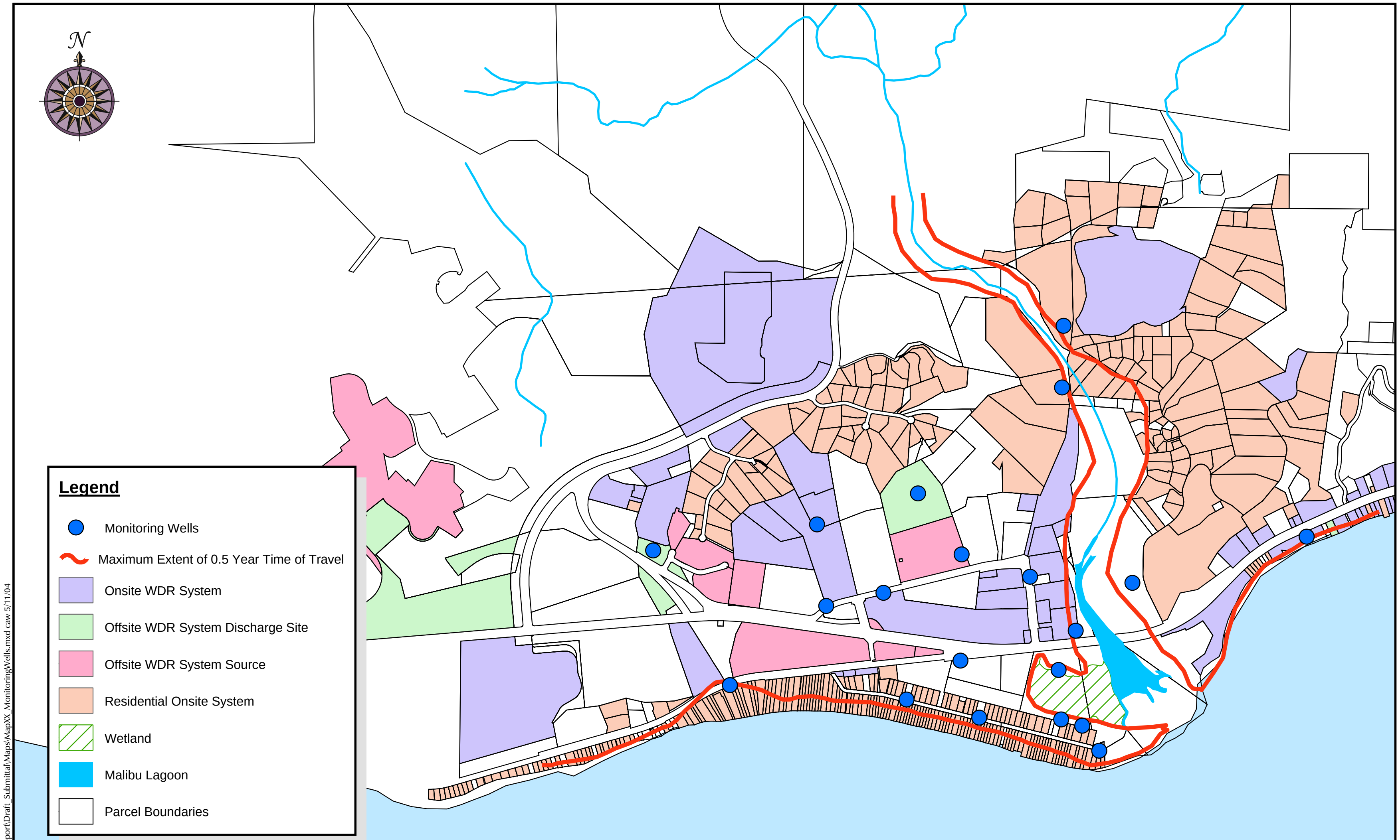

MAP 13: BACTERIA RISK ASSESSMENT - 0 TO 0.5 YEAR TIME OF TRAVEL BOUNDARY

Risk Assessment of Decentralized Wastewater Treatment Systems in High Priority Areas

City of Malibu, California

0 0.25 0.5 Miles

Source: Parcels Boundaries, LA County; Study Area Boundary, SEI; Borings from City of Malibu files;
Well locations from various Geological studies in Malibu, CA (Complete list of references available from SEI)

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TABLE 1: List of Properties in Study Area

AIN	Property Location	Property Use	Additional Description	System Type
Alluvial				
4458020010	CIVIC CENTER WAY	Commercial	Store Combination (With Office or Residential)	onsite
4458020004	CIVIC CENTER WAY	Commercial	Professional Building	onsite
4458022904	CIVIC CENTER WAY	Institutional	Govn't owned property / Govn't services, general	offsite source
4458021003	COAST VIEW DR	Commercial	Nursery or Greenhouse	onsite
4452015035	CROSS CREEK LN	Residential		onsite
4452015034	CROSS CREEK LN	Residential		onsite
4452015023	CROSS CREEK LN	Residential		onsite
4452015033	CROSS CREEK LN	Residential		onsite
4452015025	CROSS CREEK LN	Residential		onsite
4452015026	CROSS CREEK LN	Residential		onsite
4452015031	CROSS CREEK LN	Residential		onsite
4452015027	CROSS CREEK LN	Residential		onsite
4452015030	CROSS CREEK LN	Residential		onsite
4452015042	CROSS CREEK LN	Residential		onsite
4452027010	CROSS CREEK RD	Residential		onsite
4452027009	CROSS CREEK RD	Residential		onsite
4452014006	CROSS CREEK RD	Residential		onsite
4452015024	CROSS CREEK RD	Residential		onsite
4458023003	CROSS CREEK RD	Residential		onsite
4458023009	CROSS CREEK RD	Residential		onsite
4452015029	CROSS CREEK RD	Residential		onsite
4458022021	CROSS CREEK RD	Residential		onsite
4458022004	CROSS CREEK RD	Residential		onsite
4458022003	CROSS CREEK RD	Residential		onsite
4452011037	CROSS CREEK RD	Commercial	Nursery or Greenhouse	onsite
4452012024	CROSS CREEK RD	Commercial	Commercial	onsite

TABLE 1 (continued): List of Properties in Study Area

AIN	Property Location	Property Use	Additional Description	System Type
4452011035	CROSS CREEK RD	Commercial	Office Building	onsite
4458020014	CROSS CREEK RD	Commercial	Shopping center (neighborhood, community)	onsite
4452011039	CROSS CREEK RD	Commercial	Stores	onsite
4452011042	CROSS CREEK RD	Commercial	Shopping center (neighborhood, community)	onsite
4458027034	MALIBU CANYON RD	Multi-Family	multi-unit residential	
4458004044	MALIBU COLONY RD	Residential		onsite
4452008025	MALIBU COLONY RD	Residential		onsite
4452008017	MALIBU COLONY RD	Residential		onsite
4452008016	MALIBU COLONY RD	Residential		onsite
4452008014	MALIBU COLONY RD	Residential		onsite
4452008030	MALIBU COLONY RD	Residential		onsite
4452010017	MALIBU COLONY RD	Residential		onsite
4452008028	MALIBU COLONY RD	Residential		onsite
4452010024	MALIBU COLONY RD	Residential		onsite
4452008027	MALIBU COLONY RD	Residential		onsite
4452010023	MALIBU COLONY RD	Residential		onsite
4452008026	MALIBU COLONY RD	Residential		onsite
4452008024	MALIBU COLONY RD	Residential		onsite
4452010032	MALIBU COLONY RD	Residential		onsite
4452008023	MALIBU COLONY RD	Residential		onsite
4452010031	MALIBU COLONY RD	Residential		onsite
4452008022	MALIBU COLONY RD	Residential		onsite
4452008021	MALIBU COLONY RD	Residential		onsite
4452008020	MALIBU COLONY RD	Residential		onsite
4452010012	MALIBU COLONY RD	Residential		onsite
4452008019	MALIBU COLONY RD	Residential		onsite
4452008018	MALIBU COLONY RD	Residential		onsite

TABLE 1 (continued): List of Properties in Study Area

AIN	Property Location	Property Use	Additional Description	System Type
4452009027	MALIBU COLONY RD	Residential		onsite
4452009026	MALIBU COLONY RD	Residential		onsite
4452009017	MALIBU COLONY RD	Residential		onsite
4452009016	MALIBU COLONY RD	Residential		onsite
4452009025	MALIBU COLONY RD	Residential		onsite
4452010008	MALIBU COLONY RD	Residential		onsite
4452009024	MALIBU COLONY RD	Residential		onsite
4452009023	MALIBU COLONY RD	Residential		onsite
4452010028	MALIBU COLONY RD	Residential		onsite
4452010009	MALIBU COLONY RD	Residential		onsite
4452009018	MALIBU COLONY RD	Residential		onsite
4452009019	MALIBU COLONY RD	Residential		onsite
4452010029	MALIBU COLONY RD	Residential		onsite
4452009022	MALIBU COLONY RD	Residential		onsite
4452010027	MALIBU COLONY RD	Residential		onsite
4452009021	MALIBU COLONY RD	Residential		onsite
4452010005	MALIBU COLONY RD	Residential		onsite
4452009020	MALIBU COLONY RD	Residential		onsite
4452009015	MALIBU COLONY RD	Residential		onsite
4452010022	MALIBU COLONY RD	Residential		onsite
4452010003	MALIBU COLONY RD	Residential		onsite
4458004031	MALIBU COLONY RD	Residential		onsite
4458004032	MALIBU COLONY RD	Residential		onsite
4452010002	MALIBU COLONY RD	Residential		onsite
4452010019	MALIBU COLONY RD	Residential		onsite
4458004033	MALIBU COLONY RD	Residential		onsite
4458004034	MALIBU COLONY RD	Residential		onsite
4458003023	MALIBU COLONY RD	Residential		onsite

Source: City of Malibu Assessor's data, 2002.
Notes: gpd = gallons per day
Path: O:\Proj-01\1269-W-Malibu\Reports\Final\Draft_Submittal\Tables\Table01.mdb
Date/init: 4/9/04 anm; rev 5/10/04 anm

Risk Assessment of Decentralized Wastewater Treatment Systems
City of Malibu, California
TABLE 1 (continued): List of Properties in Study Area

AIN	Property Location	Property Use	Additional Description	System Type
4458004035	MALIBU COLONY RD	Residential		onsite
4458003022	MALIBU COLONY RD	Residential		onsite
4458004036	MALIBU COLONY RD	Residential		onsite
4458003021	MALIBU COLONY RD	Residential		onsite
4458004037	MALIBU COLONY RD	Residential		onsite
4458004038	MALIBU COLONY RD	Residential		onsite
4458004039	MALIBU COLONY RD	Residential		onsite
4458004040	MALIBU COLONY RD	Residential		onsite
4458003019	MALIBU COLONY RD	Residential		onsite
4458003018	MALIBU COLONY RD	Residential		onsite
4458004041	MALIBU COLONY RD	Residential		onsite
4458004042	MALIBU COLONY RD	Residential		onsite
4458003017	MALIBU COLONY RD	Residential		onsite
4458003024	MALIBU COLONY RD	Residential		onsite
4458004043	MALIBU COLONY RD	Residential		onsite
4458003015	MALIBU COLONY RD	Residential		onsite
4458004046	MALIBU COLONY RD	Residential		onsite
4458004047	MALIBU COLONY RD	Residential		onsite
4458003014	MALIBU COLONY RD	Residential		onsite
4458004048	MALIBU COLONY RD	Residential		onsite
4458004049	MALIBU COLONY RD	Residential		onsite
4458003013	MALIBU COLONY RD	Residential		onsite
4458004050	MALIBU COLONY RD	Residential		onsite
4458004051	MALIBU COLONY RD	Residential		onsite
4458003012	MALIBU COLONY RD	Residential		onsite
4458004052	MALIBU COLONY RD	Residential		onsite
4458004053	MALIBU COLONY RD	Residential		onsite
4458004054	MALIBU COLONY RD	Residential		onsite

TABLE 1 (continued): List of Properties in Study Area

AIN	Property Location	Property Use	Additional Description	System Type
4458003027	MALIBU COLONY RD	Residential		onsite
4458004055	MALIBU COLONY RD	Residential		onsite
4458003026	MALIBU COLONY RD	Residential		onsite
4458005040	MALIBU COLONY RD	Residential		onsite
4458005039	MALIBU COLONY RD	Residential		onsite
4458005038	MALIBU COLONY RD	Residential		onsite
4458003009	MALIBU COLONY RD	Residential		onsite
4458005037	MALIBU COLONY RD	Residential		onsite
4458003008	MALIBU COLONY RD	Residential		onsite
4458005036	MALIBU COLONY RD	Residential		onsite
4458005035	MALIBU COLONY RD	Residential		onsite
4458005034	MALIBU COLONY RD	Residential		onsite
4458003030	MALIBU COLONY RD	Residential		onsite
4458005033	MALIBU COLONY RD	Residential		onsite
4458003004	MALIBU COLONY RD	Residential		onsite
4458005032	MALIBU COLONY RD	Residential		onsite
4458005031	MALIBU COLONY RD	Residential		onsite
4458003029	MALIBU COLONY RD	Residential		onsite
4458005030	MALIBU COLONY RD	Residential		onsite
4458005029	MALIBU COLONY RD	Residential		onsite
4458003028	MALIBU COLONY RD	Residential		onsite
4458005028	MALIBU COLONY RD	Residential		onsite
4458002014	MALIBU COLONY RD	Residential		onsite
4458005027	MALIBU COLONY RD	Residential		onsite
4458002011	MALIBU COLONY RD	Residential		onsite
4458005026	MALIBU COLONY RD	Residential		onsite
4458005025	MALIBU COLONY RD	Residential		onsite
4458002010	MALIBU COLONY RD	Residential		onsite

Source: City of Malibu Assessor's data, 2002.
Notes: gpd = gallons per day
Path: O:\Proj-01\1269-W-Malibu\Reports\Final\Draft_Submittal\Tables\Table01.mdb
Date/init: 4/9/04 anm; rev 5/10/04 anm

TABLE 1 (continued): List of Properties in Study Area

AIN	Property Location	Property Use	Additional Description	System Type
4458005024	MALIBU COLONY RD	Residential		onsite
4458005023	MALIBU COLONY RD	Residential		onsite
4458005022	MALIBU COLONY RD	Residential		onsite
4458002006	MALIBU COLONY RD	Residential		onsite
4458005021	MALIBU COLONY RD	Residential		onsite
4458006041	MALIBU COLONY RD	Residential		onsite
4458002004	MALIBU COLONY RD	Residential		onsite
4458006040	MALIBU COLONY RD	Residential		onsite
4458002003	MALIBU COLONY RD	Residential		onsite
4458006038	MALIBU COLONY RD	Residential		onsite
4458002017	MALIBU COLONY RD	Residential		onsite
4458006037	MALIBU COLONY RD	Residential		onsite
4458006036	MALIBU COLONY RD	Residential		onsite
4458006035	MALIBU COLONY RD	Residential		onsite
4458006034	MALIBU COLONY RD	Residential		onsite
4452005025	MALIBU RD	Residential		onsite
4458004045	MALIBU RD	Residential		onsite
4458002019	MALIBU RD	Commercial	Bank, savings and loans	offsite source
4458002900	MALIBU RD	Institutional	Govn't owned property / Police & Fire stations	onsite
4458002018	MALIBU RD	Commercial	Office Building	onsite
4458006033	MALIBU RD	Residential		onsite
4458006032	MALIBU RD	Residential		onsite
4458006031	MALIBU RD	Residential		onsite
4458006030	MALIBU RD	Residential		onsite
4458006029	MALIBU RD	Residential		onsite
4458006028	MALIBU RD	Residential		onsite
4458006027	MALIBU RD	Residential		onsite
4458006026	MALIBU RD	Residential		onsite

Source: City of Malibu Assessor's data, 2002.
Notes: gpd = gallons per day
Path: O:\Proj-01\1269-W-Malibu\Reports\Final\Draft_Submittal\Tables\Table01.mdb
Date/init: 4/9/04 anm; rev 5/10/04 anm

TABLE 1 (continued): List of Properties in Study Area

AIN	Property Location	Property Use	Additional Description	System Type
4458006025	MALIBU RD	Residential		onsite
4458006023	MALIBU RD	Residential		onsite
4458006022	MALIBU RD	Residential		onsite
4458007028	MALIBU RD	Residential		onsite
4458007027	MALIBU RD	Residential		onsite
4458007026	MALIBU RD	Residential		onsite
4458007025	MALIBU RD	Residential		onsite
4458007024	MALIBU RD	Residential		onsite
4458007023	MALIBU RD	Residential		onsite
4458007022	MALIBU RD	Residential		onsite
4458007021	MALIBU RD	Residential		onsite
4458007016	MALIBU RD	Residential		onsite
4458007015	MALIBU RD	Residential		onsite
4458007020	MALIBU RD	Residential		onsite
4458007019	MALIBU RD	Residential		onsite
4458007018	MALIBU RD	Residential		onsite
4458007017	MALIBU RD	Residential		onsite
4458018004	MALIBU RD	Commercial and Multi-Family	Store and residential combination	onsite
4458008017	MALIBU RD	Residential		onsite
4458008016	MALIBU RD	Residential		onsite
4458008015	MALIBU RD	Residential		onsite
4458008014	MALIBU RD	Residential		onsite
4458008013	MALIBU RD	Residential		onsite
4458008018	MALIBU RD	Residential		onsite
4452015003	MARIPOSA DE ORO ST	Residential		onsite
4452015014	MARIPOSA DE ORO ST	Residential		onsite
4452015007	MARIPOSA DE ORO ST	Residential		onsite
4452015010	MARIPOSA DE ORO ST	Residential		onsite

Source: City of Malibu Assessor's data, 2002.
Notes: gpd = gallons per day
Path: O:\Proj-01\1269-W-Malibu\Reports\Final\Draft_Submittal\Tables\Table01.mdb
Date/init: 4/9/04 anm; rev 5/10/04 anm

Risk Assessment of Decentralized Wastewater Treatment Systems
City of Malibu, California
TABLE 1 (continued): List of Properties in Study Area

AIN	Property Location	Property Use	Additional Description	System Type
4452015040	MARIPOSA DE ORO ST	Residential		onsite
4452015006	MARIPOSA DE ORO ST	Residential		onsite
4452015036	MARIPOSA DE ORO ST	Residential		onsite
4452015021	MARIPOSA DE ORO ST	Residential		onsite
4452015020	MARIPOSA DE ORO ST	Residential		onsite
4452015022	MARIPOSA DE ORO ST	Residential		onsite
4452015019	MARIPOSA DE ORO ST	Residential		onsite
4452015018	MARIPOSA DE ORO ST	Residential		onsite
4458019006	PACIFIC COAST HWY	Commercial	Service station and office building	offsite source
4452005004	PACIFIC COAST HWY	Residential		onsite
4452005022	PACIFIC COAST HWY	Residential		onsite
4452005018	PACIFIC COAST HWY	Residential		onsite
4452005002	PACIFIC COAST HWY	Residential		onsite
4452005001	PACIFIC COAST HWY	Residential		onsite
4452011043	PACIFIC COAST HWY	Commercial	Shopping center (neighborhood, community)	onsite
4452011033	PACIFIC COAST HWY	Commercial	Service station	onsite
4458020002	PACIFIC COAST HWY	Commercial	Office Building	onsite
4458019008	PACIFIC COAST HWY	Commercial	Service station	offsite source
4458020016	PACIFIC COAST HWY	Commercial	Stores	onsite and offsite source
4452027018	PALM CANYON LN	Residential		onsite
4452027016	PALM CANYON LN	Residential		onsite
4452027013	PALM CANYON LN	Residential		onsite
4452027012	PALM CANYON LN	Residential		onsite
4452027011	PALM CANYON LN	Residential		onsite
4452014004	PALM CANYON LN	Residential		onsite
4452012028	PALM CANYON LN	Residential		onsite
4452027021	RETREAT CT	Residential		onsite

Source: City of Malibu Assessor's data, 2002.
Notes: gpd = gallons per day
Path: O:\Proj-01\1269-W-Malibu\Reports\Final\Draft_Submittal\Tables\Table01.mdb
Date/init: 4/9/04 anm; rev 5/10/04 anm

Risk Assessment of Decentralized Wastewater Treatment Systems
City of Malibu, California
TABLE 1 (continued): List of Properties in Study Area

AIN	Property Location	Property Use	Additional Description	System Type
4452027022	RETREAT CT	Residential		onsite
4452027019	RETREAT CT	Residential		onsite
4452027023	RETREAT CT	Residential		onsite
4452026008	SERRA RD	Residential		onsite
4452026009	SERRA RD	Residential		onsite
4452026007	SERRA RD	Residential		onsite
4452026006	SERRA RD	Residential		onsite
4452026010	SERRA RD	Residential		onsite
4452026011	SERRA RD	Residential		onsite
4452026019	SERRA RD	Residential		onsite
4452026018	SERRA RD	Residential		onsite
4452026012	SERRA RD	Residential		onsite
4452026013	SERRA RD	Residential		onsite
4452026016	SERRA RD	Residential		onsite
4452026014	SERRA RD	Residential		onsite
4452026015	SERRA RD	Residential		onsite
4452018006	SERRA RD	Residential		onsite
4458021173	STUART RANCH RD	Commercial	Professional Building	onsite
4458021172	STUART RANCH RD	Commercial	Office Building	onsite
4458021005	STUART RANCH RD	Commercial	Nursery or Greenhouse	
4458021002	STUART RANCH RD	Commercial	Club, lodge hall	
Amarillo Beach				
4458008003	MALIBU RD	Residential		onsite
4458008002	MALIBU RD	Residential		onsite
4458008001	MALIBU RD	Residential		onsite
4458009013	MALIBU RD	Residential		onsite
4458009012	MALIBU RD	Residential		onsite
4458009009	MALIBU RD	Residential		onsite

Source: City of Malibu Assessor's data, 2002.
Notes: gpd = gallons per day
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TABLE 1 (continued): List of Properties in Study Area

AIN	Property Location	Property Use	Additional Description	System Type
4458009001	MALIBU RD	Residential		onsite
4458010015	MALIBU RD	Residential		onsite
4458010016	MALIBU RD	Residential		onsite
4458010017	MALIBU RD	Residential		onsite
4458010019	MALIBU RD	Residential		onsite
4458010018	MALIBU RD	Residential		onsite
4458010012	MALIBU RD	Residential		onsite
4458010011	MALIBU RD	Residential		onsite
4458010010	MALIBU RD	Residential		onsite
4458010008	MALIBU RD	Residential		onsite
4458010007	MALIBU RD	Residential		onsite
4458010006	MALIBU RD	Residential		onsite
4458010005	MALIBU RD	Residential		onsite
4458010004	MALIBU RD	Residential		onsite
4458010003	MALIBU RD	Residential		onsite
4458010001	MALIBU RD	Residential		onsite
4458011002	MALIBU RD	Residential		onsite
4458011003	MALIBU RD	Residential		onsite
Bedrock				
4458026007	COAST VIEW DR	Residential		onsite
4458027002	COAST VIEW DR	Residential		onsite
4458026006	COAST VIEW DR	Residential		onsite
4458026015	COAST VIEW DR	Residential		onsite
4458026014	COAST VIEW DR	Residential		onsite
4458026004	COAST VIEW DR	Residential		onsite
4458026003	COAST VIEW DR	Residential		onsite
4458027030	COAST VIEW DR	Residential		onsite
4458025020	COLONY VIEW CIR	Residential		onsite

TABLE 1 (continued): List of Properties in Study Area

AIN	Property Location	Property Use	Additional Description	System Type
4458025016	COLONY VIEW CIR	Residential		onsite
4458025015	COLONY VIEW CIR	Residential		onsite
4458025012	COLONY VIEW CIR	Residential		onsite
4458025010	COLONY VIEW CIR	Residential		onsite
4458025011	COLONY VIEW CIR	Residential		onsite
4458025025	COLONY VIEW DR	Residential		onsite
4458024004	HARBOR VISTA DR	Residential		onsite
4458024043	HARBOR VISTA DR	Residential		onsite
4458024025	HARBOR VISTA DR	Residential		onsite
4458024031	HARBOR VISTA DR	Residential		onsite
4458024001	HARBOR VISTA DR	Residential		onsite
4458024029	HARBOR VISTA DR	Residential		onsite
4458025014	HARBOR VISTA DR	Residential		onsite
4458024034	HARBOR VISTA DR	Residential		onsite
4458025013	HARBOR VISTA DR	Residential		onsite
4458024009	HARBOR VISTA DR	Residential		onsite
4458025019	HARBOR VISTA DR	Residential		onsite
4458024010	HARBOR VISTA DR	Residential		onsite
4458024011	HARBOR VISTA DR	Residential		onsite
4458024012	HARBOR VISTA DR	Residential		onsite
4458025024	HARBOR VISTA DR	Residential		onsite
4458025006	HARBOR VISTA DR	Residential		onsite
4458025018	HARBOR VISTA DR	Residential		onsite
4458029006	MALIBU CANYON RD	Commercial	Heavy manufacturing	
4458029013	MALIBU CANYON RD	Commercial	Heavy manufacturing	
4458029012	MALIBU CANYON RD	Commercial	Heavy manufacturing	
4458029015	MALIBU CANYON RD	Commercial	Heavy manufacturing	
4458024013	MALIBU CANYON RD	Residential		onsite

Risk Assessment of Decentralized Wastewater Treatment Systems
City of Malibu, California
TABLE 1 (continued): List of Properties in Study Area

AIN	Property Location	Property Use	Additional Description	System Type
4458025017	MALIBU CANYON RD	Residential		onsite
4458025023	MALIBU CANYON RD	Institutional	Church	
4458025004	MALIBU CANYON RD	Residential		onsite
4458024038	MALIBU CREST DR	Residential		onsite
4458024042	MALIBU CREST DR	Residential		onsite
4458024041	MALIBU CREST DR	Residential		onsite
4458024039	MALIBU CREST DR	Residential		onsite
4458024040	MALIBU CREST DR	Residential		onsite
4458024022	MALIBU CREST DR	Residential		onsite
4458024023	MALIBU CREST DR	Residential		onsite
4458024021	MALIBU CREST DR	Residential		onsite
4458024015	MALIBU CREST DR	Residential		onsite
4458024014	MALIBU CREST DR	Residential		onsite
4458026010	MALIBU KNOLLS RD	Residential		onsite
4458026011	MALIBU KNOLLS RD	Residential		onsite
4458026012	MALIBU KNOLLS RD	Residential		onsite
4458026013	MALIBU KNOLLS RD	Residential		onsite
4458026009	MALIBU KNOLLS RD	Residential		onsite
4458025001	MALIBU KNOLLS RD	Residential		onsite
4458026008	MALIBU KNOLLS RD	Residential		onsite
4458025022	MALIBU KNOLLS RD	Residential		onsite
4458018005	MALIBU RD	Residential		onsite
4458018020	MALIBU RD	Residential		onsite
4458018011	MALIBU RD	Residential		onsite
4458018012	MALIBU RD	Residential		onsite
4452019008	PACIFIC COAST HWY	Residential		onsite
4452026003	SERRA RD	Residential		onsite
4452014064	SERRA RD	Institutional	Home for aged & others	

Source: City of Malibu Assessor's data, 2002.
Notes: gpd = gallons per day
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Date/init: 4/9/04 anm; rev 5/10/04 anm

STONE ENVIRONMENTAL, INC

TABLE 1 (continued): List of Properties in Study Area

AIN	Property Location	Property Use	Additional Description	System Type
4452018011	SERRA RD	Residential		onsite
4452013001	SERRA RD	Residential		onsite
4452018012	SERRA RD	Residential		onsite
4452013002	SERRA RD	Residential		onsite
4452018013	SERRA RD	Residential		onsite
4452013003	SERRA RD	Residential		onsite
4452018015	SERRA RD	Residential		onsite
4452013009	SERRA RD	Residential		onsite
4452018008	SERRA RD	Residential		onsite
4452018016	SERRA RD	Residential		onsite
4452018009	SERRA RD	Residential		onsite
4452018017	SERRA RD	Residential		onsite
4452018018	SERRA RD	Residential		onsite
4452018019	SERRA RD	Residential		onsite
4452018020	SERRA RD	Residential		onsite
4452012014	SERRA RD	Residential		onsite
4452012012	SERRA RD	Residential		onsite
4452012015	SERRA RD	Residential		onsite
4452013005	SERRA RD	Residential		onsite
4452017001	SERRA RD	Residential		onsite
4452012007	SERRA RD	Residential		onsite
4452012016	SERRA RD	Residential		onsite
4452012013	SERRA RD	Residential		onsite
4452012022	SERRA RD	Residential		onsite
4452012009	SERRA RD	Residential		onsite
4452012011	SERRA RD	Residential		onsite
4452012020	SERRA RD	Residential		onsite
4452020088	SWEETWATER CANYO	Residential		onsite

Risk Assessment of Decentralized Wastewater Treatment Systems
City of Malibu, California
TABLE 1 (continued): List of Properties in Study Area

AIN	Property Location	Property Use	Additional Description	System Type
4452016003	SWEETWATER MESA R	Commercial	Warehousing, distribution, storage	
4452025006	SWEETWATER MESA R	Residential		onsite
4452016004	SWEETWATER MESA R	Residential		onsite
4452016019	SWEETWATER MESA R	Residential		onsite
4452016020	SWEETWATER MESA R	Residential		onsite
4452016007	SWEETWATER MESA R	Residential		onsite
4452017004	SWEETWATER MESA R	Residential		onsite
4452017005	SWEETWATER MESA R	Residential		onsite
4452017009	SWEETWATER MESA R	Residential		onsite
4452013008	SWEETWATER MESA R	Residential		onsite
4452013007	SWEETWATER MESA R	Residential		onsite
Malibu Pier Beach				
4452005020	PACIFIC COAST HWY	Multi-Family	multi-unit residential	onsite
4452005031	PACIFIC COAST HWY	Commercial	Motel - under 50 units / 3 stories	onsite
4452019011	PACIFIC COAST HWY	Commercial	Office Building	onsite
4452019010	PACIFIC COAST HWY	Commercial	Stores	onsite
4452019009	PACIFIC COAST HWY	Commercial	Stores	onsite
4452019004	PACIFIC COAST HWY	Commercial	Restaurant, cocktail lounge	onsite
4452019003	PACIFIC COAST HWY	Commercial	Restaurant, cocktail lounge	onsite
4452019002	PACIFIC COAST HWY	Commercial	Motel - under 50 units	onsite
Malibu Pier Beach Bedrock				
4452016008	SWEETWATER MESA R	Residential		onsite
4452016018	SWEETWATER MESA R	Residential		onsite
4452016017	SWEETWATER MESA R	Residential		onsite
4452016016	SWEETWATER MESA R	Residential		onsite
4452016015	SWEETWATER MESA R	Residential		onsite
4452017008	SWEETWATER MESA R	Residential		onsite
Winter Canyon Alluvial				

TABLE 1 (continued): List of Properties in Study Area

AIN	Property Location	Property Use	Additional Description	System Type
4458019010	MALIBU RD	Commercial	Shopping center / Lift	offsite source
4458027904	WINTER CANYON RD	Multi-Family	multi-unit residential	
4458028020	WINTER CANYON RD	Commercial	Wastewater Treatment and Disposal Field	
4458027024	WINTER CANYON RD	Institutional	Church	
4458027023	WINTER CANYON RD	Institutional	School (private)	
4458027025	WINTER CANYON RD	Residential		onsite
Winter Canyon Bedrock				
4458027003	COAST VIEW DR	Residential		onsite
4458027004	COAST VIEW DR	Residential		onsite
4458027005	COAST VIEW DR	Residential		onsite
4458027029	COAST VIEW DR	Residential		onsite
4458038010	PACIFIC COAST HWY	Institutional	College, University (private)	onsite

Source: City of Malibu Assessor's data, 2002.
Notes: gpd = gallons per day
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Risk Assessment of Decentralized Wastewater Treatment Systems
City of Malibu, California
TABLE 2: Bacteria Load Allocations for the Malibu Pier,
Surfrider Beach, Malibu Point and Malibu Creek Watershed TMDL

Water Body Type	
In Marine Waters Designated for Water Contact Recreation (REC-1)[1]	1. Geometric Mean Limits a. Total coliform density shall not exceed 1,000/100 ml. b. Fecal coliform density shall not exceed 200/100 ml. c. *Enterococcus* density shall not exceed 35/100 ml. 2. Single Sample Limits a. Total coliform density shall not exceed 10,000/100 ml. b. Fecal coliform density shall not exceed 400/100 ml. c. *Enterococcus* density shall not exceed 104/100 ml. d. Total coliform density shall not exceed 1,000/100 ml, if the ratio of fecal-to-total coliform exceeds 0.1.
In Fresh Waters Designated for Water Contact Recreation (REC-1)[1]	1. Geometric Mean Limits a. *E. coli* density shall not exceed 126/100 ml. b. Fecal coliform density shall not exceed 200/100 ml. 2. Single Sample Limits a. *E. coli* density shall not exceed 235/100 ml. b. Fecal coliform density shall not exceed 400/100 ml.
Target Exceedances[2]	
Summer (April 1 to October 31) Dry-Weather Days	Zero (0) exceedance days based on the Single Sample Zero (0) exceedance days based on the Rolling 30-Day Geometric Mean
Winter (November 1-March 31) Dry-Weather Days	Three (3) exceedance days based on the Single Sample Zero (0) exceedance days based on the Rolling 30-Day Geometric Mean
Wet-Weather Days (days with 0.1 inch of rain or greater and three days following the rain event)	Seventeen (17) exceedance days based on the Single Sample Zero (0) exceedance days based on the Rolling 30-Day Geometric Mean

Source: LARWQCB, 2004,Total Maximum Daily Loads for Bacteria Malibu Creek Watershed 1/29/04
Notes: [1] LARWQCB. 2002. Regional Basin Plan, as amended.
[2] The allowable exceedance days are based on daily sampling. If weekly sampling is performed, the allowable exceedance days are scaled accordingly.
Path: O:\Proj-01\1269-W-Malibu\Reports\Final report\Draft_Submittal\Tables\Drafts \BacteriaLoad.xls
Date: 5/18/04, anm

Risk Assessment of Decentralized Wastewater Treatment Systems
City of Malibu, California
TABLE 3: Malibu Creek and Malibu Lagoon
Surface Water Level Measurements

	Malibu Lagoon[1]			Arizona Crossing		
Date	Time	Depth to Water (ft)[3]	Elevation of Lagoon (ft)[2]	Time	Depth to Water (ft)[4]	Elevation of Creek (ft)[2]
6/27/2003	nd[5]	nd		12:37	1.48	15.52
7/18/2003	17:02	19.45	8.08	16:10	1.72	15.28
8/15/2003	10:41	19.95	7.58	12:01	1.98	15.02
9/25/2003	8:41	21.05	6.48	9:10	2.92	14.08
9/25/2003	11:50	21.08	6.45	nd	nd	nd
10/30/2003	16:35	19.50	8.03	16:50	2.06	14.93
11/4/2003	14:48	24.40	3.13	nd	nd	nd
11/20/2003	12:36	24.20	3.33	12:53	1.15	15.85
12/15/2003	13:12	23.42	4.11	13:32	0.66	16.34
1/30/2004	11:52	23.55	3.98	12:36	0.79	16.21
3/9/2004	8:30	24.11	3.42	13:01	0.79	16.20
3/9/2004	12:42	23.98	3.55	nd	nd	nd

Source: Questa Engineering and McDonald-Morrissey field observations, 2003-2004. STONE ENVIRONMENTAL, INC.

Notes:

1. Location Designation: LVMWD - 1 (Nail on Southerly side of PCH Bridge by Las Virgenes Municipal Water District standpipe and probe)
2. Survey Elevation Data (ft): Malibu Lagoon: 27.53
   Arizona Crossing: 16.995
   Vertical datum is based on NAVD 88 (North America Vertical Datum 1988) using Los Angeles County bench marks from the "Malibu Quad 1998 Adjustment".
3. Measurements collected from bridge using weighted tape.
4. Measurements collected approximately 100 feet north of Arizona Crossing from bank.
5. nd = no data collected

Path: O:\Proj-01\1269-W-Malibu\Reports\Final report\Draft_Submittal\Tables\AZcrossing_Malibu Lagoon Water Levels.xls
Date/init: ANM, 5/6/2004

Risk Assessment of Decentralized Wastewater Treatment Systems
City of Malibu, California
TABLE 4: Summary of Continuous Water Table Monitoring Data (July 2003 - May 2004)

Monitoring Location	Monitoring Dates	Approximate Distance to Lagoon (ft)	Average Water Table Elevation (ft)[6]		Average Range of Daily Water Table Variation (ft)	
			Breached Lagoon	Unbreached Lagoon	Breached Lagoon	Unbreached Lagoon
Lagoon	7/25/2003 - 5/14/2004[3]	0	4.12	7.52	1.66	0.17
MLW-1	10/7/2003 - 5/26/2004[4]	100	5.45	5.89	0.35	0.25
P-4	9/7/2003 - 5/26/2004[5]	250	4.86	7.19	0.42	0.09
P-1	9/8/2003 - 5/26/2004	500	6.17	7.24	0.18	0.04

Source: Monitoring well observations, Bing Yen Associates, 2003-2004;
Malibu Lagoon observations, Las Virgenes Municipal Water District, 2003-2004.

STONE ENVIRONMENTAL, INC.

Notes:
1. Breached time interval = beginning of data collection - 10/31/2003
   Unbreached time interval = 11/1/2003 - approximately 5/1/2004
2. Data for each time increment was averaged to daily values, then daily values were averaged for breached and unbreached conditions. Average variation was determined by subtracting the maximum water table elevation from the minimum water table elevation for each day, and then averaging the daily variations for breached and unbreached conditions.
3. Valid data was collected during the following time periods: 7/25/2003 - 8/15/2003; 10/17/2003 - 12/17/2003; 4/30/2004 - 5/14/2004.
4. Valid data was collected between 10/7/2003 and 3/14/2004.
5. Valid data was collected during the following time periods: 10/14/2003 - 11/7/2003; 1/23/2004 - 5/26/2004.
6. Survey Elevation Data (ft):

Malibu Lagoon:	27.530
MLW-1:	11.255
P-4:	12.155
P-1:	13.465

Vertical datum is based on NAVD 88 (North America Vertical Datum 1988) using Los Angeles County benchmarks from the Malibu Quad 1998 Adjustment.

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Date/init: ANM, 5/6/2004

Risk Assessment of Decentralized Wastewater Treatment Systems
City of Malibu, California
TABLE 5: Synoptic Water Level Measurements,
Unbreached Lagoon Condition, September 25, 2003

Well ID	MP Elevation (ft. AMSL)	Depth to Water Table (ft. below MP)	Water Table Elevation (ft. AMSL)
C-1	11.47	5.38	6.09
C-2	11.19	5.02	6.17
CCPC	12.4	5.64	6.76
CCPE	12.935	6.34	6.60
CCPNE	13.675	6.95	6.73
CCPSW	13.67	6.94	6.73
CCSC-2	11.815	5.22	6.60
CCW-4	15.765	6.21	9.56
LAMW-2	97.98	44.40	53.58
LAMW-3	90.06	40.09	49.97
LAMW4	102.93	48.98	53.95
LAMW5S	104.55	50.12	54.43
LAMW5N	103.955	49.90	54.06
LAMW6	91.545	40.27	51.28
MBCMW-5	29.03	21.09	7.94
MBCMW-6	29.02	15.18	13.84
MBCMW-7	16.635	9.32	7.32
MBCMW-8	16.53	6.27	10.26
MBCMW-9	17.71	8.79	8.92
MBCMW-10	17.74	9.80	7.94
MLW-1	11.255	5.24	6.02
MR-2	NA	7.26	
P-1	13.465	6.38	7.09
P-4	12.155	5.34	6.82
P-7	10.67	4.18	6.49
P-9	12.165	5.60	6.57
SMBRP-2	13.131	6.64	6.49
SMBRP-3C	36.53	19.36	17.17
SMBRP-6	26.875	16.33	10.55
SMBRP-7B	18.985	10.52	8.47
SMBRP-8	48.685	36.20	12.49
SMBRP-9	50.32	36.10	14.22
SMBRP-10C	16.25	5.84	10.41
SMBRP-11	18.35	8.43	9.92
SMBRP-12	12.615	7.08	5.54
SMBRP-13	13.58	8.25	5.33
SMBRP-14	11.87	5.68	6.19
SMBRP-15	16.765	10.34	6.43
SMBRP-16	14.5	4.35	10.15
Lagoon - before	27.53	21.05	6.48
Lagoon - after	27.53	21.08	6.45
Arizona Crossing	16.995	2.92	14.08

Source: Field observations, McDonald Morrissey Assoc. and Questa Engineering, 2003.

STONE ENVIRONMENTAL, INC.

Notes: MP = monitoring point; ft. AMSL = feet above mean sea level.

Path: O:\Proj-01\1269-W-Malibu\Reports\Final report\Draft_Submittal\Tables\AllSynopticresultsDJM.xls

Date / init: anm, 4/29/2004

Risk Assessment of Decentralized Wastewater Treatment Systems
City of Malibu, California
TABLE 6: Synoptic Water Level Measurements,
Breached Lagoon Condition, March 9, 2004

Well ID	MP Elevation (ft. AMSL)	Depth to Water Table (ft. below MP)	Water Table Elevation (ft. AMSL)
C-1	11.47	6.67	4.80
C-2	11.19	6.51	4.68
CCPC	12.4	5.3	7.10
CCPE	12.935	9.47	3.47
CCPNE	13.675	8.89	4.79
CCPSW	13.67	8.39	5.28
CCSC-2	11.815	7.29	4.53
CCW-4	15.765	5.68	10.09
LAMW-2	97.98	45.90	52.08
LAMW-3	90.06	40.72	49.34
LAMW4	102.93	49.58	53.35
LAMW5S	104.55	50.79	53.76
LAMW5N	103.955	50.52	53.44
LAMW6	91.545	40.82	50.73
MBCMW-5	29.03	20.96	8.07
MBCMW-6	29.02	15.72	13.30
MBCMW-7	16.635	9.33	7.31
MBCMW-8	16.53	5.23	11.30
MBCMW-9	17.71	8.33	9.38
MBCMW-10	17.74	9.54	8.20
MLW-1	11.255	5.64	5.62
MR-2	NA	6.62	
P-1	13.465	7.37	6.10
P-4	12.155	7.45	4.71
P-7	10.67	5.79	4.88
P-9	12.165	7.89	4.28
SMBRP-2	13.131	8.76	4.37
SMBRP-3C	36.53	17.93	18.60
SMBRP-6	26.875	14.28	12.60
SMBRP-7B	18.985	10.09	8.90
SMBRP-8	48.685	34.11	14.58
SMBRP-9	50.32	33.96	16.36
SMBRP-10C	16.25	6.4	9.85
SMBRP-11	18.35	7.57	10.78
SMBRP-12	12.615	6.65	5.97
SMBRP-13	13.58	8.09	5.49
SMBRP-14	11.87	5.98	5.89
SMBRP-15	16.765	10.92	5.85
SMBRP-16	14.5	3.57	10.93
Lagoon - before	27.53	24.11	3.42
Lagoon - after	27.53	23.78	3.75
Arizona Crossing	16.995	1.07	15.93

Source: Field observations, Bing Yen Associates and Questa Engineering, 2004. STONE ENVIRONMENTAL, INC.
Notes: MP = monitoring point; ft. AMSL = feet above mean sea level.
Path: O:\Proj-01\1269-W-Malibu\Reports\Final report\Draft_Submittal\Tables\AllSynopticresultsDJM.xls
Date / init: anm, 4/29/2004; rev anm, 8/2/2004

TABLE 7: MALIBU GROUNDWATER ELEVATIONS SUMMARY

	Groundwater Elevation (feet above mean sea level)											
Well ID	**Event 01**	**Event 02**	**Event 03**	**Event 04**	**Event 05**	**Event 06**	**Event 07**	**Event 08**	**Event 09**	**Event 10**	**Event 11**	**Event 12**
C-1	4.88	4.86	2.88	7.11	6.64	6.06	6.15	4.47	4.51	5.29	5.63	4.84
C-2	4.78	4.76	4.71	7.14	6.66	6.07	6.16	4.33	4.44	5.31	5.59	4.75
MW-5												
P-1	6.015	6.015	5.875	8.435	7.985	7.075	7.445	5.865	5.965	6.635	6.265	6.075
P-7	4.83	4.78	2.78	7.81	7.29	6.52	6.75	4.66	4.79	5.9	5.4	4.77
P-9	4.315	4.275	4.125	8.095	7.515	6.555	6.815	4.185	4.795	6.015	5.555	5.045
SMBRP-1	7.131	6.981	6.701	6.581								
SMBRP-10c	13.41	13.36	12.03	11.36	10.7	8.33	10.31	8.33	7.46	7.63	7.73	14.22
SMBRP-11	10.87	10.66	10.36	10.34	10.36	10.03	9.87	10	10.15	10.58	10.12	10.6
SMBRP-12	5.945	5.565	5.385	5.535	5.645	5.635	5.285	5.165	5.625	6.215	5.645	5.965
SMBRP-13	5.31	5.48	5.06	5.65	5.64	5.8	5.13	5.06	5.25	6.48	6.2	5.76
SMBRP-14	6.09	5.23	5.35	6.77	6.11	6.56	5.77	5	4.97	5.3		5.8
SMBRP-15b	5.755	5.545	5.475	7.355	7.085	6.435	6.595	5.415	5.665	6.225	5.815	5.715
SMBRP-16	10.95	10.91	10.59	10.37	10.27	10.08	10.02	9.97	9.96	10.26	10.01	10.58
SMBRP-2	4.711	4.951	4.611	7.871	7.351	6.511	6.661	4.311	4.501	5.701	5.251	4.601
SMBRP-3c	18.55	18.61	18.21	18	17.61	17.24	17.68	18.38	18.33	18.2	18.16	18.41
SMBRP-6	12.485	12.555	12.205	12.445	11.525	10.705	11.665	12.465	12.365	12.275	12.225	12.425
SMBRP-7b	9.005	8.735	8.535	8.965	9.095	8.485	8.565	8.395	8.165	8.475	8.415	8.855
SMBRP-8	15.135	14.475	13.545	13.495	13.175	12.495	12.405	12.055	11.605	11.325	11.595	14.495
SMBRP-9	17.03	17.85	18.33	18.5	18.16	17.56	17.22	17.13	16.74	16.39	16.25	16.41

Source: Field observations, Biosolutions, Inc., 2003-2004.
Date/Initials:8/6/2003 anm
Path: O:\Proj-01\1269-W-Malibu\Data\WellData\AnalyticalResults\MalibuAnalytes.mdb

TABLE 8: MALIBU ANALYTE RESULTS SUMMARY - EVENT 01 (4/22/03-4/25/03)

Well ID	Sample Date	Ammonia (mg/l) N/EPA 350.2	Chloride (mg/l) EPA 300.0	Nitrate (mg/l) N/EPA 300	Nitrite (mg/l) N/EPA 300	TKN (mg/l) EPA 351.2	Enterococcus (MPN/100ml) SM 9230B	Fecal Coliform (MPN/100ml) SM 9221	Total Coliform (MPN/100ml) SM 922121
C-1	4/24/2003	3.27	1320	0.60	ND	4.1	ND	ND	ND
C-2	4/24/2003	0.11	1620	0.61	ND	0.57	200.0	ND	14
MW-5	4/25/2003	0.10	551	3.52	ND	3.0	ND	ND	ND
P-1	4/25/2003	0.08	141	6.58	ND	0.15	ND	ND	ND
P-7	4/25/2003	ND	178	0.68	ND	0.26	3.1	ND	23
P-9	4/23/2003	0.88	321	1.54	ND	1.6	4.1	ND	ND
SMBRP-1	4/23/2003	0.78	1130	0.15	ND	2.7	ND	7	50
SMBRP-10c	4/23/2003	0.09	1570	3.41	ND	0.35	ND	ND	ND
SMBRP-11	4/25/2003	0.04	184	5.66	ND	0.85	ND	ND	ND
SMBRP-12	4/22/2003	5.14	241	ND	ND	13	2.0	2	50
SMBRP-13	4/22/2003	0.16	125	1.00	ND	0.59	34.1	ND	ND
SMBRP-14	4/22/2003	17.4	150	ND	ND	25	21.1	17000	17000
SMBRP-15b	4/25/2003	0.14	175	0.91	ND	1.0	67.6	ND	ND
SMBRP-16	4/23/2003	0.20	324	2.88	0.49	0.64	33.3	ND	ND
SMBRP-2	4/25/2003	2.72	679	ND	ND	29	7200.0	3000	3000
SMBRP-3c	4/25/2003	ND	130	2.82	ND	0.10	30.8	ND	ND
SMBRP-6	4/25/2003	ND	122	2.02	ND	0.36	ND	ND	13
SMBRP-7b	4/23/2003	0.69	562	0.16	ND	1.4	ND	ND	ND
SMBRP-8	4/25/2003	ND	180	46.3	ND	0.33	2.0	2	8
SMBRP-9	4/23/2003	0.01	250	3.03	ND	1.1	ND	ND	ND

Source: Raw Data, Pat-Chem Laboratories, 2003.
Abbreviations: ND=non-detect mg/l=milligrams per liter MPN/100ml=most prabale number per 100 milliliters
Date/Initials: CAW 6/20/03

Pathname: O:\Proj-01\1269-W-Malibu\Sampling_SlugTests\MalibuAnalytes.mdb rptMalibuAnalyte

TABLE 9: MALIBU ANALYTE RESULTS SUMMARY - EVENT 02 (5/28/03-5/30/03)

Well ID	Sample Date	Ammonia (mg/l) N/EPA 350.2	Chloride (mg/l) EPA 300.0	Nitrate (mg/l) N/EPA 300	Nitrite (mg/l) N/EPA 300	TKN (mg/l) EPA 351.2	Enterococcus (MPN/100ml) SM 9230B	Fecal Coliform (MPN/100ml) SM 9221	Total Coliform (MPN/100ml) SM 922121
C-1	5/30/2003	1.97	2150	0.05	ND	3.2	648.8	ND	22
C-2	5/30/2003	0.44	6140	0.07	ND	0.85	2.0	ND	4
MW-5	5/30/2003	0.07	179	15.3	ND	0.13	6.0	ND	4
P-1	5/29/2003	0.21	140	2.85	ND	ND	19.5	ND	2
P-7	5/28/2003	0.50	205	0.19	ND	0.29	66.4	2	240
P-9	5/29/2003	0.31	252	1.83	ND	1.3	21.3	ND	ND
SMBRP-1	5/30/2003	0.52	414	0.49	ND	2.0	11.0	ND	2
SMBRP-10c	5/29/2003	0.47	1630	1.66	ND	1.1	157.8	ND	2
SMBRP-11	5/28/2003	0.30	200	3.85	ND	0.51	2419.2	ND	4
SMBRP-12	5/28/2003	9.29	492	ND	ND	12	ND	4	4
SMBRP-13	5/28/2003	6.03	1550	0.49	ND	0.28	54.8	ND	2
SMBRP-14	5/28/2003	0.26	128	ND	ND	15	91.4	1600	1600
SMBRP-15b	5/28/2003	1.21	187	1.03	ND	0.42	2419.2	ND	21
SMBRP-16	5/28/2003	6.08	314	4.02	0.31	1.2	2419.2	ND	4
SMBRP-2	5/30/2003	0.72	734	0.05	ND	14	2419.2	70	300
SMBRP-3c	5/30/2003	0.20	133	2.78	ND	0.37	2419.2	ND	ND
SMBRP-6	5/30/2003	0.16	163	0.33	ND	1.2	16.5	11	26
SMBRP-7b	5/29/2003	2.29	448	0.56	ND	0.39	ND	ND	ND
SMBRP-8	5/29/2003	0.22	176	55.6	ND	ND	2419.2	2	6
SMBRP-9	5/28/2003	0.47	260	32.1	ND	ND	4.1	ND	4

Source: Raw Data, Pat-Chem Laboratories, 2003.
Abbreviations: ND=non-detect mg/l=milligrams per liter MPN/100ml=most prabale number per 100 milliliters
Date/Initials: CAW 6/20/03

Pathname: O:\Proj-01\1269-W-Malibu\Sampling_SlugTests\MalibuAnalytes.mdb rptMalibuAnalyte

TABLE 10: MALIBU ANALYTE RESULTS SUMMARY - EVENT 03 (6/26/03-6/30/03)

Well ID	Sample Date	Ammonia (mg/l) N/EPA 350.2	Chloride (mg/l) EPA 300.0	Nitrate (mg/l) N/EPA 300	Nitrite (mg/l) N/EPA 300	TKN (mg/l) EPA 351.2	Enterococcus (MPN/100ml) SM 9230B	Fecal Coliform (MPN/100ml) SM 9221	Total Coliform (MPN/100ml) SM 922121
C-1	6/30/2003	2.88	3230	ND	ND	3.5	61.3	ND	20
C-2	6/30/2003	0.76	8030	ND	ND	0.88	6.3	ND	ND
MW-5	6/30/2003	0.03	350	7.49	ND	0.05	2.0	ND	17
P-1	6/26/2003	0.08	144	5.49	ND	0.85	ND	ND	4
P-7	6/27/2003	0.20	178	0.11	ND	0.37	ND	ND	ND
P-9	6/26/2003	3.35	189	0.14	ND	3.4	4.1	ND	ND
SMBRP-1	6/27/2003	2.52	1920	ND	ND	4.9	ND	ND	ND
SMBRP-10c	6/26/2003	0.04	1490	1.27	ND	1.3	ND	2	4
SMBRP-11	6/26/2003	0.03	227	2.48	ND	0.49	ND	ND	2
SMBRP-12	6/27/2003	10.2	462	ND	ND	12	ND	ND	ND
SMBRP-13	6/27/2003	0.15	3400	0.30	ND	0.35	5.0	ND	ND
SMBRP-14	6/27/2003	13.1	118	ND	ND	16	ND	1600	1600
SMBRP-15b	6/26/2003	0.05	168	0.94	ND	0.28	3.1	ND	ND
SMBRP-16	6/26/2003	0.83	482	2.38	0.19	1.6	29.2	ND	ND
SMBRP-2	6/30/2003	1.29	766	0.11	ND	20	2419.2	120	250
SMBRP-3c	6/27/2003	0.22	114	0.97	ND	0.40	ND	ND	ND
SMBRP-6	6/27/2003	0.16	120	0.21	ND	1.1	ND	2	2
SMBRP-7b	6/30/2003	0.74	466	ND	ND	1.7	ND	ND	ND
SMBRP-8	6/30/2003	0.26	149	11.1	ND	0.28	1.0	ND	ND
SMBRP-9	6/26/2003	0.40	236	25.8	ND	0.52	ND	ND	11

Source: Raw Data, Pat-Chem Laboratories, 2003.
Abbreviations: ND=non-detect mg/l=milligrams per liter MPN/100ml=most prabale number per 100 milliliters
Date/Initials: CAW 6/20/03

Pathname: O:\Proj-01\1269-W-Malibu\Sampling_SlugTests\MalibuAnalytes.mdb rptMalibuAnalyte

TABLE 11: MALIBU ANALYTE RESULTS SUMMARY - EVENT 04 (7/21/03-7/24/03)

Well ID	Sample Date	Ammonia (mg/l) N/EPA 350.2	Chloride (mg/l) EPA 300.0	Nitrate (mg/l) N/EPA 300	Nitrite (mg/l) N/EPA 300	TKN (mg/l) EPA 351.2	Enterococcus (MPN/100ml) SM 9230B	Fecal Coliform (MPN/100ml) SM 9221	Total Coliform (MPN/100ml) SM 9221
C-1	7/24/2003	0.51	3270	ND	ND	5.4	178.5	ND	17
C-2	7/24/2003	0.22	9510	ND	ND	0.55	2419.2	7	7
MW-5	7/24/2003	0.39	343	14.9	ND	0.39	ND	ND	4
P-1	7/21/2003	0.41	142	3.55	ND	0.22	ND	ND	2
P-7	7/24/2003	0.23	174	ND	ND	0.92	65.3	ND	4
P-9	7/21/2003	3.00	613	0.71	ND	3.2	2.0	ND	2
SMBRP-1	7/24/2003	1.72	1410	0.14	ND	2.5	2419.2	ND	50
SMBRP-10c	7/21/2003	0.44	1540	0.93	ND	2.3	770.1	2	130
SMBRP-11	7/21/2003	0.37	248	1.48	ND	0.52	1203.3	2	110
SMBRP-12	7/21/2003	8.60	538	0.06	ND	11	ND	ND	ND
SMBRP-13	7/21/2003	0.38	622	0.23	ND	0.40	ND	ND	ND
SMBRP-14	7/21/2003	23.8	130	0.18	ND	26	2419.2	900	1600
SMBRP-15b	7/21/2003	0.37	187	0.94	ND	0.25	ND	ND	ND
SMBRP-16	7/21/2003	0.52	393	4.50	0.24	0.56	5.2	ND	ND
SMBRP-2	7/24/2003	0.56	283	ND	ND	6.0	2419.2	4	500
SMBRP-3c	7/24/2003	0.24	128	ND	ND	0.41	4.1	ND	ND
SMBRP-6	7/24/2003	0.36	135	ND	ND	0.44	1.0	ND	2
SMBRP-7b	7/21/2003	0.53	536	0.06	ND	1.0	29.3	ND	ND
SMBRP-8	7/24/2003	1.44	150	61.5	ND	1.9	148.5	ND	11
SMBRP-9	7/21/2003	0.29	224	21.6	ND	0.22	2419.2	240	1600

Source: Raw Data, Pat-Chem Laboratories, 2003.
Abbreviations: ND=non-detect mg/l=milligrams per liter MPN/100ml=most prabale number per 100 milliliters
Date/Initials: CAW 6/20/03

Pathname: O:\Proj-01\1269-W-Malibu\Sampling_SlugTests\MalibuAnalytes.mdb rptMalibuAnalyte

TABLE 12: MALIBU ANALYTE RESULTS SUMMARY - EVENT 05 (8/18/03-8/20/03)

Well ID	Sample Date	Ammonia (mg/l) N/EPA 350.2	Chloride (mg/l) EPA 300.0	Nitrate (mg/l) N/EPA 300	Nitrite (mg/l) N/EPA 300	TKN (mg/l) EPA 351.2	Enterococcus (MPN/100ml) SM 9230B	Fecal Coliform (MPN/100ml) SM 9221	Total Coliform (MPN/100ml) SM 9221
C-1	8/19/2003	3.02	4340	ND	ND	6.9	63.7	4	17
C-2	8/19/2003	0.47	5190	ND	ND	0.77	1203.3	ND	50
MW-5	8/19/2003	0.02	337	11.7	ND	1.6	2.0	ND	ND
P-1	8/18/2003	0.13	114	7.16	ND	0.18	ND	ND	4
P-7	8/19/2003	0.08	180	ND	ND	0.27	547.5	ND	ND
P-9	8/18/2003	1.69	233	0.42	ND	3.4	17.1	ND	4
SMBRP-10c	8/18/2003	0.11	1590	0.65	ND	1.0	1986.3	ND	ND
SMBRP-11	8/18/2003	0.17	226	1.35	ND	0.98	2419.2	2	240
SMBRP-12	8/18/2003	6.45	535	ND	ND	12	1.0	ND	ND
SMBRP-13	8/18/2003	0.09	374	0.09	ND	0.34	2.0	ND	8
SMBRP-14	8/18/2003	8.23	103	ND	ND	28	16.6	220	1600
SMBRP-15b	8/18/2003	0.05	165	1.31	ND	0.18	2.0	ND	2
SMBRP-16	8/18/2003	0.04	428	4.58	ND	1.1	2419.2	ND	ND
SMBRP-2	8/20/2003	0.57	254	ND	ND	10	ND	ND	4
SMBRP-3c	8/19/2003	0.14	154	0.52	ND	0.25	7.4	ND	ND
SMBRP-6	8/19/2003	0.05	144	0.22	ND	0.14	ND	ND	ND
SMBRP-7b	8/18/2003	0.33	523	ND	ND	0.91	2419.2	ND	300
SMBRP-8	8/20/2003	ND	145	63.8	ND	0.86	ND	ND	14
SMBRP-9	8/18/2003	0.02	168	18.7	ND	0.29	2419.2	ND	500

Source: Raw Data, Pat-Chem Laboratories, 2003.
Abbreviations: ND=non-detect   mg/l=milligrams per liter   MPN/100ml=most prabale number per 100 milliliters
Date/Initials: CAW 6/20/03

Pathname: O:\Proj-01\1269-W-Malibu\Sampling_SlugTests\MalibuAnalytes.mdb rptMalibuAnalyte

TABLE 13: MALIBU ANALYTE RESULTS SUMMARY - EVENT 06 (9/29/03-9/30/03)

Well ID	Sample Date	Ammonia (mg/l) N/EPA 350.2	Chloride (mg/l) EPA 300.0	Nitrate (mg/l) N/EPA 300	Nitrite (mg/l) N/EPA 300	TKN (mg/l) EPA 351.2	Enterococcus (MPN/100ml) SM 9230B	Fecal Coliform (MPN/100ml) SM 9221	Total Coliform (MPN/100ml) SM 9221
C-1	9/30/2003	8.57	4690	ND	ND	9.7	2.0	6	6
C-2	9/30/2003	.44	5540	ND	ND	0.87	15.5	ND	ND
MW-5	9/29/2003	ND	377	6.13	ND	.16	5.2	ND	ND
P-1	9/29/2003	ND	112	2.82	ND	.42	9.8	ND	ND
P-7	9/30/2003	ND	167	ND	ND	.44	721.5	9	9
P-9	9/29/2003	1.56	199	.42	ND		44.1	ND	4
SMBRP-10c	9/29/2003	ND	1260	.32	ND	2.7	33.7	ND	4
SMBRP-11	9/29/2003	ND	213	.55	ND	.8	28.1	4	7
SMBRP-12	9/29/2003	7.26	458	ND	ND	12	ND	ND	ND
SMBRP-13	9/29/2003	.03	296	.06	ND	.62	5.1	ND	ND
SMBRP-14	9/29/2003	21.1	94.2	.07	ND	26	8.4	1600	1600
SMBRP-15b	9/29/2003	ND	161	1.15	ND	.4	ND	2	2
SMBRP-16	9/29/2003	ND	350	2.77	.1	1.4	42.8	ND	ND
SMBRP-2	9/30/2003	ND	237	ND	ND	1.1	2419.2	ND	9
SMBRP-3c	9/30/2003	ND	125	.37	ND	.44	1.0	ND	ND
SMBRP-6	9/30/2003	ND	125	.17	ND	0.44	ND	4	110
SMBRP-7b	9/30/2003	.35	468	.1	ND	.60	4.1	2	4
SMBRP-8	9/30/2003	.04	166	43.1	ND	.45	3.0	2	300
SMBRP-9	9/29/2003	ND	157	13.2	ND	.16	6.3	ND	7

Source: Raw Data, Pat-Chem Laboratories, 2003.
Abbreviations: ND=non-detect   mg/l=milligrams per liter   MPN/100ml=most prabale number per 100 milliliters
Date/Initials: CAW 6/20/03

Pathname: O:\Proj-01\1269-W-Malibu\Sampling_SlugTests\MalibuAnalytes.mdb rptMalibuAnalyte

TABLE 14: MALIBU ANALYTE RESULTS SUMMARY - EVENT 07 (10/20/03-10/21/03)

Well ID	Sample Date	Ammonia (mg/l) N/EPA 350.2	Chloride (mg/l) EPA 300.0	Nitrate (mg/l) N/EPA 300	Nitrite (mg/l) N/EPA 300	TKN (mg/l) EPA 351.2	Enterococcus (MPN/100ml) SM 9230B	Fecal Coliform (MPN/100ml) SM 9221	Total Coliform (MPN/100ml) SM 9221
C-1	10/21/2003	7.22	3490	ND	ND	10	ND	2	2
C-2	10/21/2003	0.27	5330	ND	ND	0.79	ND	ND	ND
MW-5	10/20/2003	ND	291	6.46	ND	2.0	1553.1	ND	ND
P-1	10/20/2003	ND	116	4.07	ND	0.10	1.0	ND	2
P-7	10/21/2003	ND	153	0.07	ND	0.65	125.4	23	1600
P-9	10/20/2003	1.49	214	0.66	ND	1.5	13.2	ND	2
SMBRP-10c	10/20/2003	ND	1440	0.67	ND	2.6	125.7	2	2
SMBRP-11	10/20/2003	ND	234	0.45	ND	0.16	3.0	ND	ND
SMBRP-12	10/20/2003	6.29	263	ND	ND	6.5	ND	ND	ND
SMBRP-13	10/20/2003	ND	260	ND	ND	0.15	2.0	ND	ND
SMBRP-14	10/20/2003	20.4	91.8	ND	ND	100	1.0	300	1600
SMBRP-15b	10/20/2003	0.18	155	1.64	ND	0.48	ND	ND	ND
SMBRP-16	10/20/2003	ND	355	3.66	ND	0.73	ND	ND	ND
SMBRP-2	10/21/2003	ND	242	ND	ND	1.3	2419.2	ND	ND
SMBRP-3c	10/21/2003	ND	123	0.37	ND	1.4	2.0	2	1600
SMBRP-6	10/21/2003	ND	130	0.27	ND	1.3	ND	ND	900
SMBRP-7b	10/21/2003	ND	534	ND	ND	0.43	ND	ND	ND
SMBRP-8	10/21/2003	ND	213	31.6	ND	0.53	2419.2	ND	ND
SMBRP-9	10/20/2003	ND	163	31.2	ND	0.10	124.5	ND	ND

Source: Raw Data, Pat-Chem Laboratories, 2003.
Abbreviations: ND=non-detect mg/l=milligrams per liter MPN/100ml=most prabale number per 100 milliliters
Date/Initials: CAW 6/20/03

Pathname: O:\Proj-01\1269-W-Malibu\Sampling_SlugTests\MalibuAnalytes.mdb rptMalibuAnalyte

TABLE 15: MALIBU ANALYTICAL RESULTS SUMMARY - EVENT 8 (11/17/03-11/18/03)

Well ID	Sample Date	Ammonia (mg/l) N/EPA 350.2	Chloride (mg/l) EPA 300.0	Nitrate (mg/l) N/EPA 300	Nitrite (mg/l) N/EPA 300	TKN (mg/l) EPA 351.2	Enterococcus (MPN/100ml) SM 9230B	Fecal Coliform (MPN/100ml) SM 9221	Total Coliform (MPN/100ml) SM 9221
C-1	11/18/2003	3.75	4050	0.02	ND	8.3	ND	ND	8
C-2	11/18/2003	0.21	2670	0.03	ND	0.78	4	8	30
MW-5	11/18/2003	ND	119	2.39	ND	0.16	4.1	8	23
P-1	11/18/2003	0.08	115	4.99	ND	0.74	1	ND	14
P-7	11/18/2003	0.04	160	0.09	0.02	0.35	55.9	50	900
P-9	11/17/2003	2.11	241	0.12	ND	5	1	ND	6
SMBRP-10c	11/17/2003	0.06	1280	0.7	ND	1.4	43.5	ND	ND
SMBRP-11	11/18/2003	0.11	259	0.09	ND	0.38	ND	13	13
SMBRP-12	11/17/2003	3.66	225	0.02	ND	8.7	ND	ND	ND
SMBRP-13	11/17/2003	0.06	312	0.03	ND	0.27	2	ND	2
SMBRP-14	11/17/2003	15.5	105	0.03	0.02	33	5.2	500	1600
SMBRP-15b	11/18/2003	ND	138	1.56	0.03	0.4	ND	ND	ND
SMBRP-16	11/17/2003	0.32	418	3	0.09	1.5	3.1	ND	2
SMBRP-2	11/18/2003	0.07	330	0.14	ND	0.9	1119.8	ND	23
SMBRP-3c	11/18/2003	ND	125	0.48	ND	0.16	1	ND	17
SMBRP-6	11/18/2003	ND	145	0.93	ND	0.2	2	33	34
SMBRP-7b	11/18/2003	0.18	497	ND	ND	0.79	19.6	4	4
SMBRP-8	11/18/2003	ND	169	48.1	ND	0.9	8.4	22	23
SMBRP-9	11/17/2003	0.15	183	22.3	ND	0.48	1	17	500

Source: Raw Data, Pat-Chem Laboratories, 2004.
Abbreviations: ND=non-detect mg/l=milligrams per liter MPN/100ml=most prabale number per 100 milliliters
Date/Initials: CAW 6/20/03; rev ANM 2/3/04.

Pathname: O:\Proj-01\1269-W-Malibu\Sampling_SlugTests\MalibuAnalytes.mdb rptMalibuAnalyte

TABLE 16: MALIBU ANALYTICAL RESULTS SUMMARY - EVENT 9 (12/15/03-12/16/03)

Well ID	**Sample Date**	**Ammonia (mg/l) N/EPA 350.2**	**Chloride (mg/l) EPA 300.0**	**Nitrate (mg/l) N/EPA 300**	**Nitrite (mg/l) N/EPA 300**	**TKN (mg/l) EPA 351.2**	**Enterococcus (MPN/100ml) SM 9230B**	**Fecal Coliform (MPN/100ml) SM 9221**	**Total Coliform (MPN/100ml) SM 9221**
C-1	12/16/2003	3.42	7130	ND	ND	6.3	ND	ND	ND
C-2	12/16/2003	0.3	5750	ND	ND	1	571.7	ND	ND
MW-5	12/16/2003	ND	139	28.5	0.39	0.19	ND	ND	2
P-1	12/15/2003	ND	62.3	2.89	ND	0.18	1	ND	ND
P-7	12/16/2003	ND	168	0.57	0.03	0.23	3	8	23
P-9	12/16/2003	1.17	270	1.11	ND	2	8.5	ND	ND
SMBRP-10c	12/15/2003	ND	1450	0.59	ND	1.5	5.2	ND	2
SMBRP-11	12/16/2003	ND	257	0.26	ND	0.29	7	ND	ND
SMBRP-12	12/15/2003	7.19	411	0.02	ND	9.6	1	2	4
SMBRP-13	12/15/2003	0.14	356	0.02	ND	1.2	19.9	ND	ND
SMBRP-14	12/15/2003	16.4	98.6	0.02	ND	31	2	1600	1600
SMBRP-15b	12/15/2003	0.02	161	1.7	ND	0.66	ND	ND	ND
SMBRP-16	12/15/2003	0.04	404	4.11	ND	1.1	1	ND	ND
SMBRP-2	12/16/2003	ND	453	0.18	ND	0.93	1413.6	ND	2
SMBRP-3c	12/16/2003	ND	168	1	ND	0.2	1	ND	ND
SMBRP-6	12/16/2003	ND	145	1.55	ND	0.35	ND	ND	ND
SMBRP-7b	12/15/2003	0.17	565	0.03	ND	0.59	ND	ND	ND
SMBRP-8	12/16/2003	ND	226	2.61	ND	0.2	2419.7	ND	ND
SMBRP-9	12/15/2003	ND	166	21.9	ND	0.48	ND	ND	ND

Source: Raw Data, Pat-Chem Laboratories, 2004.
Abbreviations: ND=non-detect   mg/l=milligrams per liter   MPN/100ml=most prabale number per 100 milliliters
Date/Initials: CAW 6/20/03; rev ANM 2/3/04.

Pathname: O:\Proj-01\1269-W-Malibu\Sampling_SlugTests\MalibuAnalytes.mdb rptMalibuAnalyte

TABLE 17: MALIBU ANALYTICAL RESULTS SUMMARY - EVENT 10 (1/19/04-1/20/04)

Well ID	Sample Date	Ammonia (mg/l) N/EPA 350.2	Chloride (mg/l) EPA 300.0	Nitrate (mg/l) N/EPA 300	Nitrite (mg/l) N/EPA 300	TKN (mg/l) EPA 351.2	Enterococcus (MPN/100ml) SM 9230B	Fecal Coliform (MPN/100ml) SM 9221	Total Coliform (MPN/100ml) SM 9221
C-1	1/20/2004	ND	6380	0.06	0.02	7.3	ND	2	2
C-2	1/20/2004	0.48	6560	0.02	0.02	0.94	4.1	ND	ND
MW-5	1/20/2004	ND	90	1.31	0.02	ND	ND	ND	ND
P-1	1/19/2004	ND	150	4.58	ND	ND	ND	ND	4
P-7	1/20/2004	0.04	177	0.5	0.04	0.52	12	12	80
P-9	1/20/2004	0.51	290	2.13	0.1	1	13.4	4	8
SMBRP-10c	1/19/2004	ND	1530	1.43	ND	0.24	2	ND	ND
SMBRP-11	1/20/2004	ND	193	1.54	0.03	0.2	15.3	ND	ND
SMBRP-12	1/19/2004	7.82	535	0.07	ND	22	ND	2	2
SMBRP-13	1/19/2004	ND	464	0.24	ND	ND	2	ND	2
SMBRP-14	1/19/2004	16.2	106	0.05	0.02	36	22.8	1600	1600
SMBRP-15b	1/20/2004	ND	162	1.46	0.05	ND	ND	ND	ND
SMBRP-16	1/19/2004	0.06	453	4.68	0.06	0.1	ND	ND	ND
SMBRP-2	1/20/2004	0.25	543	0.06	0.02	0.81	1413.6	ND	ND
SMBRP-3c	1/20/2004	0.03	185	2.31	0.02	ND	1	2	4
SMBRP-6	1/20/2004	ND	158	4.34	0.03	ND	7.4	ND	2
SMBRP-7b	1/19/2004	0.1	543	0.07	ND	0.13	ND	6	350
SMBRP-8	1/20/2004	ND	230	48.4	0.04	ND	2419.2	60	170
SMBRP-9	1/19/2004	ND	211	30.8	ND	ND	14.2	ND	ND

Source: Raw Data, Pat-Chem Laboratories, 2004.
Abbreviations: ND=non-detect   mg/l=milligrams per liter   MPN/100ml=most prabale number per 100 milliliters
Date/Initials: CAW 6/20/03; rev ANM 2/3/04.

Pathname: O:\Proj-01\1269-W-Malibu\Sampling_SlugTests\MalibuAnalytes.mdb rptMalibuAnalyte

TABLE 18: MALIBU ANALYTE RESULTS SUMMARY - EVENT 11 (2/16/04-2/17/04)

Well ID	Sample Date	Ammonia (mg/l) N/EPA 350.2	Chloride (mg/l) EPA 300.0	Nitrate (mg/l) N/EPA 300	Nitrite (mg/l) N/EPA 300	TKN (mg/l) EPA 351.2	Enterococcus (MPN/100ml) SM 9230B	Fecal Coliform (MPN/100ml) SM 9221	Total Coliform (MPN/100ml) SM 9221
C-1	2/17/2004	3.78	577	0.08	ND	6.3	1	ND	ND
C-2	2/17/2004	0.61	8100	0.08	ND	1.3	7.3	ND	ND
MW-5	2/17/2004	0.12	86.9	1.46	ND	0.28	ND	ND	ND
P-1	2/16/2004	0.25	137	3.53	ND	0.61	ND	ND	2
P-7	2/17/2004	0.02	169	0.54	0.05	0.24	22.5	2	23
P-9	2/17/2004	3.09	267	0.15	ND	3.9	20.9	ND	ND
SMBRP-10c	2/16/2004	0.26	1410	1.31	ND	1.3	1	ND	ND
SMBRP-11	2/17/2004	0.11	306	0.25	ND	0.28	5	ND	ND
SMBRP-12	2/16/2004	ND	496	0.03	ND	12	1	ND	ND
SMBRP-13	2/16/2004	0.05	2290	0.42	ND	0.4	26	2	2
SMBRP-15b	2/17/2004	0.09	172	1.24	0.06	0.2	9.1	ND	ND
SMBRP-16	2/16/2004	0.04	400	5	0.03	0.99	ND	ND	2
SMBRP-2	2/17/2004	0.33	6750	0.09	ND	0.64	435.2	ND	ND
SMBRP-3c	2/17/2004	0.16	314	3.79	ND	0.38	1	ND	ND
SMBRP-6	2/17/2004	0.05	157	6.88	ND	0.27	5.2	ND	ND
SMBRP-7b	2/16/2004	0.42	524	0.03	ND	0.49	ND	ND	ND
SMBRP-8	2/17/2004	0.09	221	48.6	0.02	0.18	5	ND	2
SMBRP-9	2/16/2004	0.09	201	34.7	0.02	0.11	ND	ND	ND

Source: Raw Data, Pat-Chem Laboratories, 2004.
Abbreviations: ND=non-detect mg/l=milligrams per liter MPN/100ml=most prabale number per 100 milliliters
Date/Initials: CAW 6/20/03; rev ANM 2/3/04.

Pathname: O:\Proj-01\1269-W-Malibu\Sampling_SlugTests\MalibuAnalytes.mdb rptMalibuAnalyte

TABLE 19: MALIBU ANALYTE RESULTS SUMMARY - EVENT 12 (3/15/04-3/16/04)

Well ID	Sample Date	Ammonia (mg/l) N/EPA 350.2	Chloride (mg/l) EPA 300.0	Nitrate (mg/l) N/EPA 300	Nitrite (mg/l) N/EPA 300	TKN (mg/l) EPA 351.2	Enterococcus (MPN/100ml) SM 9230B	Fecal Coliform (MPN/100ml) SM 9221	Total Coliform (MPN/100ml) SM 922121
C-1	3/16/2004	2.65	3280	0.04	ND	4.7	32.3	ND	ND
C-2	3/16/2004	0.23	6920	0.03	ND	0.84	4.1	ND	ND
MW-5	3/16/2004	0.02	89.2	2.57	ND	0.29	ND	ND	ND
P-1	3/15/2004	0.04	151	3.75	ND	0.11	ND	ND	ND
P-7	3/15/2004	0.02	169	0.57	ND	0.18	7.4	ND	30
P-9	3/16/2004	2.59	228	0.32	ND	3.6	45.7	ND	110
SMBRP-10c	3/15/2004	0.05	1340	1.79	0.02	1.3	5.1	ND	ND
SMBRP-11	3/15/2004	0.04	164	3.43	ND	0.11	2	ND	ND
SMBRP-12	3/15/2004	1.01	206	ND	ND	12	ND	ND	ND
SMBRP-13	3/15/2004	0.02	6900	0.41	ND	1.2	7.4	ND	2
SMBRP-14	3/15/2004	0.48	105	0.02	ND	22	6.3	1600	1600
SMBRP-15b	3/16/2004	0.08	176	1.05	0.03	0.25	2	ND	2
SMBRP-16	3/15/2004	0.03	212	5.12	0.05	0.7	1	ND	2
SMBRP-2	3/16/2004	0.17	537	0.07	ND	0.58	25.7	ND	30
SMBRP-3c	3/16/2004	0.12	146	4.27	ND	0.18	ND	ND	ND
SMBRP-6	3/16/2004	0.11	126	2.74	ND	0.3	10.7	11	110
SMBRP-7b	3/15/2004	0.03	260	0.02	ND	0.67	691	ND	20
SMBRP-8	3/16/2004	0.02	139	60.2	ND	0.18	10.5	ND	ND
SMBRP-9	3/16/2004	0.02	228	38.5	ND	0.24	10.7	ND	ND

Source: Raw Data, Pat-Chem Laboratories, 2004.
Abbreviations: ND=non-detect mg/l=milligrams per liter MPN/100ml=most prabale number per 100 milliliters
Date/Initials: CAW 6/20/03; rev ANM 2/3/04.

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Risk Assessment of Decentralized Wastewater Treatment Systems
City of Malibu, California
TABLE 20: Summary of Sampling Program Results for Total N

Well ID	Number of Samples	Minimum Total N (mg/L)	Mean Total N +/- 1 Standard Deviation (mg/L)	Maximum Total N (mg/L)
MW-5	12	1.31	9.43 +/- 9.27	31.89
SMBRP-11	12	0.2	2.28 +/- 2.03	6.67
SMBRP-9	12	3.03	24.88 +/- 10.24	39.62
SMBRP-10c	12	0.56	2.67 +/- 1.61	6.13
SMBRP-16	12	2.48	5.03 +/- 1.53	7.21
SMBRP-15b	12	0.91	1.70 +/- 0.54	2.76
SMBRP-12	12	6.5	11.95 +/- 3.70	22.07
SMBRP-8	12	2.61	44.02 +/- 19.86	65.74
SMBRP-7b	12	0.13	0.89 +/- 0.62	2.26
SMBRP-13	12	ND	0.83 +/- 0.64	2.20
SMBRP-6	12	ND	2.37 +/- 2.58	8.21
P-1	12	2.82	4.72 +/- 1.73	8.01
P-9	12	0.12	3.61 +/- 1.99	7.23
P-7	12	0.18	0.80 +/- 0.47	1.65
C-1	12	3.2	6.47 +/- 2.49	10.62
C-2	12	0.55	1.01 +/- 0.43	1.93
SMBRP-14	11	ND	32.63 +/- 23.34	100.20
SMBRP-3c	12	ND	2.20 +/- 1.81	5.69
SMBRP-2	12	0.58	7.23 +/- 9.45	29.20
SMBRP-1	4	ND	3.29 +/- 1.48	5.39

Source: Laboratory reports from Pat-Chem Laboratories, Inc., 2003 and 2004. STONE ENVIRONMENTAL, INC.

Notes: Mean total nitrogen concentrations were calculated using the following formula:

[Mean Nitrate-N] + [Mean Nitrite-N] + [Mean Total Kjeldahl N] = [Mean Total N] (all concentrations in mg/L)

Total N = Total nitrogen; ND = not detected

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Date/init: 05-12-04, anm

Risk Assessment of Decentralized Wastewater Treatment Systems
City of Malibu, California
TABLE 21: Summary of Sampling Program Results for Ammonia-N

Well ID	Number of Samples	Minimum Ammonia-N (mg/L)	Mean Ammonia-N +/- 1 Standard Deviation (mg/L)	Maximum Ammonia-N (mg/L)
MW-5	12	ND	0.11 +/- 0.13	0.39
SMBRP-11	12	ND	0.15 +/- 0.13	0.37
SMBRP-9	12	ND	0.18 +/- 0.18	0.47
SMBRP-10c	12	ND	0.19 +/- 0.18	0.47
SMBRP-16	12	ND	0.82 +/- 1.87	6.08
SMBRP-15b	12	ND	0.24 +/- 0.38	1.21
SMBRP-12	12	ND	6.63 +/- 2.62	10.2
SMBRP-8	12	ND	0.35 +/- 0.55	1.44
SMBRP-7b	12	ND	0.53 +/- 0.63	2.29
SMBRP-13	12	ND	0.71 +/- 1.87	6.03
SMBRP-6	12	ND	0.15 +/- 0.11	0.36
P-1	12	ND	0.16 +/- 0.12	0.41
P-9	12	0.31	1.81 +/- 1.02	3.35
P-7	12	ND	0.14 +/- 0.17	0.5
C-1	12	ND	3.73 +/- 2.28	8.57
C-2	12	0.11	0.38 +/- 0.19	0.76
SMBRP-14	11	ND	13.90 +/- 7.86	23.8
SMBRP-3c	12	ND	0.16 +/- 0.07	0.24
SMBRP-2	12	ND	0.74 +/- 0.83	2.72
SMBRP-1	4	ND	1.39 +/- 0.92	2.52

Source: Laboratory reports from Pat-Chem Laboratories, Inc., 2003 and 2004. STONE ENVIRONMENTAL, INC.

Notes: Mean ammonia-N concentrations were calculated as arithmetic means.

Path: O:\Proj-01\1269-W-Malibu\Reports\Final report\Final_Submittal\Tables\Table20-28_AnalyteStatistics.xls

Date/init: 05-12-04, anm

Risk Assessment of Decentralized Wastewater Treatment Systems
City of Malibu, California
TABLE 22: Summary of Sampling Program Results for TKN

Well ID	Number of Samples	Minimum TKN (mg/L)	Mean TKN +/- 1 Standard Deviation (mg/L)	Maximum TKN (mg/L)
MW-5	12	ND	0.75 +/- 0.99	3.00
SMBRP-11	12	0.11	0.46 +/- 0.28	0.98
SMBRP-9	12	ND	0.37 +/- 0.30	1.10
SMBRP-10c	12	0.24	1.42 +/- 0.78	2.70
SMBRP-16	12	0.1	0.97 +/- 0.44	1.60
SMBRP-15b	12	ND	0.41 +/- 0.24	1.00
SMBRP-12	12	6.5	11.90 +/- 3.68	22.00
SMBRP-8	12	ND	0.58 +/- 0.53	1.90
SMBRP-7b	12	0.13	0.76 +/- 0.44	1.70
SMBRP-13	12	ND	0.53 +/- 0.36	1.20
SMBRP-6	12	ND	0.55 +/- 0.43	1.30
P-1	12	ND	0.36 +/- 0.28	0.85
P-9	12	ND	2.72 +/- 1.29	5.00
P-7	12	0.18	0.39 +/- 0.21	0.92
C-1	12	3.2	6.31 +/- 2.26	10.00
C-2	12	0.55	0.85 +/- 0.19	1.30
SMBRP-14	11	ND	32.55 +/- 23.28	100.00
SMBRP-3c	12	ND	0.39 +/- 0.36	1.40
SMBRP-2	12	0.58	7.11 +/- 9.41	29.00
SMBRP-1	4	ND	3.03 +/- 1.28	4.90

Source: Laboratory reports from Pat-Chem Laboratories, Inc., 2003 and 2004. STONE ENVIRONMENTAL, INC.

Notes: Mean total Kjeldahl nitrogen concentrations were calculated as arithmetic means.

TKN = Total Kjeldahl nitrogen; ND = not detected

Path: O:\Proj-01\1269-W-Malibu\Reports\Final report\Final_Submittal\Tables\Table20-28_AnalyteStatistics.xls

Date/init: 05-12-04, anm

Risk Assessment of Decentralized Wastewater Treatment Systems
City of Malibu, California
TABLE 23: Summary of Sampling Program Results for Nitrate-N

Well ID	Number of Samples	Minimum Nitrate-N (mg/L)	Mean Nitrate-N +/- 1 Standard Deviation (mg/L)	Maximum Nitrate-N (mg/L)
MW-5	12	1.31	8.48 +/- 8.02	28.5
SMBRP-11	12	0.09	1.78 +/- 1.75	5.66
SMBRP-9	12	3.03	24.49 +/- 9.94	38.5
SMBRP-10c	12	0.32	1.23 +/- 0.83	3.41
SMBRP-16	12	2.38	3.89 +/- 0.94	5.12
SMBRP-15b	12	0.91	1.24 +/- 0.29	1.7
SMBRP-12	12	ND	0.04 +/- 0.02	0.07
SMBRP-8	12	2.61	43.41 +/- 19.32	63.8
SMBRP-7b	12	ND	0.13 +/- 0.18	0.56
SMBRP-13	12	ND	0.30 +/- 0.29	1
SMBRP-6	12	ND	1.79 +/- 2.15	6.88
P-1	12	2.82	4.36 +/- 1.45	7.16
P-9	12	0.12	0.80 +/- 0.70	2.13
P-7	12	ND	0.37 +/- 0.25	0.68
C-1	12	ND	0.14 +/- 0.23	0.6
C-2	12	ND	0.14 +/- 0.23	0.61
SMBRP-14	11	ND	0.06 +/- 0.06	0.18
SMBRP-3c	12	ND	1.79 +/- 1.45	4.27
SMBRP-2	12	ND	0.10 +/- 0.05	0.18
SMBRP-1	4	ND	0.26 +/- 0.20	0.49

Source: Laboratory reports from Pat-Chem Laboratories, Inc., 2003 and 2004. STONE ENVIRONMENTAL, INC.

Notes: Mean nitrate-N concentrations were calculated as arithmetic means.

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Risk Assessment of Decentralized Wastewater Treatment Systems
City of Malibu, California
TABLE 24: Summary of Sampling Program Results for Nitrite-N

Well ID	Number of Samples	Minimum Nitrite-N (mg/L)	Mean Nitrite-N +/- 1 Standard Deviation (mg/L)	Maximum Nitrite-N (mg/L)
MW-5	12	ND	0.205 +/- 0.26	0.39
SMBRP-11	12	ND	0.030 +/- NC	0.03
SMBRP-9	12	ND	0.020 +/- NC	0.02
SMBRP-10c	12	ND	0.020 +/- NC	0.02
SMBRP-16	12	ND	0.173 +/- 0.15	0.49
SMBRP-15b	12	ND	0.043 +/- 0.02	0.06
SMBRP-12	12	ND	ND +/- NC	ND
SMBRP-8	12	ND	0.030 +/- 0.01	0.04
SMBRP-7b	12	ND	ND +/- NC	ND
SMBRP-13	12	ND	ND +/- NC	ND
SMBRP-6	12	ND	0.030 +/- NC	0.03
P-1	12	ND	ND +/- NC	ND
P-9	12	ND	0.100 +/- NC	0.1
P-7	12	ND	0.035 +/- 0.01	0.05
C-1	12	ND	0.020 +/- NC	0.02
C-2	12	ND	0.020 +/- NC	0.02
SMBRP-14	11	ND	0.020 +/- NC	0.02
SMBRP-3c	12	ND	0.020 +/- NC	0.02
SMBRP-2	12	ND	0.020 +/- NC	0.02
SMBRP-1	4	ND	ND +/- NC	ND

Source: Laboratory reports from Pat-Chem Laboratories, Inc., 2003 and 2004. STONE ENVIRONMENTAL, INC.

Notes: Mean nitrite-N concentrations were calculated as arithmetic means.

ND = not detected; NC = not calculated--insufficient data

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Risk Assessment of Decentralized Wastewater Treatment Systems
City of Malibu, California
TABLE 25: Summary of Sampling Program Results for Total Coliform

Well ID	Number of Samples	Minimum Total Coliform (MPN/100 mL)	Mean Total Coliform +/- 1 Standard Deviation (MPN/100 mL)	Maximum Total Coliform (MPN/100 mL)
MW-5	12	ND	7 +/- 9	23
SMBRP-11	12	ND	16 +/- 96	240
SMBRP-9	12	ND	71 +/- 619	1600
SMBRP-10c	12	ND	5 +/- 52	130
SMBRP-16	12	ND	2 +/- 1	4
SMBRP-15b	12	ND	4 +/- 10	21
SMBRP-12	12	ND	6 +/- 23	50
SMBRP-8	12	ND	19 +/- 110	300
SMBRP-7b	12	ND	32 +/- 174	350
SMBRP-13	12	ND	3 +/- 2	8
SMBRP-6	12	ND	22 +/- 291	900
P-1	12	ND	3 +/- 4	14
P-9	12	ND	6 +/- 40	110
P-7	12	ND	57 +/- 535	1600
C-1	12	ND	8 +/- 8	22
C-2	12	ND	14 +/- 19	50
SMBRP-14	11	ND	1983 +/- 4643	17000
SMBRP-3c	12	ND	48 +/- 918	1600
SMBRP-2	12	ND	56 +/- 970	3000
SMBRP-1	4	ND	17 +/- 28	50

Source: Laboratory reports from Pat-Chem Laboratories, Inc., 2003 and 2004. STONE ENVIRONMENTAL, INC.
Notes: Mean total coliform concentrations were calculated as geometric means.
MPN = most probable number; ND = not detected
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Risk Assessment of Decentralized Wastewater Treatment Systems
City of Malibu, California
TABLE 26: Summary of Sampling Program Results for Fecal Coliform

Well ID	Number of Samples	Minimum Fecal Coliform (MPN/100 mL)	Mean Fecal Coliform +/- 1 Standard Deviation (MPN/100 mL)	Maximum Fecal Coliform (MPN/100 mL)
MW-5	12	ND	8 +/- NC	8
SMBRP-11	12	ND	4 +/- 5	13
SMBRP-9	12	ND	64 +/- 158	240
SMBRP-10c	12	ND	2 +/- NC	2
SMBRP-16	12	ND	ND +/- NC	ND
SMBRP-15b	12	ND	2 +/- NC	2
SMBRP-12	12	ND	2 +/- 1	4
SMBRP-8	12	ND	6 +/- 25	60
SMBRP-7b	12	ND	4 +/- 2	6
SMBRP-13	12	ND	2 +/- NC	2
SMBRP-6	12	ND	8 +/- 12	33
P-1	12	ND	ND +/- NC	ND
P-9	12	ND	4 +/- NC	4
P-7	12	ND	9 +/- 17	50
C-1	12	ND	3 +/- 2	6
C-2	12	ND	7 +/- 1	8
SMBRP-14	11	ND	1214 +/- 4813	17000
SMBRP-3c	12	ND	2 +/- NC	2
SMBRP-2	12	ND	100 +/- 1468	3000
SMBRP-1	4	ND	7 +/- NC	7

Source: Laboratory reports from Pat-Chem Laboratories, Inc., 2003 and 2004. STONE ENVIRONMENTAL, INC.

Notes: Mean fecal coliform concentrations were calculated as geometric means.

MPN = most probable number; ND = not detected; NC = not calculated--insufficient data

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Risk Assessment of Decentralized Wastewater Treatment Systems
City of Malibu, California
TABLE 27: Summary of Sampling Program Results for Enterococcus

Well ID	Number of Samples	Minimum Enterococcus (MPN/100 mL	Mean Enterococcus +/- 1 Standard Deviation (MPN/100 mL)	Maximum Enterococcus (MPN/100 mL)
MW-5	12	ND	10 +/- 632	1553
SMBRP-11	12	ND	44 +/- 1062	2419
SMBRP-9	12	ND	36 +/- 1108	2419
SMBRP-10c	12	ND	34 +/- 633	1986
SMBRP-16	12	ND	25 +/- 1060	2419
SMBRP-15b	12	ND	16 +/- 981	2419
SMBRP-12	12	ND	1 +/- 1	2
SMBRP-8	12	ND	55 +/- 1208	2420
SMBRP-7b	12	ND	83 +/- 1040	2419
SMBRP-13	12	ND	7 +/- 17	55
SMBRP-6	12	ND	5 +/- 6	17
P-1	12	ND	3 +/- 8	20
P-9	12	1	10 +/- 15	46
P-7	12	ND	38 +/- 246	722
C-1	12	ND	31 +/- 232	649
C-2	12	ND	32 +/- 767	2419
SMBRP-14	11	ND	16 +/- 759	2419
SMBRP-3c	12	ND	5 +/- 763	2419
SMBRP-2	12	ND	1279 +/- 1883	7200
SMBRP-1	4	ND	163 +/- 1703	2419

Source: Laboratory reports from Pat-Chem Laboratories, Inc., 2003 and 2004. STONE ENVIRONMENTAL, INC.

Notes: Mean Enterococcus concentrations were calculated as geometric means.

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Risk Assessment of Decentralized Wastewater Treatment Systems
City of Malibu, California
TABLE 28: Summary of Sampling Program Results for Chloride

Well ID	Number of Samples	Minimum Chloride (mg/L)	Mean Chloride +/- 1 Standard Deviation (mg/L)	Maximum Chloride (mg/L)
MW-5	12	86.9	246 +/- 150	551
SMBRP-11	12	164	226 +/- 39	306
SMBRP-9	12	157	204 +/- 36	260
SMBRP-10c	12	1260	1461 +/- 121	1630
SMBRP-16	12	212	378 +/- 72	482
SMBRP-15b	12	138	167 +/- 14	187
SMBRP-12	12	206	405 +/- 132	538
SMBRP-8	12	139	180 +/- 34	230
SMBRP-7b	12	260	494 +/- 83	565
SMBRP-13	12	125	1412 +/- 2000	6900
SMBRP-6	12	120	139 +/- 15	163
P-1	12	62.3	127 +/- 25	151
P-9	12	189	276 +/- 112	613
P-7	12	153	173 +/- 13	205
C-1	12	577	3659 +/- 1880	7130
C-2	12	1620	5947 +/- 2208	9510
SMBRP-14	11	ND	112 +/- 18	150
SMBRP-3c	12	114	154 +/- 55	314
SMBRP-2	12	237	984 +/- 1826	6750
SMBRP-1	4	ND	1219 +/- 628	1920

Source: Laboratory reports from Pat-Chem Laboratories, Inc., 2003 and 2004. STONE ENVIRONMENTAL, INC.

Notes: Mean chloride concentrations were calculated as arithmetic means.

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Risk Assessment of Decentralized Wastewater Treatment Systems
City of Malibu, California
TABLE 29: Calculation of Average Nitrogen Concentrations from Nitrogen Loading Using Water Balance

Lagoon Condition	Average Modeled Groundwater Discharge to Creek/ Lagoon[1] (ft^3/day)	Nitrogen Load[2] (lb/day)	Average Nitrogen Concentration (mg/L)
flooded	78,397	8	1.7
breached	78,397	28	5.8
	126,800	11	1.4
	126,800	31	4.0

Notes / Sources:

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[1] Water budget outflow from Table 6 and 7 in Appendix 4.

[2] Current conditions based on Figures 29 and 30 in Appendix 4.

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Risk Assessment of Decentralized Wastewater Treatment Systems
City of Malibu, California
TABLE 30: Evaluation of Potentially Feasible Corrective Actions Involving Wastewater Infrastructure

Corrective Action	Water Quality Target	Implementation Time frame (years)	Time to Achieve Maximum Water Quality Benefit	Uncertainty	Costs (to be refined after stakeholder input)
Onsite Disinfection And Denitrification For Large Commercial And Multi-Family Occupancies In Malibu Lagoon Contributing Area	104 MPN/100 mL *Enterococcus* and 80% total nitrogen reduction	2 to 5	Nitrogen: 20 Years Bacteria in groundwater: <1 year	Moderate	Property Specific
Onsite Or Cluster Advanced Treatment And Disinfection For Systems With Inadequate Separation To Groundwater Within 6 Month Time Of Travel	104 MPN/100 mL *Enterococcus*	2 to 5 years	Bacteria in groundwater: <1 year	Low	Property Specific
Community Wastewater Reclamation System With Onsite Dispersal	2.2 MPN/100 mL total coliform and 80% total nitrogen reduction	6 to 10 years	Nitrogen: 20 Years Bacteria in groundwater: <1 year	Low	$9 M to $16.2 M (depending on flows) plus land acquisition[1]
Community Reclamation And Dispersal Outside Of Contributing Area	2.2 MPN/100 mL total coliform and 100% total nitrogen reduction	10 years	Nitrogen: up to 50 Years Bacteria in groundwater: <1 year	Low	Greater than or equal to $9 M to $16.2 M (depending on flows) plus land acquisition[1]
Combination Of Above	Combination dependent	Combination dependent	Combination dependent	Combination dependent	Combination dependent

Notes: [1]Questa Engineering Corporation. 2003. Preliminary Conceptual Plan for Wastewater Reclamation in the Civic Center Area, Malibu, California, Prepared for the City of Malibu.

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Risk Assessment of Decentralized Wastewater Treatment Systems
City of Malibu, California

TABLE 31: Evaluation of Existing and Potentially Feasible OWTS Management Strategies

OWTS Management Strategies	**Water Quality Target**	**Implementation Time frame (years)**	**Time to Achieve Maximum Water Quality Benefit**	**Uncertainty**	**Costs**
Site Specific Groundwater Monitoring for Large Commercial and Multifamily Systems (ongoing)[1]	REC-1 Water Quality Standards For Bacteria And 75% Nitrogen Removal	<1 To 4 Years	Requires Corrective Action To Have Water Quality Benefit	High	Property Specific
Point of Sale Inspections with Operating Permits for all systems[2]	>99% Bacteria Removal And Complete Nitrification Prior To Reaching Groundwater	10 Years	Nitrogen: 5 To 20 Years	Moderate	Property Specific
Mandatory Inspections for OWTS in Malibu Lagoon Contributing Area with operating permits for all systems	>99% Bacteria Removal And 50% Denitrification using Advanced Treatment	1-4 Years	Nitrogen: 5 To 20 Years Bacteria In Groundwater: <1 Year	Low	Property Specific
OWTS with Regional Groundwater Quality Monitoring in Malibu Lagoon Contributing Area Sampling for Nitrogen constituents and Microbial Source Tracking for bacteria identification	Determination Of Sources Of Indicator Bacteria To Receiving Waters	Depends On Types Of Sources	< 1 Year If Sources Are Removed Or Otherwise Mitigated.	Low	$400,000 to $800,000
Combination Of Above	Combination dependent	Combination dependent	Combination dependent	Combination dependent	Combination dependent

Notes: [1]Current LARWQCB WDR program
[2]City of Malibu Onsite Wastewater Management Plan, 2001

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Risk Assessment of Decentralized Wastewater Treatment Systems
City of Malibu, California
TABLE 32: Distribution of OWTS by Contributing Area and Occupancy

Contributing Area	Type of Occupancy	Approximate Number of OWTS	Estimate of Wastewater Flows (gallons per day)
Nitrogen	Commercial/Multifamily	14	65,000
	Single Family Residential	68	34,000
	Subtotal	82	99,000
Bacteria	Commercial/Multifamily	10	29,000
	Single Family Residential	151	75,000
	Subtotal	161	104,000
Nitrogen and Bacteria	Commercial/Multifamily	0	0
	Single Family Residential	8	4,000
	Subtotal	8	4,000
	TOTAL	251	207,000

RISK ASSESSMENT OF DECENTRALIZED WASTEWATER TREATMENT SYSTEMS
CITY OF MALIBU, CALIFORNIA
TABLE 33. Comparative Summary of Nitrogen Treatment Alternatives

Nitrogen Treatment Alternatives	Pretreatment Requirement/Land Area	Visual	Odors	Noise	Treatment/ Effluent Quality	Maintenance Requirements	Annual Energy Cost* (at $0.14 / Kilowatt-hour)	Estimated Construction Costs For Single Family Residential System**
N-1 Recirculating Sand Filter (non-proprietary)	▪ Septic Tank Required/ ▪ 530 ft^2 ▪ Raised bed, 2 to 3 ft high	▪ Visible gravel surface bed ▪ Wood retaining wall or earthen side slopes (2 to 3 ft high) ▪ Limited vegetative planting	▪ Minimal ▪ Vent through septic tank and building sewers	▪ Pump operation inaudible	▪ BOD/TSS: <10 mg/L ▪ Nitrogen: 50-75% removal	▪ Check pump, control, panel, alarm function ▪ Flush pressure lines annually ▪ Check inspection well levels	Recirculation Pump: ▪ 500 to 1,000 KWH ▪ $70 to $140/year	▪ Equipment: $14,000 - $18,000 ▪ Installation: $14,000 - $36,000 ▪ Subtotal: $28,000 - $54,000 ▪ Contingency: $14,000 ▪ **Total: $40,000 - $68,000**
N-2 a. Continuous Flow Suspended Growth with Internal Packing (e.g., BioMicrobics)	▪ No Septic Tank Required/ ▪ Buried tank ▪ Small aboveground blower (2-ft diameter)	▪ Blower housing visible; mitigate with enclosure	▪ Mitigated with subsurface biofilter vent	▪ Constant blower noise runs 24 hours a day ▪ Mitigate with soundproof housing	▪ BOD/TSS: <20 mg/L ▪ Nitrogen: 60-80% removal	▪ Check blower function every 6 months ▪ Clean air intake filter and sludge removal annually	Blower: ▪ 2,000 - 3,000 KWH ▪ $280 to $420/year	▪ Equipment: $9,000 - $16,000 ▪ Installation: $9,000 - $32,000 ▪ Subtotal: $18,000 - $48,000 ▪ Contingency: $12,000 ▪ **Total: $30,000 - 60,000**
N-2 b. Continuous Flow Suspended Growth with Internal Packing (e.g., MicroSepTec)	▪ No Septic Tank Required/ ▪ Buried tank ▪ Small aboveground blower (2-ft diameter)	▪ Blower housing visible; mitigate with enclosure	▪ Mitigated with subsurface biofilter vent	▪ Constant blower noise runs 24 hours a day ▪ Mitigate with soundproof housing	▪ BOD/TSS: <20 mg/L ▪ Nitrogen: 60-80% removal	▪ Check blower function every 6 months ▪ Clean air intake filter and sludge removal annually	Blower: ▪ 2,000 - 3,000 KWH ▪ $280 to $420/year	▪ Equipment: $9,000 -$13,000 ▪ Installation: $9,000 - 26,000 ▪ Subtotal: $18,000 - 39,000 ▪ Contingency: $10,000 ▪ **Total: $28,000 - $49,000**
N-3 Synthetic Media Trickling Biofilter Systems (e.g., OSI)	▪ Septic Tank Required/ ▪ 130 ft^2 ▪ Extends 2 ft above grade	▪ Fiberglass lids visible (2 ft ± above grade) ▪ No planting over units	▪ Mitigated with carbon filter	▪ Pump operation inaudible	▪ BOD/TSS: <10 mg/L ▪ Nitrogen: 50-75% removal	▪ Check pumps, control panel, and float alarms ▪ Clean media filters	Recirculation Pump: ▪ 500 to 1,000 KWH ▪ $70 to $140/year	▪ Equipment: $9,000 - $15,000 ▪ Installation: $9,000 - $30,000 ▪ Subtotal: $18,000 - $45,000 ▪ Contingency: $11,000 ▪ **Total: $29,000 - $56,000**
N-4 Anoxic System (e.g., Nitrex)	▪ Secondary Treatment Unit Required/ ▪ 60 to 75 ft^2 ▪ Below grade	▪ Two flush manhole covers visible	▪ Mitigated with carbon filter	▪ None if gravity	▪ Nitrogen 80-90% removal	▪ Replace media after 15- 20 years	▪ no energy requirements unless pump is required to dose unit	▪ Equipment: $3,000 - $10,000 ▪ Installation: $5,000 - 20,000 ▪ Subtotal: $8,000 - 30,000 ▪ Contingency: $8,000 ▪ **Total: $16,000 - $38,000**

Source: Questa Engineering Corp., 2004.

Notes: * Treatment unit only

** Not including collection system, landscaping, site access constraints, engineering, or permitting costs. Contingencies are estimated at 25% of highest subtotal cost.

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RISK ASSESSMENT OF DECENTRALIZED WASTEWATER TREATMENT SYSTEMS
CITY OF MALIBU, CALIFORNIA
TABLE 34. Comparative Summary of Bacteria Treatment Alternatives

Bacteria Treatment Alternatives	Pretreatment Requirements	Land Area	Visual	Odors	Noise	Treatment/ Effluent Quality	Maintenance Requirements	Annual Energy Cost* (at $0.14 / Kilowatt-hour)	Estimated Construction Costs For Single Family Residential System**
B-1 Traditional Septic Tank & Drainfield System	▪ Septic Tank	▪ 400-1,000 ft^2	▪ Septic Tank riser lids ▪ Drainfield inspection ports	▪ Minimal ▪ Vent through septic tank and building sewers	▪ None	▪ Bacteria removal is presumed by application rate, uniform distribution, and separation to groundwater	▪ Check solids accumulation in septic tank and pump if solids greater than 40% of tank volume ▪ Inspection every 5 years	▪ None	▪ Equipment: $8,000 ▪ Installation: $8,000 - 16,000 ▪ Subtotal: $16,000 - 24,000 ▪ Contingency $6,000 ▪ **Total: $22,000-$28,000**
B-2 Drip Dispersal System	▪ Secondary Treatment	▪ 1,000 – 10,000 ft^2	▪ Riser lid for pump chamber ▪ Valve boxes	▪ Minimal ▪ Vent through septic tank and building sewers	▪ Pump operation inaudible	▪ Enhanced bacteria removal due to separation to groundwater and very low application rates	▪ Check pump, control, panel, alarm function ▪ Flush pressure lines annually ▪ Check inspection well levels	Pump: ▪ 100 - 200 KWH ▪ $14 to $28/year	▪ Equipment: $10,000 ▪ Installation: $10,000 - $20,000 ▪ Subtotal: $20,000 - $30,000 ▪ Contingency $8,000 ▪ **Total: $28,000 - $38,000**
B-3 Bottomless Intermittent Sand Filters	▪ Septic Tank	▪ 400-1,000 ft^2	▪ Septic Tank riser lids ▪ Raised bed	▪ Minimal ▪ Vent through septic tank and building sewers	▪ Pump operation inaudible	▪ Bacteria Removal: 99% to 99.9%	▪ Check pump, control, panel, alarm function ▪ Flush pressure lines annually ▪ Check inspection well levels	Pump: ▪ 100 - 200 KWH ▪ $14 to $28/year	▪ Equipment: $17,000 ▪ Installation: $17,000 - $28,000 ▪ Subtotal: $34,000 - $45,000 ▪ Contingency $11,000 ▪ **Total: $45,800 - $56,800**
B-4 – Ultraviolet Radiation.	▪ Secondary Treatment	▪ 2-4 ft^2	▪ Riser lid	▪ Minimal ▪ Vent through treatment unit	▪ None	▪ Bacteria Removal: 99.9% to 99.99%	▪ Check twice per year and clean lamp ▪ Replace lamp as necessary	▪ 200 – 400 KWH ▪ $28 to $56/year	▪ Equipment: $1,200 ▪ Installation: $1,200 - $2,400 ▪ Subtotal: $2,400 - $3,600 ▪ Contingency $900 ▪ **Total: $3,300 - $4,500**
B-5 – Stack-Feed Chlorination	▪ Secondary Treatment	▪ 4-8 ft^2	▪ Riser lids for chlorinator and contact tank	▪ Minimal ▪ Vent through treatment unit	▪ None	▪ Bacteria Removal: 99.9% to 99.99%	▪ Inspect monthly ▪ Replace tablets every 2 to 6-months	▪ None	▪ Equipment: $500 ▪ Installation: $500 - $1,000 ▪ Subtotal: $1,000 - $1,500 ▪ Contingency $400 ▪ **Total: $1,400 - $1,900**

Source: Questa Engineering Corp., 2004.
Notes: * Treatment unit only
** Not including collection system, landscaping, site access constraints, engineering, or permitting costs. Contingencies are estimated at 25% of highest subtotal cost.
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