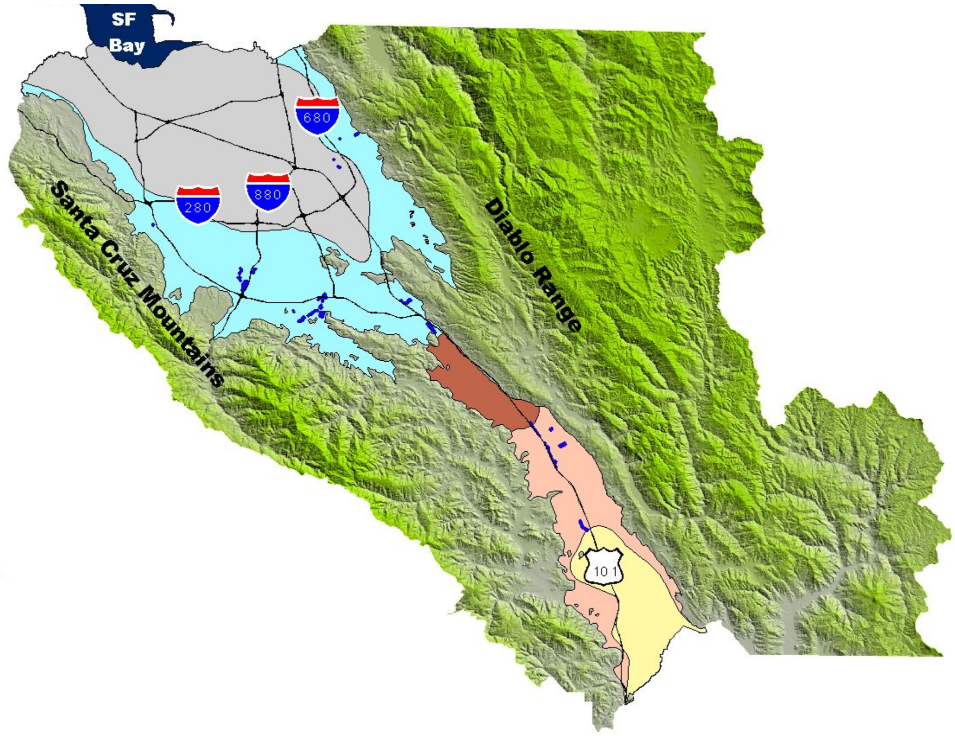
Final Report

Recycled Water Irrigation and Groundwater Study

Santa Clara and Llagas Groundwater Subbasins
Santa Clara County, California



Prepared for:

Santa Clara Valley Water District

31 August 2011

Locus Technologies

Project Overview

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Santa Clara and Llagas Groundwater Subbasins
Santa Clara County, California

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PROJECT OVERVIEW
RECYCLED WATER STUDY

1. INTRODUCTION

This report presents the results of a study to evaluate how recycled water used for irrigation may affect groundwater resources in the Santa Clara and Llagas Groundwater Subbasins in Santa Clara County. The study was completed by Locus Technologies (Locus) on behalf of the Santa Clara Valley Water District (SCVWD), in five phases which are presented in Volumes I through V of this report. The recycled water study includes a series of evaluations to determine the potential for changes to groundwater quality from using recycled water for irrigation. The study includes a literature review, data analysis, soil model, bench test, pilot study, and an assessment of soil aquifer treatment capacity and groundwater degradation potential. In addition to these assessments, the study develops proposed recycled water irrigation screening levels, best management practices, and ongoing monitoring requirements.

1.1. Purpose

The use of recycled water for irrigation presents one of the best available opportunities for water conservation efforts for Santa Clara County. The water source is renewable and readily available, with a distribution network in place for many areas. However, previous studies have identified potential impacts to groundwater resulting from the use of recycled water. The overall goal of this study is to compile and obtain information that can be used to apply recycled water for irrigation in a manner that maintains protection of groundwater resources. This goal is consistent with objectives of the SCVWD and the California State Water Resources Control Board (SWRCB).

1.1.1. SCVWD Objectives

According to the Santa Clara Valley Water District Act, SCVWD objectives related to groundwater management are to recharge the groundwater basin, conserve water, increase water supply, and to prevent waste or diminution of the SCVWD's water supply, including the groundwater. The SCVWD Board of Directors has adopted policies to expand the use of recycled water and to aggressively protect groundwater quality. One of the SCVWD's water use efficiency programs is to increase use of recycled water which promotes effective use of water supply. The SCVWD has been involved in water recycling since the 1970s. Recycled water use in the county has grown from about 1,000 acre-ft in 1998 to over 15,000 acre-ft in 2008. The SCVWD implemented this study to gain a better understanding of how recycled water used for irrigation may affect groundwater quality so that measures may be implemented to ensure that future use of recycled water will continue to increase water supply while protecting groundwater quality.

1.1.2. State Water Resources Control Board Objectives

In May 2009, the SWRCB adopted a Recycled Water Policy, which includes a goal for California to increase recycled water use above 2002 levels by at least one million acre feet per year (afy) by 2020 and by at least two million afy by 2030. The expanded use of recycled water use for irrigation would assist in meeting these goals.

SWRCB's *Statement of Policy with Respect to Maintaining High Quality Waters in California* (SWRCB Resolution No. 68-16, also known as the State Antidegradation Policy) establishes that current groundwater quality will not be degraded to the point where beneficial uses are impacted. Therefore, the expanded use of recycled water for irrigation needs to be implemented in a manner that protects the quality of groundwater.

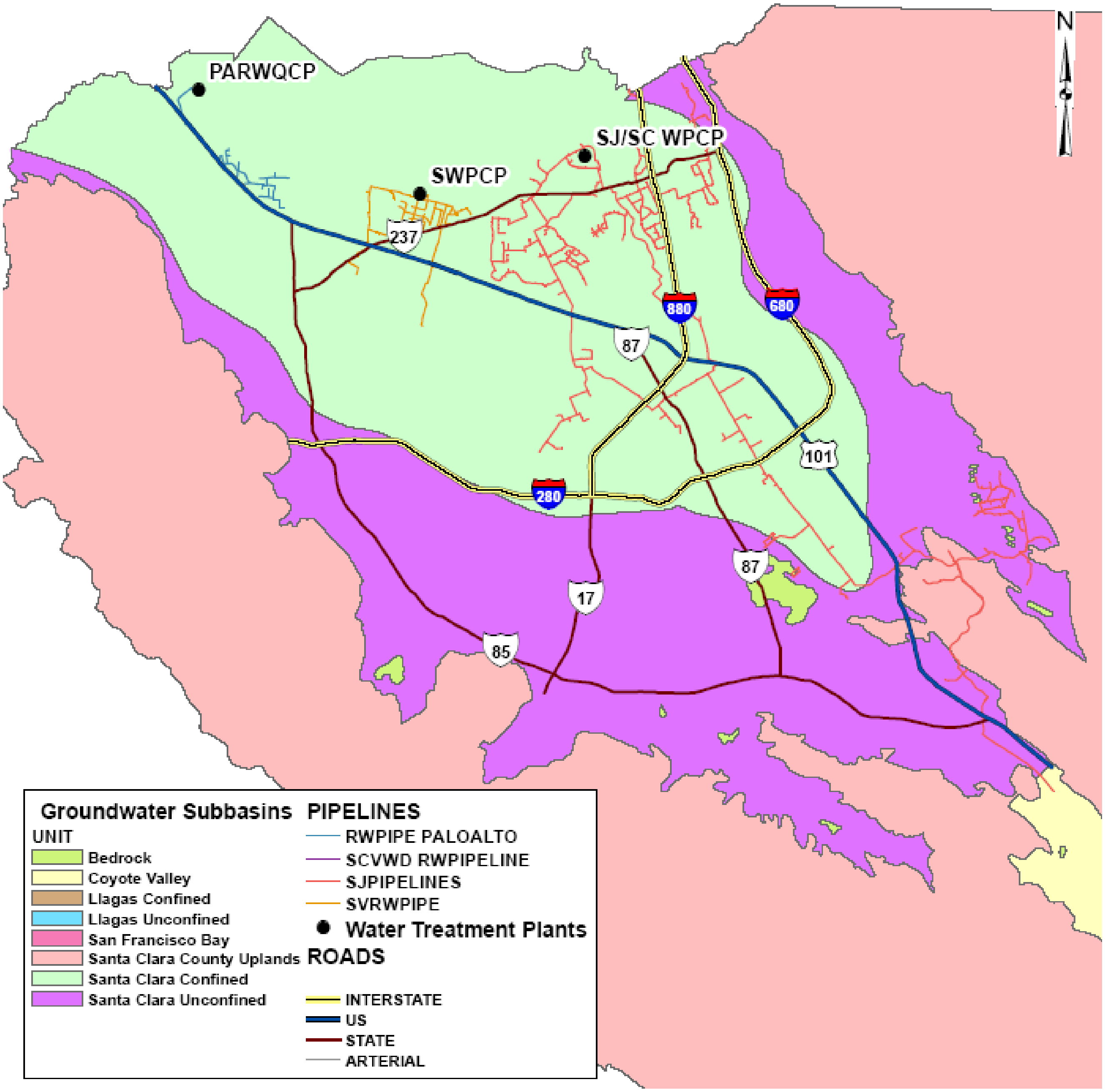
This study is designed to help expand the use of recycled water in Santa Clara County while protecting groundwater quality.

1.2. Project Study Area

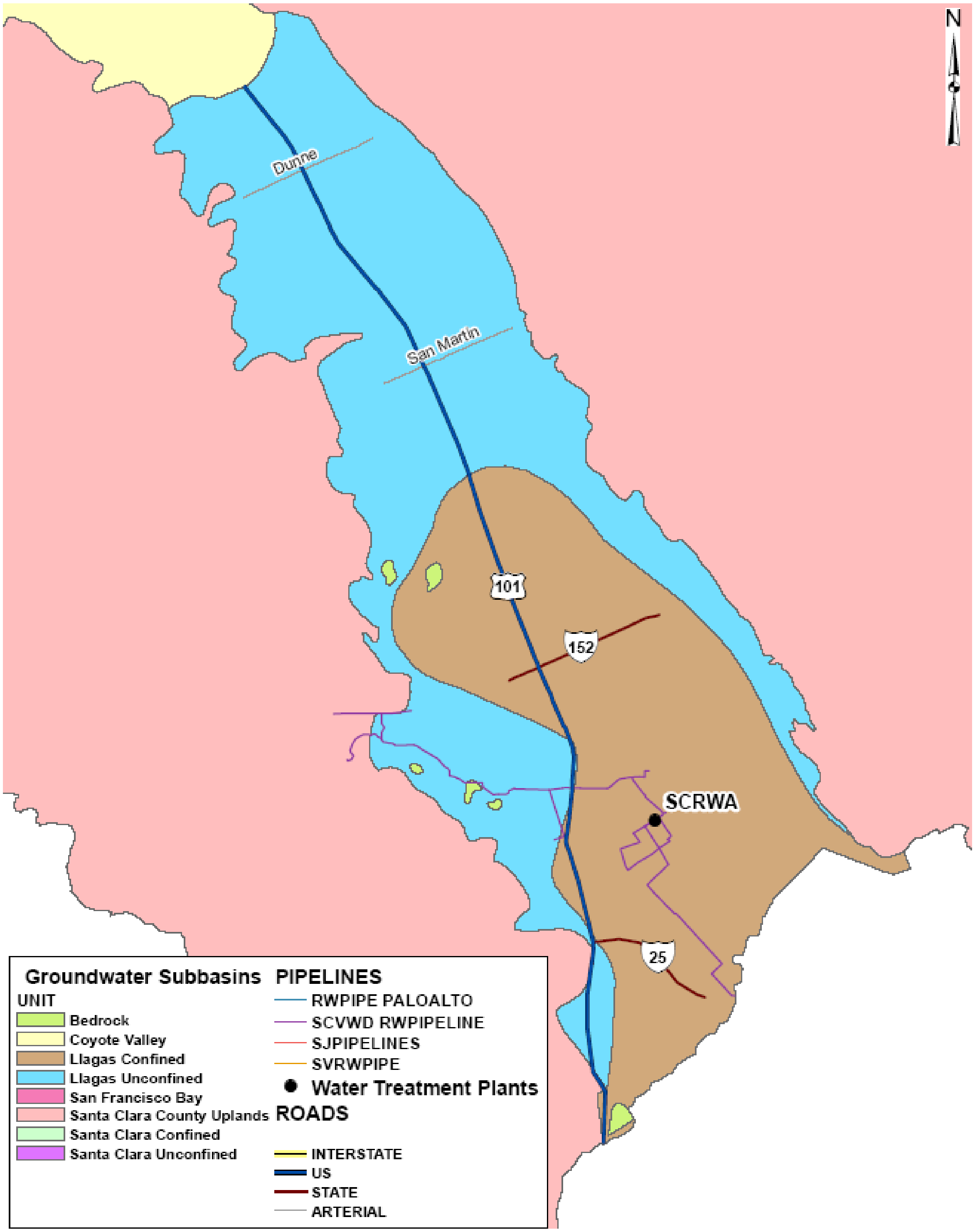
The study area for this project is defined by the Santa Clara and Llagas Groundwater Subbasins in Santa Clara County, California. The Santa Clara and Llagas Groundwater Subbasins contain both confined and unconfined areas. With few exceptions, current use of recycled water for irrigation in these groundwater subbasins is limited to confined areas, where a protective aquitard prevents direct percolation from the surface to groundwater. The overall goal of this study is to evaluate how the expanded use of recycled water for irrigation may affect groundwater quality in the Santa Clara and Llagas Subbasins. Potential impacts include changes in soil hydraulic conductivity and changes in groundwater quality.

The study area includes four sources of recycled water: Palo Alto Regional Water Quality Control Plant (PARWQCP), Sunnyvale Water Pollution Control Plant (SWPCP), San Jose/Santa Clara Water Pollution Control Plant (SJ/SC WPCP), and the South County Regional Wastewater Authority (SCRWA) in Gilroy. These four sources produce tertiary treated effluent that is currently being used within the study area. The figures below display the treatment plants in the study area and the current recycled water pipeline network.

Recycled Water Sources in Santa Clara Groundwater Subbasin:



Recycled Water Sources in Llagas Groundwater Subbasin:



1.3. Report Organization

This study includes several technical evaluations, which are organized into five volumes as follows:

1.3.1. Volume I: Literature Review and Data Analysis

The first phase of this study was a literature review, which assessed relevant recycled water studies, including those previously conducted by SCVWD. The literature review pooled current knowledge related to the fate and transport of recycled water, investigated the effects on soil permeability, identified areas where further investigation is needed, and identified investigative techniques to be used for the remainder of the study. The review also compiled a comprehensive list of constituents that have been previously detected in recycled water sources. The literature review is documented in Volume I of this report.

The data analysis is a review of the water quality of recycled water and groundwater in the study area. The available data analyzed, which originated from the District database, included groundwater samples from the Santa Clara and Llagas Subbasins and recycled water samples from the four treatment plants: PARWQCP, SWPCP, SJ/SC WPCP, and SCRWA. The analysis identified major constituents in recycled water and compared the quality to groundwater quality. The data analysis is documented in Volume I of this report.

The literature review and data analysis were used to determine which constituents should be sampled during the course of the study, including the bench test and pilot study.

1.3.2. Volume II: Soil Attenuation Model and Bench Test

As the next phase of the study, a numerical soil attenuation model was used to estimate the transport of tertiary treated recycled water constituents from the surface to groundwater. The one-dimensional model was run with scenarios in different soil types, with four recycled water constituents: bromodichloromethane, chloroform, N-nitrosodimethylamine (NDMA), and m-xylene. The model determined the attenuation of these constituents over time and depth. In addition, a sensitivity analysis was done to test the sensitivity of the different input parameters in the model. The soil attenuation model is documented in Volume II of this report.

A laboratory bench test was constructed to obtain actual physical and chemical data on recycled water transport through a range of local soil types in a controlled environment. Tertiary treated recycled water from the SJ/SC WPCP and SCRWA was applied to two-inch diameter soil cores for four months. The bench test was used to determine the permeability of varying soil cores with recycled water, quantify changes in the soil hydraulic conductivity from use of recycled water, and quantify the attenuation of recycled water constituents from percolation through the soil cores. The bench test is documented in Volume II of this report.

1.3.3. Volume III: San Jose Pilot Study

A full-scale pilot study of irrigation using tertiary treated recycled water from the SJ/SC WPCP was implemented and monitored at a site in San Jose, California. The selected pilot study site was a commercial office property with large areas of turf and other landscaping. The subsurface and irrigation characteristics were similar to many other sites within the study area that would be considered for future recycled water use. The pilot study monitored the quality of the irrigation water, pore water, and shallow groundwater to a depth of 30 feet over an 18-month period to evaluate the impact of recycled water constituents. The pilot study is documented in Volume III of this report.

1.3.4. Volume IV: Evaluation of Potential Impacts

Extrapolating data from the previous findings of the study, the soil aquifer treatment capacity and groundwater degradation potential were geographically rated, in a one to ten rating system (with ten being the worst case scenario), across the study area. Soil aquifer treatment capacity was defined in this study as the ability of the subsurface to naturally treat contaminants and is dependent on hydrogeological characteristics of a given area. The groundwater degradation potential was defined as the potential for groundwater to be impacted by recycled water used for irrigation based on the soil aquifer treatment capacity and the quality of the recycled water applied for a given area. The evaluation used is an adaptation of EPA’s DRASTIC method utilizing geographic information system (GIS) software. The evaluation is documented in Volume IV of this report.

1.3.5. *Volume V: Proposed Recycled Water Irrigation Screening Levels, Best Management Practices, and Ongoing Monitoring Recommendations*

This volume of the report includes proposed recycled water irrigation screening levels (PRWISLs), best management practices (BMPs), and ongoing monitoring recommendations. PRWISLs are advisory levels for recycled water quality and are defined as the maximum concentration of a recycled water constituent at which the minimal groundwater degradation potential could be achieved. BMPs are effective and practical methods for using recycled water in irrigation that provide successful protection to groundwater resources. BMPs evaluated in this report are specific to recycled water use as an irrigation source for landscaping with the goal of minimizing the degradation of groundwater resources. Ongoing monitoring recommendations are established to provide timely recognition of any adverse changes in groundwater quality due to application of recycled water.

1.4. Review Process

This study was peer reviewed by an expert review panel consisting of three leading experts in recycled water and contaminant fate and transport. The expert review panel provides quality assurance in each phase of the study through technical guidance and direction. The following are the members of the expert review panel:

Dr. David L. Sedlak
Professor at Department of Civil and Environmental Engineering, University of California Berkeley

Dr. Joseph P. LeClaire
Principal Scientist at Wildermuth Environmental, Inc.

Jill Robinson Haizlip
Senior Geochemist at Geologica

2. FINDINGS AND MAJOR CONCLUSIONS

Overall, the findings from the study have indicated that within the Santa Clara and Llagas Subbasins, recycled water can be used as an irrigation source in a manner that protects the groundwater quality. However, the implementation of recycled water for irrigation should proceed with some considerations in order to minimize the potential groundwater degradation. The study has shown from the literature review, bench test, and the pilot study that there are numerous constituents found in recycled water, many of which have different fate and transport characteristics. Some constituents were observed in the study to not pose an impact to groundwater while others, such as perfluorochemicals (PFCs) and NDMA, prompt some concern due to their detection in shallow groundwater during the pilot study. It was determined from the soil aquifer treatment (SAT) capacity and groundwater degradation potential (GWDP) maps of the Santa Clara and Llagas Subbasins that the most ideal areas for recycled water irrigation are generally in the areas with a confining layer and deep groundwater. These areas are found in the northern section of the confined areas in the Santa Clara Subbasin and in the southern section of the confined areas in the Llagas Subbasin.

In light of the study findings, best management practices (BMPs), ongoing monitoring recommendations, and proposed recycled water irrigation screening levels (PRWISLs) were developed. Major best management practices (BMPs) include careful site selection (considering soil aquifer treatment capacity and other methods) and consideration of improved recycled water quality (i.e. dilution, source control, or additional treatment) particularly where recycled water quality is worse than PRWISLs. Ongoing monitoring is intended to provide timely recognition of any adverse changes in groundwater quality due to application of recycled water.

2.1. Potential Threat Values

Below is a table summarizing the potential threat to groundwater with respect to each constituent based on findings from the pilot study and bench test. Each constituent is given a rating between 1 and 5, with 5 representing the highest threat. The criteria for assigning each threat are the observed attenuation of the constituent in the pilot study and bench test and the type of constituent. In general, the greater the overall attenuation behavior displayed from the bench test and pilot study the lower the threat is. Also considered is whether the constituent is naturally occurring (which would results in a lower threat) or has known health impacts (resulting in a higher threat). The type of constituent can range from general water quality parameters like alkalinity and dissolved oxygen, to emerging contaminants such as NDMA and PFCs. The threat assigned for each constituent below is a culmination of these factors. While general water quality parameters are evaluated here in terms of threat, they are useful as indicators for water stability.

Some monitored constituents were not consistently detected in the recycled water source during the study. Since the attenuation of those constituents could not be evaluated, the threat value is assigned as inconclusive. Further monitoring of recycled water sources is needed to determine whether those constituents are sufficiently present to pose a threat to groundwater.

In addition to the threat value, the table includes a recommendation on whether further monitoring of each constituent is warranted. Constituents that are recommended for further monitoring are those with a threat value of three or higher or regarded as inconclusive. Bromide, which is regarded as a good tracer for recycled water, is also recommended for further monitoring.

Constituent	**Potential Threat**	**Findings**	**Recommend for Further Monitoring?**
ORP	1	ORP is a general water quality parameter. Measurements of ORP in the bench test and pilot study suggest no major shifts in redox conditions.	N
pH	1	The pH is a general water quality parameter. The pH was near neutral throughout the pilot study and bench test. Similarity of pH across depth has indicated stable conditions in each test.	N

Chlorine, Total	1	Concentrations of chlorine were higher in groundwater than in recycled water and pore water in the pilot study.	N
Dissolved Oxygen	1	DO is a general water quality parameter. DO was 0.01 mg/L or above across depth in the pilot study indicating that anoxic conditions were unlikely. Samples from the bench test indicated oxic conditions.	N
Alkalinity, Total	1	Alkalinity is a general water quality parameter monitored in the bench test and pilot study. A greater alkalinity in the pore water equates to more stability in pH conditions.	N
Bicarbonate Alkalinity	1		N
Boron	3	Boron removal was not well observed in the bench test or pilot study.	Y
Calcium	2	Calcium concentrations are greater in the subsurface than in the recycled water in the pilot study.	Y (See SAR)
Magnesium	2	Magnesium concentrations are greater in the subsurface than in the recycled water in the pilot study.	Y (See SAR)
Sodium	4	Sodium is directly related to SAR, as well as having a direct potential effect on groundwater.	Y
Sodium Adsorption Ratio (SAR)	4	The SAR may indicate impact to soil drainage from clay swelling as a result of recycled water application when the SAR in the recycled water is higher than the SAR of the previous irrigation source.	Y
Potassium	1	Potassium data from bench test and pilot study suggested good removal.	N
Sulfate	3	In the pilot study, sulfate increased in concentration in the pore water, likely due to the contribution from soil and fertilizer. Sulfate concentration in groundwater was relatively stable in the pilot study. In the bench test, removal was not well observed. The constituent also contributes to the total dissolved solids.	Y
Nitrite	2	Nitrate/Nitrite data showed removal with depth in the pilot study. The mechanism is suspected to be attenuation by root uptake pathway.	N
Nitrate	2		N
Chloride	4	Chloride over time has shown an increasing trend in concentrations in groundwater and pore water in the pilot study. At the end of the pilot study, chloride had not yet reached stable conditions. Attenuation of chloride in the bench test was not well observed. The constituent also contributes to the total dissolved solids.	Y

Total Organic Carbon (TOC)	2	TOC was decreased by microbial activity and adsorption to soil in the pilot study and bench test; groundwater was relatively stable in pilot study. The bench test findings were consistent with the pilot study.	N
Total Filterable Residue at 180C (TDS)	3	Although TDS in the pilot study in groundwater appeared relatively stable, levels have been observed above secondary drinking water standards in both the baseline and subsequent events. The TDS in recycled water and lysimeters are also above secondary drinking water standards. In the bench test, attenuation was not well observed.	Y
Dissolved Organic Carbon	2	DOC was decreased by microbial activity and adsorption to soil in the pilot study and bench test; groundwater was relatively stable in pilot study. The bench test findings were consistent with the pilot study.	N
Bromodichloromethane (THM)	2	Bromodichloromethane was removed in the vadose zone in the pilot study. Bromodichloromethane was not detected in groundwater during the pilot study. THM data in the bench test also showed attenuative behavior.	N
Bromoform (THM)	2	Bromoform was removed in the vadose zone in the pilot study. Bromoform was not detected in groundwater during the pilot study. THM data in the bench test also showed attenuative behavior.	N
Chloroform (THM)	2	Chloroform was removed in the vadose zone in the pilot study. Chloroform was not detected in groundwater during the pilot study. THM data in the bench test also showed attenuative behavior.	N
Dibromochloromethane (THM)	2	Dibromochloromethane was removed in the vadose zone in the pilot study. Dibromochloromethane was not detected in groundwater during the pilot study. THM data in the bench test also showed attenuative behavior.	N
Carbon Tetrachloride (VOC)	1	Carbon tetrachloride was not detected in recycled water in pilot study or bench test. The constituent was also categorized as having minimal potential impact in Volume I.	N
Xylenes, Total (VOC)	1	Xylenes were not detected in recycled water in pilot study or bench test. The constituent was also categorized as having minimal potential impact in Volume I.	N
Additional 8010-list VOCs	1	VOCs were not detected in recycled water in the pilot study or bench test. VOCs excluding xylene and carbon tetrachloride were also not detected in the data analysis of Volume I.	N

Haloacetic Acids (HAA6): Bromochloroacetic Acid Dibromoacetic Acid Monobromoacetic Acid Monochloroacetic Acid Trichloroacetic Acid	4	HAA6 were not observed in the baseline groundwater samples, but were observed in the applied recycled water, pore water, and groundwater during the pilot study. In the bench test, HAA6 attenuation was not well observed. HAA6 are also anthropogenic compounds.	Y
Heterotrophic Plate Count	3	Growth was present in pore water and groundwater in the pilot study. Growth was also observed in the bench test. Attenuation was not observed.	Y
Coliforms, Total	3	Growth was present in pore water and groundwater. Growth was also observed in the bench test. Attenuation was not observed.	Y
Fecal Coliforms	3	Fecal Coliforms were not present in groundwater during the pilot study. In the bench test, fecal coliforms were not frequently detected. Attenuation was not well observed.	Y
E. Coli	Inconclusive	E. Coli was minimally detected in recycled water in the pilot study. In the bench test, E. coli was not frequently detected. Therefore the attenuation behavior could not be examined. The constituent may be present in the other recycled water sources in the study area.	Y
N-Nitroso Dimethylamine (NDMA)	5	NDMA was not observed in the baseline groundwater samples, but was observed in the applied recycled water, pore water, and groundwater during the pilot study. The majority of attenuation of NDMA could potentially be from volatilization in the vadose zone and/or biotransformation in the soil. In the bench test, NDMA attenuation was not strongly observed. NDMA is an emerging contaminant.	Y
Perfluorochemicals	5	PFCs were not observed in the baseline groundwater samples, but were observed in the applied recycled water, pore water, and groundwater during the pilot study. Similarly, in the bench test, some PFCs were observed in the effluent but not in the influent. There is potential for PFC formation from precursors. PFCs are emerging contaminants.	Y
Phosphate	1	Phosphate removal was observed in the pilot study and bench test. Mechanisms that caused removal of phosphates are suspected to be the root uptake pathway and precipitation.	N
Ethylenediaminetetraacetic acid (EDTA)	3	EDTA was not detected in recycled water in the pilot study. In the bench test attenuation was not consistently observed.	Y

Surfactants (MBAS)	3	Surfactants were minimally detected in recycled water in the pilot study. In the bench test attenuation was not consistently observed.	Y
Bromide	2	Removal of bromide in the vadose zone is low in the pilot study; however the degree of toxicity of bromide is low. Together with chloride bromide can be used as a tracer for recycled water.	Y
Nitrilotriacetic acid (NTA)	Inconclusive	NTA was not detected in the pilot study or bench test. Therefore the attenuation behavior could not be fully examined. This constituent may be present in the other recycled water sources in the study area.	Y
Perchlorate	Inconclusive	Perchlorate was not detected in recycled water during the pilot study or bench test. Therefore the attenuation behavior could not be fully examined. This constituent may be present in the other recycled water sources in the study area.	Y
Cyanide	Inconclusive	Cyanide was minimally detected in pilot study or bench test. Therefore the attenuation behavior could not be fully examined. This constituent may be present in the other recycled water sources in the study area.	Y
Terbuthylazine	Inconclusive	Terbuthylazine was minimally detected in recycled water in pilot study and bench test. Therefore the attenuation behavior could not be fully examined. The constituent may be present in the other recycled water sources in the study area.	Y

2.2. Soil Aquifer Treatment Capacity

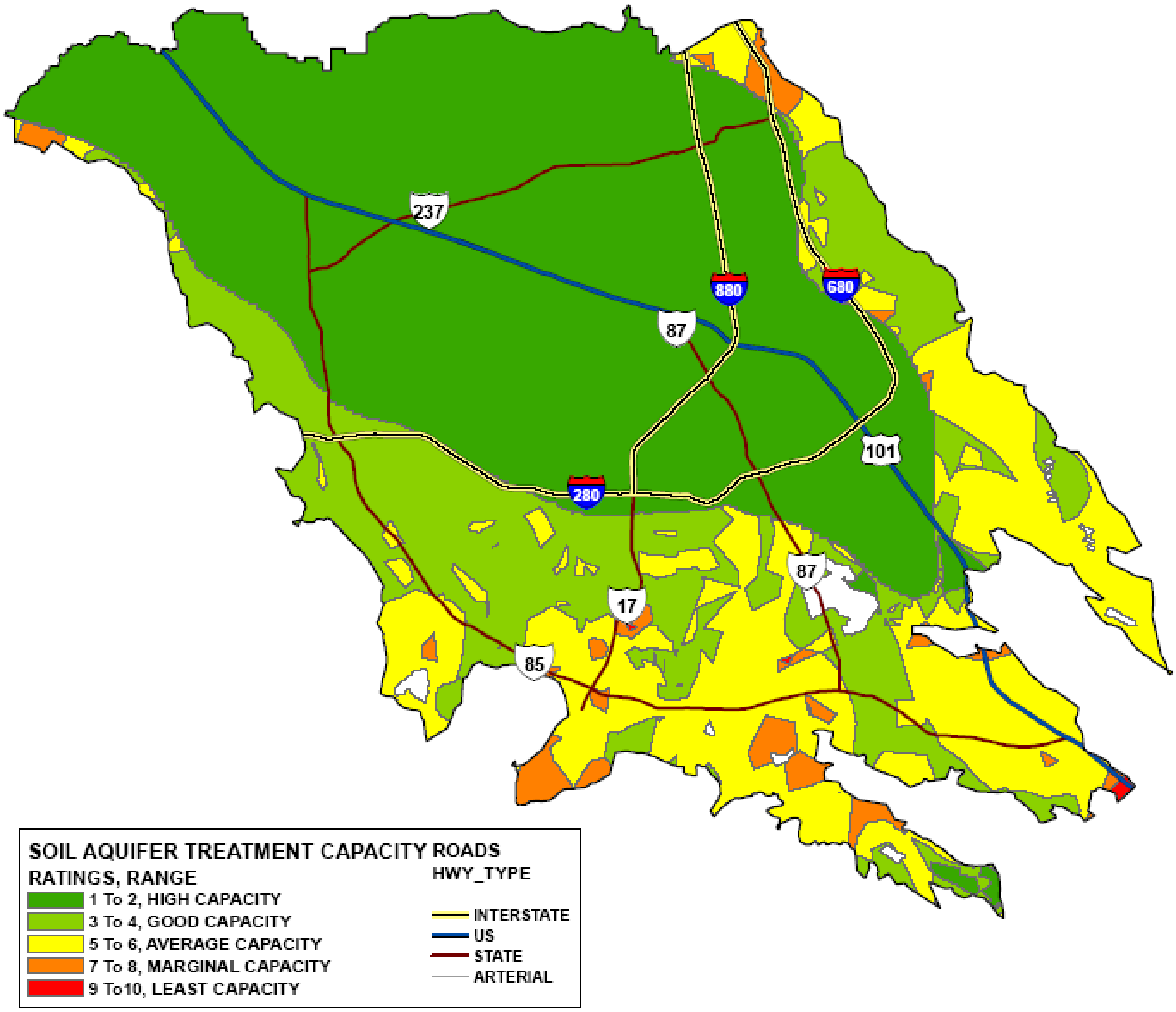
For this study, soil aquifer treatment capacity is defined as the ability of the vadose zone soil to naturally treat contaminants. The study focuses on contaminants found in recycled water. Mechanisms to lower the concentrations of contaminants include but are not exclusive to volatilization, dispersion, diffusion, sorption, precipitation, ion exchange, oxidation-reduction, transformation, and filtration. Soil aquifer treatment capacity is established from the hydrogeological characteristics of a given area.

Soil aquifer treatment capacity was determined for the entire study area on a scale of 1 to 10, with 1 representing areas with physical characteristics that are most ideal for the application of recycled water and protection of groundwater quality and 10 representing the least ideal areas.

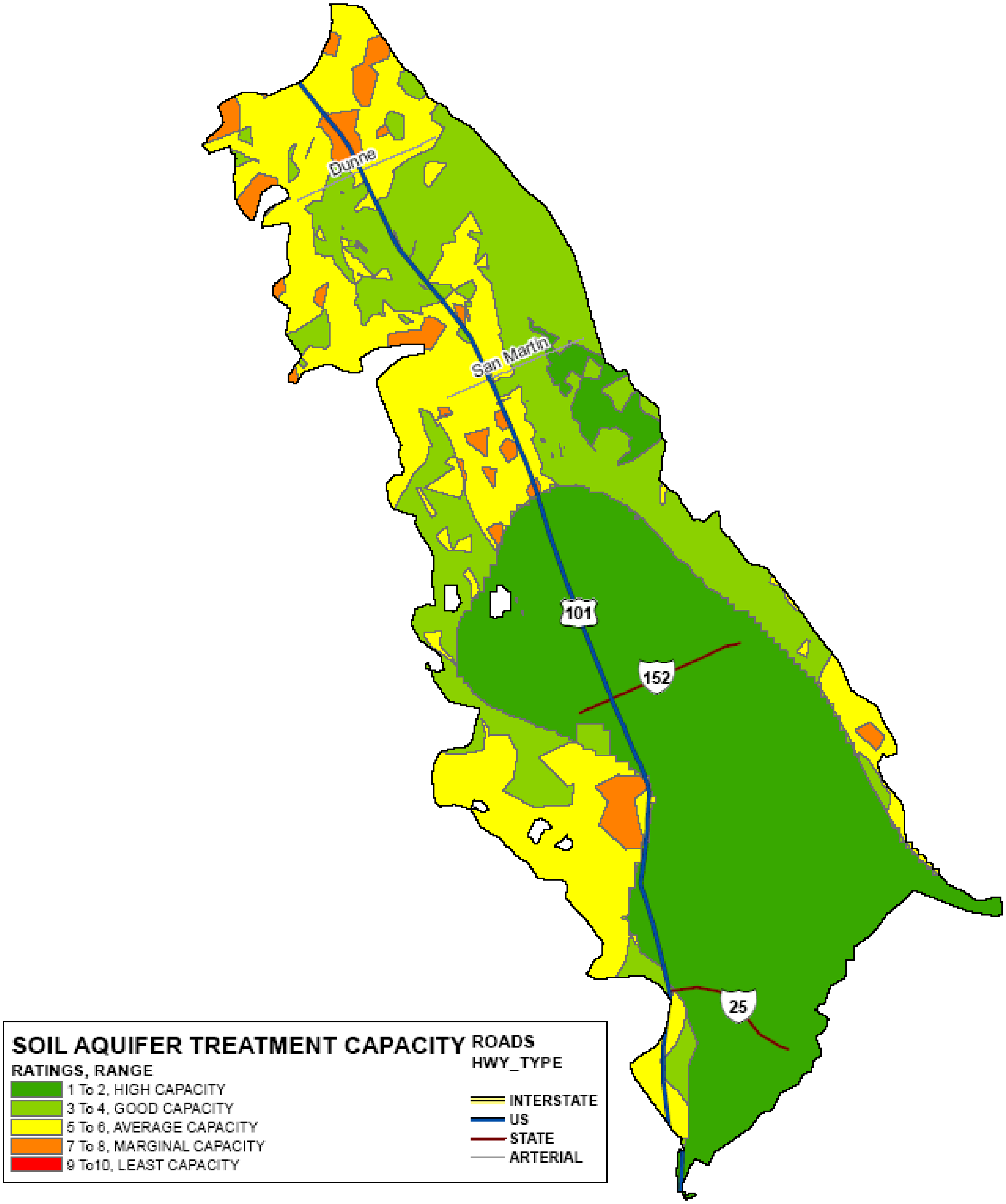
The SAT rating in the Santa Clara Subbasin ranges from 1 to 10. In the Llagas Subbasin, the SAT rating ranges from 1.5 to 9.5. In both subbasins, the confined areas were determined to have relatively high capacity due to the confining layer and deep groundwater. The unconfined areas were largely of good or average capacity. Only a few areas in the unconfined areas were regarded as having relatively marginal capacity and even fewer areas were regarded as least capacity. Areas with a lower rating tended to be characterized with a shallow depth to water and a coarse grain size distribution in the subsurface. The confining layer and deep depth to groundwater are characteristics of the most ideal areas within the study area for soil aquifer treatment capacity.

The following figures present the soil aquifer treatment capacity distribution in Santa Clara and Llagas Groundwater Subbasins.

Soil Aquifer Treatment Capacity for the Santa Clara Groundwater Subbasin:



Soil Aquifer Treatment Capacity for the Llagas Groundwater Subbasin:



2.3. Groundwater Degradation Potential

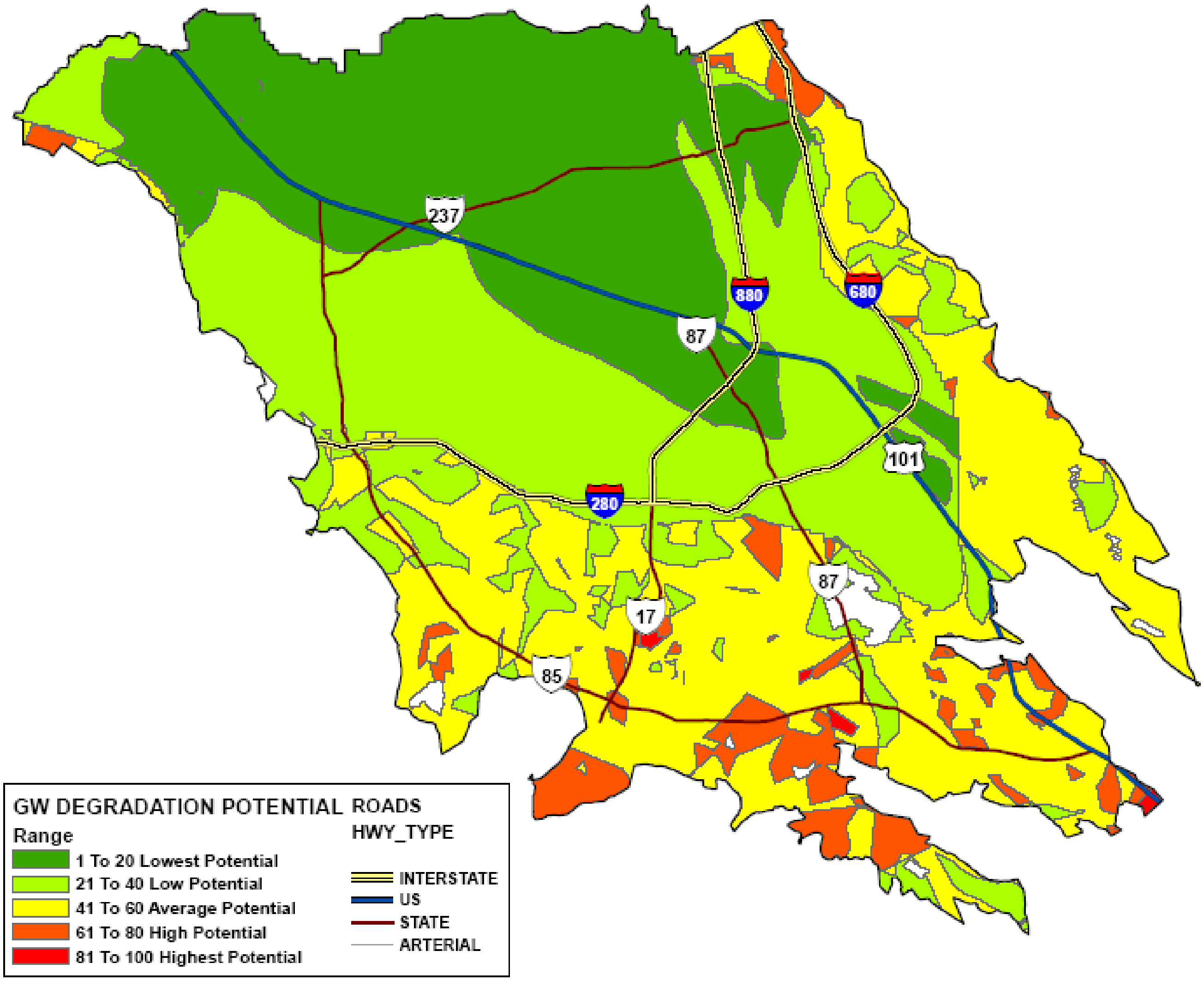
Groundwater degradation potential is defined as the potential for groundwater to be impacted by recycled water used in irrigation. Groundwater is regarded as degraded when the quality is worse than current groundwater quality as a result of irrigation, with consideration of the available assimilative capacity. For the purpose of this study, the available assimilative capacity is determined in a manner consistent with the SWRCB Recycled Water Policy by comparing current groundwater quality with applicable water quality standards, and calculating 20% of the difference between those two values. For constituents where the current groundwater concentration exceeds the water quality standard, there is zero available assimilative capacity for that constituent.

Groundwater degradation potential was determined for the entire study area on a scale of 1 to 100, with 1 representing ideal locations for irrigation with recycled water with regard to groundwater protection based on the area's physical characteristics and the quality of the local recycled water source. The maximum score of 100 represents the least ideal conditions for recycled water irrigation.

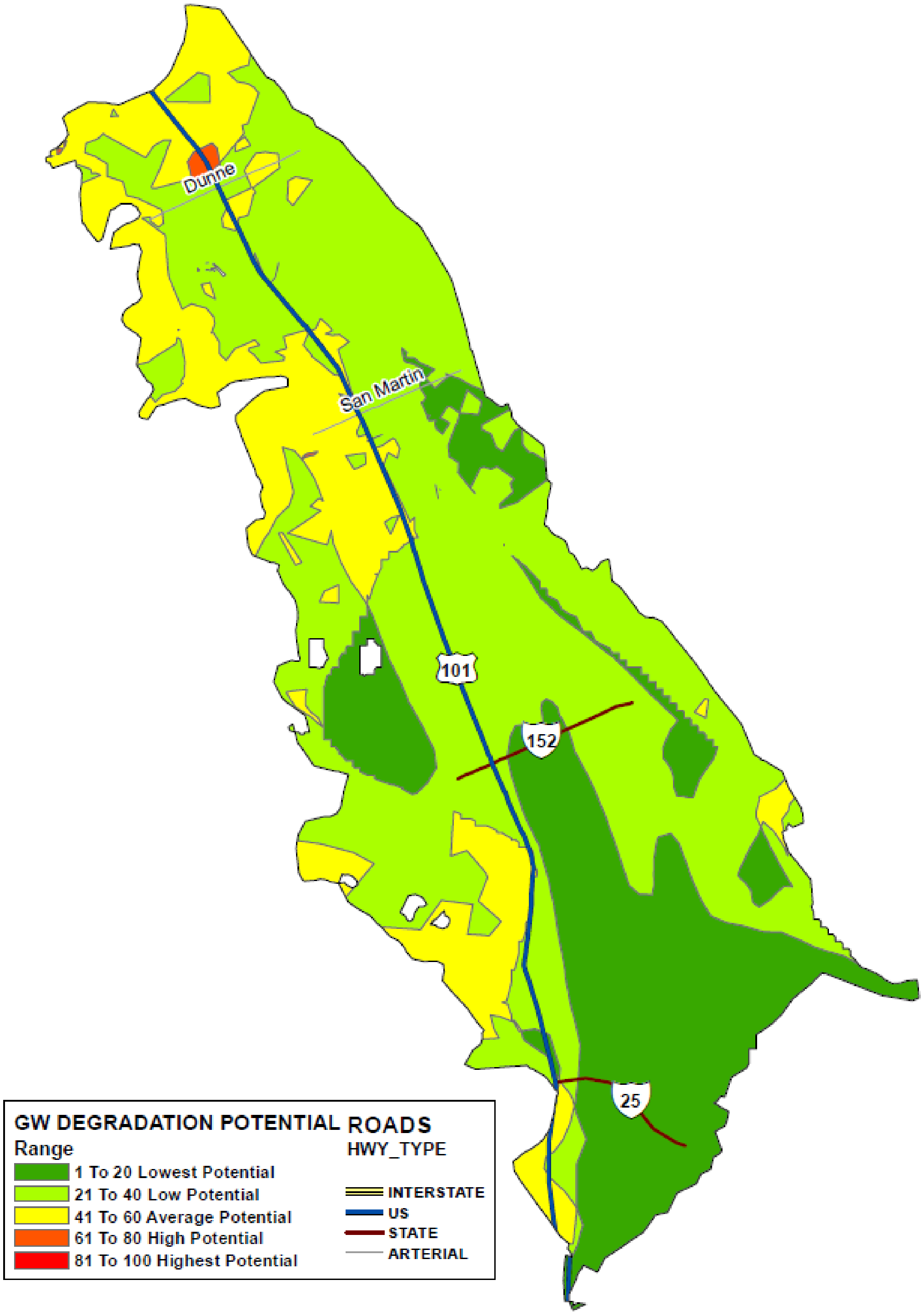
The groundwater degradation potential in the Santa Clara Subbasin is largely of lowest to average potential with a few areas regarded as high or highest. The rating in the Santa Clara Subbasin ranges from 8 to 96. Groundwater degradation potential in the Llagas Subbasin is largely of lowest to average potential and with a few areas regarded as high. The evaluation did not find any areas of the highest groundwater degradation potential in the Llagas Subbasin. In the Llagas Subbasin, the groundwater degradation potential rating ranges from 11 to 70. Comparatively, the Santa Clara and Llagas Subbasins share a similar distribution in groundwater degradation potential with a majority of lowest and low potential found in the confined areas and more average potential in the unconfined areas. Groundwater degradation potential was found to be generally low in the confined areas. Groundwater degradation potential in the unconfined areas was found to be generally average with some areas regarded as high or highest.

The distribution of the relative rating for groundwater degradation potential for the Santa Clara and Llagas Groundwater Subbasins is shown below.

Groundwater Degradation Potential for the Santa Clara Groundwater Subbasin:



Groundwater Degradation Potential for the Llagas Groundwater Subbasin:



2.4. Proposed Recycled Water Irrigation Screening Levels

Proposed recycled water irrigation screening levels (PRWISLs) are developed for irrigation, in conjunction with best management practices (BMPs) and ongoing monitoring recommendations, to protect groundwater quality. PRWISLs are based on the soil aquifer treatment capacity of a given area, the representative groundwater quality, and the constituent’s potential threat level.

The PRWISL is defined as the maximum concentration of a recycled water constituent for irrigation at which minimal groundwater degradation potential can be achieved. The PRWISL of a given constituent is developed by assuming that the other recycled water constituents are equal to or less than the representative groundwater quality. The PRWISL of a single constituent represents the maximum tolerable concentration at which the target groundwater degradation potential can no longer be achieved independent of what the other constituent concentrations are. PRWISLs are advisory levels based on the findings from this study and may be used to help guide the use and expansion of recycled water. The inputs to the PRWISLs calculations are dependent on current groundwater quality and soil aquifer treatment capacity. Therefore, the applicable PRWISL varies depending on these two factors. Tables of PRWISLs for Santa Clara and Llagas Groundwater Subbasins are shown below.

If adequate site-specific information is available, the soil aquifer treatment capacity, groundwater degradation potential, and proposed recycled water irrigation screening levels can also be calculated directly.

Recycled Water Screening Levels for the Santa Clara Groundwater Subbasin:

		Santa Clara Subbasin				
		SAT zone: 1-2	SAT zone: 3-4	SAT zone: 5-6	SAT zone: 7-8	SAT zone: 9-10
Parameter	Units					
Biological						
Coliforms, Total	%	66.67%	66.67%	66.67%	44.91%	29.06%
E. Coli	%	20.00%	20.00%	7.57%	3.45%	2.24%
Fecal Coliforms	%	20.00%	20.00%	7.57%	3.45%	2.24%
Inorganics						
Boron	µg/L	505.00	505.00	505.00	505.00	505.00
Bromide	mg/L	0.38	0.38	0.38	0.38	0.38
Calcium	mg/L	69.20	69.20	69.20	69.20	69.20
Chloride	mg/L	320.00	320.00	277.81	187.73	151.00
Magnesium	mg/L	42.20	42.20	42.20	42.20	42.20
Nitrate as NO3	mg/L	122.00	122.00	122.00	122.00	122.00
Nitrite as NO2	mg/L	5.59	5.59	5.59	5.59	5.59
Phosphate	mg/L	14.13	14.13	14.13	14.13	14.13
Potassium	mg/L	32.00	32.00	32.00	32.00	32.00
Sodium	mg/L	230.00	230.00	121.58	82.15	66.08
Sulfate	mg/L	247.00	247.00	247.00	247.00	210.79
Emerging Contaminants and DBPs						
N-Nitroso Dimethylamine (NDMA)	ng/L	490.00	11.51	6.61	5.22	4.58
Perfluorochemicals (PFBA)	ng/L	12.00	12.00	12.00	12.00	12.00
Perfluorochemicals (PFOS)	ng/L	87.00	87.00	80.74	63.82	56.01
Perfluorochemicals (PFOA)	ng/L	109.00	109.00	109.00	109.00	106.93
HAA5	µg/L	263.00	75.48	42.85	35.90	33.06
Bromochloroacetic Acid	µg/L	36.90	6.94	2.75	1.86	1.50
Total THMs	µg/L	366.00	366.00	366.00	251.23	221.17
General Water Quality Parameters						
Dissolved Organic Carbon	mg/L	9.00	9.00	9.00	9.00	9.00
Total Organic Carbon (TOC)	mg/L	9.62	9.62	9.62	9.62	5.58
Parameters with Low Occurrence in the Pilot Study						
Cyanide	mg/L	0.06	0.06	0.06	0.06	0.06
Ethylenediaminetetraacetic acid (EDTA)	µg/L	305.00	305.00	305.00	305.00	223.53
NTA	µg/L	0.00	0.00	0.00	0.00	0.00
Perchlorate	µg/L	0.00	0.00	0.00	0.00	0.00
Surfactants (MBAS)	mg/L	0.36	0.36	0.36	0.36	0.36
Terbuthylazine	µg/L	0.10	0.10	0.10	0.10	0.10

Recycled Water Screening Levels for the Llagas Groundwater Subbasin:

		PRWISLs for Llagas Subbasin				
		SAT zone: 1-2	SAT zone: 3-4	SAT zone: 5-6	SAT zone: 7-8	SAT zone: 9-10
Parameter	Units					
Biological						
Coliforms, Total	%	66.67%	66.67%	66.67%	44.91%	29.06%
E. Coli	%	20.00%	20.00%	7.57%	3.45%	2.24%
Fecal Coliforms	%	20.00%	20.00%	7.57%	3.45%	2.24%
Inorganics						
Boron	µg/L	505.00	505.00	505.00	505.00	505.00
Bromide	mg/L	0.38	0.38	0.38	0.38	0.38
Calcium	mg/L	69.20	69.20	69.20	69.20	69.20
Chloride	mg/L	320.00	320.00	235.73	159.29	128.13
Magnesium	mg/L	42.20	42.20	42.20	42.20	42.20
Nitrate as NO3	mg/L	122.00	122.00	122.00	122.00	122.00
Nitrite as NO2	mg/L	5.59	5.59	5.59	5.59	5.59
Phosphate	mg/L	14.13	14.13	14.13	14.13	14.13
Potassium	mg/L	32.00	32.00	32.00	32.00	32.00
Sodium	mg/L	230.00	230.00	110.57	74.72	60.10
Sulfate	mg/L	247.00	247.00	247.00	247.00	190.00
Emerging Contaminants and DBPs						
N-Nitroso Dimethylamine (NDMA)	ng/L	490.00	11.51	6.61	5.22	4.58
Perfluorochemicals (PFBA)	ng/L	12.00	12.00	12.00	12.00	12.00
Perfluorochemicals (PFOS)	ng/L	87.00	87.00	80.74	63.82	56.01
Perfluorochemicals (PFOA)	ng/L	109.00	109.00	109.00	109.00	106.93
HAA5	µg/L	263.00	75.48	42.85	35.90	33.06
Bromochloroacetic Acid	µg/L	36.90	6.94	2.75	1.86	1.50
Total THMs	µg/L	366.00	366.00	366.00	251.23	221.17
General Water Quality Parameters						
Dissolved Organic Carbon	mg/L	9.00	9.00	9.00	9.00	9.00
Total Organic Carbon (TOC)	mg/L	9.62	9.62	9.62	9.62	5.58
Parameters with Low Occurrence in the Pilot Study						
Cyanide	mg/L	0.06	0.06	0.06	0.06	0.06
Ethylenediaminetetraacetic acid (EDTA)	µg/L	305.00	305.00	305.00	305.00	223.53
NTA	µg/L	0.00	0.00	0.00	0.00	0.00
Perchlorate	µg/L	0.00	0.00	0.00	0.00	0.00
Surfactants (MBAS)	mg/L	0.36	0.36	0.36	0.36	0.36
Terbuthylazine	µg/L	0.10	0.10	0.10	0.10	0.10

2.5. Best Management Practices

Best management practices (BMPs) are recommendations to maintain optimal use of recycled water for irrigation while protecting groundwater. BMPs evaluated in this report are specific to recycled water use as an irrigation source for landscape with the goal of minimizing degradation of groundwater resources. BMPs to help protect groundwater quality include:

- Improve Recycled Water Quality: Dilution with higher quality water (such as potable or advance treated water) may be an appropriate measure for areas where the quality of the recycled water is above proposed recycled water irrigation screening levels. In addition, source control such as modification to the treatment processes or investigation and elimination of constituent sources from the waste stream may be options for improving recycled water quality.
- Fertilizer Application: Reduced fertilizer application can minimize potential impacts of migration of nutrients found in recycled water to groundwater.
- Site Selection: Careful selection of sites for recycled water application, through use of soil aquifer treatment capacity, and other methods, is important for avoiding areas that have poor hydrogeological conditions for recycled water application and avoiding the mobilization of other contamination sources that may be present onsite.
- Irrigation Optimization: Optimizing the irrigation system minimizes the total volume of irrigation needed for application and consequently minimizes the mass loading of recycled water constituents.
- Salt and Nutrient Management Plan: The purpose of a salt and nutrient management plan is to protect groundwater from accumulating concentrations of salts and nutrients that would degrade the quality of groundwater and limit its beneficial uses.
- Gypsum Application: Gypsum application can promote soil drainage which is important in preventing water logging and possible runoff of recycled water to surface waters, but also accelerates migration of recycled water constituents to groundwater. Therefore, its use needs to be carefully balanced.

2.6. Ongoing Monitoring Recommendations

Recommendations for ongoing monitoring were developed to monitor the potential long term impacts to groundwater from use of recycled water for irrigation in the Santa Clara and Llagas Subbasins. The goal of the ongoing monitoring is to provide timely recognition of any adverse changes in groundwater quality due to application of recycled water. This monitoring schedule serves as a general guideline for monitoring activities. Future modifications to this monitoring approach may be appropriate to optimize this program.

Site-specific data can be used to directly calculate the groundwater degradation potential to help determine if additional monitoring is needed. The use of this data, along with available groundwater monitoring results from areas with similar physical and recycled water quality characteristics may reduce the need for additional monitoring.

The following is a summary of proposed criteria for achieving adequate monitoring:

1) Select or install wells at or adjacent to sites where recycled water irrigation is implemented. Monitoring wells should be downgradient of the application area.
2) While not every irrigation site needs to be monitored, at least one should be monitored to represent each region of expansion with similar calculated GWDP values. If a region of expansion contains different rating categories of GWDP, consider monitoring an irrigation site in each unique subregion.
3) Monitoring wells between application areas and production wells will be useful in monitoring water quality that may affect production.
4) Monitor for the groundwater of interest (i.e. in the principal aquifer) and in shallower aquifers. Shallower aquifers can provide an early indication of changes in water quality.
5) Avoid monitoring wells that are screened in multiple aquifers, since samples would effectively be an average groundwater concentration across multiple aquifers.

6) Use denser monitoring well spacing in areas of higher GWDP where groundwater degradation is most likely to occur.

Below is a recommended schedule of groundwater sampling, with the year indicating the amount of time after recycled water application begins:

Highest Groundwater Degradation Potential in Represented Area	Monitoring Frequency		
	Year 1	Year 2-4	Year 5 and beyond
1-20	Quarterly	Semi-annually in spring and fall	Annually in fall
21-40	Quarterly	Quarterly	Semi-annually in spring and fall
41-60	Monthly	Quarterly	Semi-annually in spring and fall
61-100	Monthly	Quarterly	Quarterly

After a period of monitoring events, if evaluation of the data obtained demonstrates that the quality of groundwater has not degraded past 20 percent of the assimilative capacity and does not show an increasing trend, consideration may be given to reducing the groundwater monitoring scope by decreasing the monitoring frequency or the number of wells monitored. Reduced groundwater monitoring scope should still be within reason to adequately ensure groundwater quality is maintained. Before a reduction in monitoring scope, trend analysis with forward projection of the groundwater concentrations should be used to demonstrate that the concentrations will not exceed 20 percent of the assimilative capacity over a longer time frame. Conversely, if adverse impacts are encountered in a specific area the monitoring scope can be adjusted to increase in frequency or in the number of wells monitored in the specific area.

Recycled water monitoring is recommended for wastewater treatment plants in order to verify that recycled water quality does not change over time. If recycled water quality worsens over time, additional measures, such as dilution or source control as specified in BMPs should to be implemented in order to maintain the same level of groundwater protection. At minimum, annual monitoring of recycled water is recommended from each wastewater treatment plant that provides recycled water for irrigation use. More frequent monitoring of recycled water may be useful for determining seasonal changes in the water quality, or evaluating water quality changes when improvements in the treatment process are implemented. During the pilot study, as discussed in Volume III, constituent concentrations in recycled water were observed to vary within the distribution system. Therefore, it is recommended that samples are collected at various points in the distribution system to evaluate the quality of recycled water being applied for irrigation. Samples should be collected at the irrigation site closest to the recycled water source, and at the irrigation site furthest from the recycled water source.

2.7. Further Study

The conclusions made in this report are supported with the findings from the evaluations conducted in this study using the best professional judgment. Further monitoring and additional site-specific data can strengthen and refine the findings of this report. Further monitoring of recycled water constituents, particularly the emerging contaminants for which limited data are currently available, will increase sample size, which could be used to more accurately evaluate concerns such as groundwater degradation potential. Groundwater monitoring is ongoing at the pilot study site, and those results should be considered along with the findings of this study. Additional studies, such the ongoing monitoring of the recycled water irrigation at the pilot study site, pilot testing of areas within the study area with hydrogeological settings different from those found in at the IDT site, could also help verify and/or update the findings of this study. Additional study of recycled water in the deeper zones may be appropriate where impacts have occurred in the shallow zones.

Volume I
Literature Review and Data Analysis

Recycled Water Irrigation and Groundwater Study
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LIST OF ACRONYMS AND ABBREVIATIONS

ACRONYM	DESCRIPTION
APECs	alkylphenol ethoxycarboxylates
APEOs	alkylphenol ethoxylates
AP1ECs	alkylphenoxy acetic acids
AP1EO	alkylphenol mono-ethoxylate
AP2EO	alkylphenol di-ethoxylate
AP3EO	alkylphenol tri-ethoxylate
APs	alkylphenols
ARWT	Advanced Recycled Water Treatment
AWWA	American Water Works Association
BOD	biological oxygen demand
BPA	bisphenol-A
CA MCL	California MCL
CAPECs	carboxyalkylphenol ethoxycarboxylates
CAP1ECs	carboxyalkylphenoxy acetic acids
CW2D	Constructed Wetlands 2D
DBPs	disinfection by-products
DEHP	di(2-ethylhexyl)phthalate
DOC	dissolved organic carbon
EDCs	endocrine disrupting compounds
EDTA	ethylenediaminetetraacetic acid
HAA5	haloacetic acids
LACSD	Los Angeles County Sanitation District
Locus	Locus Technologies
MBAS	methylene blue active substances
MCL	Maximum Contaminant Level
m/z	mass-charge ratio

LIST OF ACRONYMS AND ABBREVIATIONS

NBBS	N-butyl benzenesulfonamide
NCSWS	National Center for Sustainable Water Supply
NDCs	Naphthalenedicarboxylic Acids
NDMA	N-nitrosodimethylamine
NICNAS	National Industrial Chemicals Notification and Assessment Scheme
NOM	natural organic matter
NP	nonylphenol
NTA	nitrilotriacetic acid
OP	octylphenol
ORP	oxidation reduction potential
PAHs	polycyclic aromatic hydrocarbons
PARWQCP	Palo Alto Regional Water Quality Control Plant
PFCs	perfluorochemicals
PhACs	pharmaceutically active compounds
SAM	Soil Attenuation Model
SAR	sodium adsorption ratio
SCRWA	South County Regional Wastewater Authority
SCVWD	Santa Clara Valley Water District
SJ/SC WPCP	San Jose/Santa Clara Water Pollution Control Plant
SWPCP	Sunnyvale Water Pollution Control Plant
TDS	total dissolved solids
THMs	trihalomethanes
TOC	total organic carbon
TSS	total suspended solids
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
VOCs	volatile organic compounds
µg/L	micrograms per liter

VOLUME I
LITERATURE REVIEW AND DATA ANALYSIS RECYCLED WATER STUDY

1. INTRODUCTION

This report presents the results of a study to evaluate the impacts of recycled water on groundwater resources in the Santa Clara and Llagas Groundwater Subbasins in Santa Clara County. The study was completed by Locus Technologies (Locus) on behalf of the Santa Clara Valley Water District (SCVWD). This study used a combination of approaches, including literature review, data analysis, fate and transport evaluations, and a full pilot study at a site in the Santa Clara Groundwater Subbasin. Volume I includes the first of these approaches, the literature review and the data analysis, which includes 1) available data from related studies that can be used for this project, 2) relevant hydrogeological data, 3) methodologies proposed for assessing impact to groundwater from recycled water, 4) available geochemistry of recycled water, including a prioritized list of chemicals of concern.

1.1. Purpose

Volume I covers two major components of this study: literature review and data analysis. The purpose of the literature review is to collect and summarize relevant recycled water studies in Santa Clara County, including studies previously conducted by the SCVWD. In addition, literature related to recycled water and relevant studies were reviewed. The goals for the literature review were identified as the following:

- Determine the range of characteristics of recycled water found in recycled water from the four producers (common chemical and biological constituents that should be evaluated in this study);
- Investigate the effects of soil permeability from recycled water;

- Review conclusions of previous relevant studies, and determine areas that require further investigation (i.e. chemicals that lack information in terms of fate and transport); and
- Identify investigative techniques (e.g. modeling tools) that could be used for the remainder of the study.

Part of determining the range of characteristics of recycled water involves a data analysis. The purpose of the data analysis is to review available data related to hydrogeology, recycled water, and groundwater quality. The data will be used to observe the fate and transport of identified chemicals of concern. The data analysis evaluated the overall quality of recycled water using data from the four producers (i.e. PARQWCP, SWPCP, SJ/SC WPCP and SCRWA) which have varying recycled water qualities. Similarly, the data analysis evaluated the overall quality of groundwater using data from the two subbasins (ie Santa Clara and Llagas) which have varying groundwater qualities. The following goals were identified for the data analysis:

- Identify which constituents have been detected in recycled water sources;
- Determine the frequency of detection of each constituent in recycled water;
- Determine the maximum, minimum, and representative concentration of each constituent in recycled water;
- If available, compare recycled water constituent concentrations with available groundwater chemistry data from the Santa Clara and Llagas Groundwater Subbasins, and evaluate the overall difference in water quality; and
- Identify constituents which may or may not have the potential to impact groundwater quality based on significantly higher overall concentrations.

1.2. Volume I Organization

During the course of the literature review, three overall subjects were found to be prevalent in previous studies of recycled water application for irrigation. This volume of the report is subdivided into these three subjects. The first subject is the origin, fate, and transport of chemical and biological constituents commonly found in recycled water. To consolidate the available information for each constituent, the results of the data analysis are discussed in Section 2 of this volume along with the literature review information for each constituent. The second subject is a general evaluation of the potential for soil plugging that can occur when using recycled water for irrigation. The final subject is the evaluation and use of modeling tools for predicting the fate and transport of chemicals through the unsaturated vadose zone. These subjects are addressed in Sections 3 and 4, respectively, of this volume of the report.

1.3. Approach

Resources for the literature review were identified through SCVWD as well as other experts in the field of recycled water application. Based on previous relevant SCVWD reports and the advice of an expert panel, Locus prepared a list of key topics for locating references. The topics were used with online resources such as the U.S. Salinity Laboratory (*http://www.ars.usda.gov/main/main.htm*), and conventional sources including local university libraries. Using this approach, Locus maximized use of available resources to address the goals of this study. The literature review was conducted in 2007 at the beginning of this study. However, the review does include updates using selected literature as current as 2009 as part of the review process for this document.

For the data analysis, the ranges of concentrations for each constituent were compared between populations of recycled water from the four local sources and groundwater samples from the Santa Clara and Llagas Groundwater Subbasins. SCVWD provided available chemistry data for groundwater and recycled water samples in electronic and hard copy laboratory reports. The results were compiled into histograms or box plots depending on the amount of data available and plotted for comparison.

To prioritize the chemicals in recycled water, categories were developed to distinguish chemicals that may have a greater potential to impact groundwater than others. The categories were developed based on the available fate and transport information for the constituents in recycled water and the available data analyses.

2. CONSTITUENTS OF RECYCLED WATER

Recycled water commonly contains a number of unique chemical and biological constituents introduced through the original use of the water, or through the treatment processes that the water undergoes after use. One major goal of this study is to determine whether any of these constituents have the potential to negatively impact groundwater if recycled water is used for irrigation. In this section, each of these constituents is discussed, either individually or as a group of related constituents as appropriate.

2.1. Methodologies

The data analysis for each constituent includes a comparison between recycled water and groundwater quality data. The methods used to make this comparison are discussed below.

2.1.1. Data Sources

For the data analysis, SCVWD provided available water quality data for historic groundwater and recycled water samples. Historic groundwater data includes data from the SCVWD database, including data from the City of San Jose’s Groundwater Monitoring and Mitigation Program (GMMP), which has sampled from numerous monitoring wells in the Santa Clara County. The date range of the historic groundwater data is from 1973 to 2007, and includes data from the shallow and deep aquifers. Both shallow and deep groundwater were included to adequately represent groundwater concentrations. Recycled water data used in the evaluation ranged from 2001 to 2007. The data were not reviewed for quality assurance/quality control (QA/QC) as part of this project and are assumed to have met the SCVWD quality assurance and quality control requirements.

Many data were available in electronic form, but some, particularly the recycled water analyses, were only available in hard copy laboratory reports. In order to adequately represent every constituent of recycled water, some manual data entry was required for the statistical analysis. First, the laboratory reports were reviewed to identify each constituent that had been detected in at least one of the recycled water samples.

The laboratory reports included many analyses, but there were many analytes that were not detected in any samples. To minimize the manual data entry, constituents that were not detected in any recycled water samples were not tabulated. A complete list of all chemicals that were analyzed in the recycled water from the SCVWD database is presented in Table I-2-1. Results for each parameter that was detected in at least one of the recycled water samples are presented in Table I-2-2.

SCVWD maintains a large database of groundwater quality information, which was used to identify the representative characteristics of groundwater in the Santa Clara and Llagas Groundwater Subbasins. Some of the hard copy laboratory reports provided by SCVWD included groundwater samples that were not entered in the database. However, for most of the analytes in the laboratory reports, the existing SCVWD database already includes a large amount of groundwater quality data. Many of the monitoring parameters have thousands of records in the database. Therefore, the additional benefit of manually adding the approximately twenty samples from the laboratory reports was minimal. Data for constituents found in the laboratory reports but not in the SCVWD database were manually entered so that some representation of groundwater quality could be obtained.

2.1.2. Data Analysis

Once the available chemistry data for groundwater and recycled water were compiled, exploratory statistical analyses were applied to the data. Using the SCVWD groundwater quality database, histograms were prepared for each constituent detected in recycled water. For this analysis, concentration values below detection were considered zero values. This simplification of the data set was necessary to avoid skewing the histograms, since there is a significant amount of variability in the reporting limits in the database. The use of the reporting limit or half the reporting limit is common in statistical analyses of this type, but for this analysis it would show false variability for nondetect values. Another simplification used for this study was to consider all available concentration data equally. That is, no consolidation was made for multiple samples collected from the same well or at the same time. However, given the large data count for the groundwater samples, the potential error caused by this simplification is minimal.

Groundwater chemistry histograms are shown in Appendix I-A. For many constituents, the histograms provide a good representation of the range of concentrations in groundwater. The histograms are scaled so that the majority of the data are visible on the plot. Some data outliers may not be represented, but the scale presents the best resolution for most of the data. The histograms are less useful for some constituents that are infrequently detected in groundwater, where almost all of the data are plotted as zero values. For these constituents, it is useful to review the summary statistics included on each histogram. Summary statistics calculated for each constituent include the minimum, maximum, median, mean, count, and frequency of detection are provided in figures found in the appendices and within the text of Section 2.

Recycled water chemistry data are also presented on each of the groundwater histograms in Appendix I-A. Due to the small number of recycled water samples available for this study, a full histogram of the data does not return useful results. However there were a sufficient number of samples to prepare simplified box plots of the data, showing the minimum, maximum, and median concentrations. For these box plots, the median was selected as the most representative concentration as opposed to the mean, since it is not impacted by outliers in the data set. However, the mean and other summary statistics for recycled water are also presented on the histogram for comparison.

Appendix I-B includes box plots for additional constituents where there was insufficient data (less than 40 data values) to prepare a histogram. These constituents are not commonly monitored in groundwater, therefore there is a limited amount of data for them. However, some groundwater samples collected as part of the SCVWD Advanced Recycled Water Treatment (ARWT) Feasibility Project were analyzed for these constituents, and there is a sufficient number of results to perform the comparison.

During the data analysis, three recycled water constituents were identified for which there were no corresponding groundwater analyses. These constituents are presented with only recycled water data in Appendix I-C.

2.1.3. Parameter Categorization

Constituents are prioritized based on their potential to negatively impact the beneficial uses of groundwater. A beneficial use includes municipal, domestic, industrial, and irrigation. Five categories were developed to classify constituents. The classification of these constituents is based on the current available knowledge of fate and transport characteristics and on the results from the data analysis. The five categories are:

A) Significant Potential for Impact. The fate and transport characteristics and data analysis suggest that the constituent may negatively impact ground water.

B) Important Parameter. Although this constituent may not directly impact groundwater, it is useful to monitor because it can influence other constituents.

C) Inconclusive. Different studies concerning the same constituent present conflicting information on fate and transport characteristics or based on the constituent’s characteristics, it is still unknown how groundwater may be impacted.

D) Minimal Potential for Impact. Groundwater is not likely to be impacted because 1) the fate and transport characteristics suggest that the constituent has a high affinity for attenuation and/or 2) the concentration in recycled water is less than or similar to the concentration found in groundwater or less than water quality standards. Therefore, recycled water cannot impact the constituent concentrations in groundwater.

E) Insufficient Information. There is not enough information concerning the fate and transport of the constituent to evaluate the potential impacts to groundwater.

The assigned categories for each of the evaluated constituents were used as a guide for to develop monitoring plans for the bench test and pilot study, which are described in Volumes II and III, respectively .

2.2. General Water Quality

General water quality parameters are typically inexpensive to monitor. Many of these parameters can be easily monitored in the field, and can provide an overall indication of water quality. In addition, these parameters provide critical information about the chemistry of the water and how constituents may react with the environment when applied as irrigation water. Many of the parameters discussed below are reactive either with soil, in-situ waters, and/or plants depending on the water chemistry. Therefore, the general water chemistry provides a basis for understanding the potential fate and transport of recycled water constituents through the vadose zone to groundwater even if the parameters themselves do not represent potential constituents of concern to groundwater.

2.2.1. pH and Alkalinity

The ARWT Feasibility Project reported that pH from surface water, groundwater, and recycled water were found to be near neutral (SCVWD, 2004). The data analysis performed for this project confirms this conclusion, as shown in the histogram in Appendix I-A. The median pH value is slightly lower for recycled water, but the range of pH values for recycled water is still within the range for the majority of groundwater values.

One study in Florida using recycled water for irrigation of several golf courses found that the pH of recycled water ranged from 5.3 to 8.7, which was similar but more variable than the pH of the local groundwater. The study also found that the pH was lower in groundwater at golf courses irrigated with recycled water compared to those irrigated with local well water, although the mechanism for that difference was not determined (United States Geological Survey [USGS], 1996). As with any irrigation water, the pH of recycled water used for irrigation may change during exposure to the environment through reactions between the dissolved constituents and the environment. Direct comparison of recycled water pH and groundwater pH may not be an accurate method of evaluating the potential effects, although establishing pH is important for understanding the fate and transport of other recycled water constituents.

Another potential issue associated with the pH of water used for irrigation is the potential for additional solubilization of metals. The amount of metals that can be leached from soil is highly dependent on the pH of the infiltrating water. Lower pH values have the potential to mobilize metals out of the soil. However, the median pH observed in recycled water samples from the data analysis is 7.4, which is above neutral. Therefore, infiltration of recycled water with this pH is not expected to have a significant effect on the mobilization of metals.

Alkalinity is the measure of the ability of water to neutralize acids, caused by the presence of hydroxide, carbonate, and bicarbonate anions. High alkalinity indicates a resistance to changes in pH. In a Florida study using recycled water for irrigation of several golf courses, alkalinity was found to be lower in groundwater at golf courses irrigated with recycled water compared to those irrigated with local well water (USGS, 1996).

Recycled water samples included in the data analysis showed pH values ranging from 6.5 to 8.1, with a median value of 7.4. The groundwater samples tend to be slightly more basic, with a median of 7.7. The total alkalinity and bicarbonate alkalinity values for recycled water samples are similar to the groundwater samples. Since both pH and alkalinity values are similar for recycled water and groundwater, there is very little potential for recycled water application to affect the pH of groundwater. However, these parameters are ranked as category B) Important Parameters because they are useful parameters influencing the fate and transport of metals.

Summary Data for pH (pH units), Category B

	Minimum	Median	Mean	Maximum	Count	Detect Frequency
Recycled Water	6.5	7.4	7.300	8.1	25	100%
Groundwater	0	7.68	8.66	832	8729	100%

Summary Data for Alkalinity (Total) As CaCO3 (mg/l), Category B

	Minimum	Median	Mean	Maximum	Count	Detect Frequency
Recycled Water	65	172	171	263	22	100%
Groundwater	1.9	219	237	5500	5549	100%

Summary Data for Bicarbonate Alkalinity (mg/l), Category B

	Minimum	Median	Mean	Maximum	Count	Detect Frequency
Recycled Water	77	191	188	320	29	100%
Groundwater	0	227	258	1600	1802	100%

2.2.2. Hardness

Hardness measurements represent the presence of polyvalent cations (typically calcium and magnesium) in water. The hardness of recycled water is not expected to have any impact on groundwater quality, since the range of hardness in recycled water is within the majority of hardness values for groundwater. All of the recycled water sample results fall within a relatively narrow range of values (180 to 319 milligrams per liter (mg/L) as $CaCO_3$). Hardness in groundwater samples ranges from 0 to 2150 mg/L as $CaCO_3$. Hardness is ranked in category D) Minimal Potential for Impact, because the concentrations in recycled water and groundwater are similar.

Summary Data for Hardness (Total) As CaCO3 (mg/l), Category D						
	Minimum	Median	Mean	Maximum	Count	Detect Frequency
Recycled Water	180	245	243.150	319	20	100%
Groundwater	0	250	267	2150	5986	99.9%

2.2.3. Turbidity

Turbidity is the measure of the light-transmitting properties of water, which primarily represents the presence of suspended and colloidal material. Since pathogens can be attached to these particles, higher turbidity values can be correlated to higher levels of pathogens. Previous studies have shown some impact to groundwater turbidity caused by recharge from a low-quality water source. However, the results appeared to be temporary, and groundwater turbidity returned to normal after recharge from the water source ceased (Pitt et al., 1996).

The USEPA drinking water standard for turbidity is one nephelometric turbidity unit (NTU). Although the representative turbidity values for recycled water are higher than those for groundwater, median turbidity values for both groundwater and recycled water are below the USEPA drinking water standard, as shown in Appendix I-B. However, turbidity is typically higher in surface water than groundwater and the process of infiltration through soil typically changes the turbidity of infiltrating water depending on the depth to groundwater, soil characteristics, and the rate of inflow. In addition, while the turbidity of groundwater is often controlled by the hydrogeology of the aquifer, the measured turbidity of groundwater samples is highly affected by well construction and sampling procedures. Because turbidity in recycled water is similar to groundwater in mean concentrations, it is ranked in category D) Minimal Potential for Impact, and is not recommended for monitoring in the study.

Summary Data for Turbidity (NTU), Category D						
	Minimum	Median	Mean	Maximum	Count	Detect Frequency
Recycled Water	0.19	0.7	0.804	2.2	18	100%
Groundwater	0	0.15	0.780	120	3775	86.4%

2.2.4. Total Dissolved and Suspended Solids

Total dissolved solids (TDS) and total suspended solids (TSS) are parameters of concern because of the potential adverse impacts on the permeability of the soil (see Section 3). High TDS levels can also retard the growth of vegetation and at extremely high levels, can affect the potability of water. SCVWD's ARWT Feasibility Project technical memo reported that use of recycled water for irrigation will most likely cause TDS levels in groundwater to rise under long term conditions for an unconfined aquifer (SCVWD, 2004). A recycled water irrigation study in Hawaii compared irrigated recycled water to pore water collected at a 5 foot depth, and found that dissolved salts were not removed by the soil filtration process. Dissolved salts were regarded as posing the largest impact from recycled water used for irrigation (Brown and Caldwell, 2005).

TDS is reported in Appendix I-B as Total Filterable Residue. Concentrations of TDS in recycled water range from 630 to 1000 mg/L, consistently higher than concentrations in groundwater. USEPA has set a secondary drinking water standard for TDS of 500 mg/L. TDS is ranked in category A) Significant Potential for Impact, and should be included for monitoring in the study in the study. TSS is also reported in Appendix I-B. The range, detection frequency, and representative values for TSS are all similar for groundwater and recycled water. TSS is ranked in category D) Minimal Potential for Impact, and is not recommended for monitoring.

Summary Data for Total Filterable Residue at 180C (Total Dissolved Solids) (mg/l), Category A						
	Minimum	Median	Mean	Maximum	Count	Detect Frequency
Recycled Water	630	724.5	752.100	1000	20	100%
Groundwater	0	384.5	456.59	12180*	3872	100%

Note: *TDS value from well located next to San Francisco Bay, sampled once in 1972.

Summary Data for Total Suspended Solids (mg/l), Category D						
	Minimum	Median	Mean	Maximum	Count	Detect Frequency
Recycled Water	0	0	2.167	10	18	44%
Groundwater	0	0	3.737	10	19	42%

2.2.5. Dissolved and Total Organic Carbon

Total organic carbon (TOC) poses a concern to groundwater because TOC can react with disinfectants to form disinfection by-products. Previous studies have found that that TOC and dissolved organic carbon (DOC) concentrations in recycled water are generally higher than corresponding concentrations in drinking water derived from the same source (American Water Works Association [AWWA], 2001). TOC concentrations in recycled water for groundwater recharge projects are regulated by the California Department of Public Health (DPH) according to Draft DPH Groundwater Recharge Reuse Regulations (SCVWD, 2004).

The ARWT Feasibility Project ranks TOC to have "insignificant" to "slight" potential impact on groundwater in the unconfined portion of the Santa Clara Subbasin, depending on the type of irrigation (agricultural or landscape). TOC is expected to have a minimal potential impact because the mass quantity of TOC added is relatively low and there are known soil attenuation factors. TOC can be attenuated in the environment through adsorption and biodegradation. However, in the unconfined portion of the Llagas Subbasin, the ARWT project ranked TOC to have "slight" to "moderate" potential impact due to the larger quantity of water applied and shallower depth to the unconfined zone (5 -15 feet). Due to parts of the Llagas Subbasin which have shallower groundwater, the ARWT Feasibility Project recommended monitoring of this parameter.

A case study by the Los Angeles County Sanitation District (LACSD) where groundwater recharge was applied to a basin through surface spreading found that most TOC was removed in the top several inches of the recharge basin. Hence, TOC concentration was found to not be a function of depth. Another study looking at DOC at the Sweetwater Recharge Facility in Tucson, Arizona found that DOC was reduced from concentrations of 12 to 25 mg/L at the surface to 2 to 3 mg/L at a depth of 125 feet below ground surface (bgs). The Arizona study also found that the concentrations at 125 ft bgs were largely independent of the initial DOC concentration at the surface (AWWA, 2001).

Concentrations of TOC in groundwater ranged from below detection to 0.69 mg/L in the samples included in the data analysis (Appendix I-B). Recycled water concentrations of TOC ranged from 3.99 to 9.62 mg/L, indicating a significant difference. Measurements of UV-254, which are typically correlated directly to TOC concentrations, show a similar distribution. DOC concentrations in recycled water sources ranged from 5 to 9 mg/L. Because of potential impacts particularly to the shallowest zones in the study area, TOC and DOC are ranked in category A) Significant Potential for Impact, and should be included for monitoring in the study.

Summary Data for Dissolved Organic Carbon (mg/l), Category A

	Minimum	Median	Mean	Maximum	Count	Detect Frequency
Recycled Water	5	6.3	6.560	9	5	100%
Groundwater	NA	NA	NA	NA	NA	NA

Summary Data for Total Organic Carbon (mg/l), Category A

	Minimum	Median	Mean	Maximum	Count	Detect Frequency
Recycled Water	3.99	6.595	6.630	9.62	18	100%
Groundwater	0	0.31	0.319	0.69	19	79%

2.2.6. Redox Potential and Dissolved Oxygen

The oxygenation state of water either measured as oxidation reduction potential (ORP) or represented by dissolved oxygen is an important physio-chemical parameter of water which affects the chemical state and therefore the fate and transport of many organic and inorganic constituents of recycled water. Because it is a very reactive condition, differences between the oxidation state of recycled water and groundwater do not in and of themselves present a potential impact. However, the oxidation state and the redox potential of the recycled water and soil present an important parameter affecting the fate and transport of constituents which are mobile or immobilized based on oxidation state.

Recycled water can theoretically alter the redox conditions of groundwater if the biological oxygen demand (BOD) of the recycled water is very high and persists during transport to groundwater. During interaction with soil, oxygen in the water is consumed as organic material is degraded (oxidized), and the redox potential becomes more negative. If the water already contains a high BOD, then the recycled water could presumably continue to scavenge oxygen or oxidants from soil and groundwater after it reaches the water table, thereby lowering the oxidation state of groundwater. Because mechanisms for oxygen transport into the saturated zone are minor, oxygen depletion can occur creating an anoxic plume of recharged water that may affect the aquifer.

This effect was observed in a case study of groundwater recharge through surface spreading of recycled water by the LACSD, where oxygen levels in the groundwater were found to be below saturation. However, the oxygen content remained above zero at the site (SCVWD, 2004). Although generally not a concern in the US, anoxic aquifers have occurred elsewhere in the world (Metcalf and Eddy, 2007).

Low redox potential in recycled water remains an indirect concern for groundwater, by reducing iron, manganese, and arsenic compounds in soils to soluble forms. Distribution of recycled water through spray irrigation systems may alleviate this concern by aerating the water prior to infiltration into the soil. Therefore the type of irrigation system may be a significant factor in determining the potential impact of low redox potential in recycled water. A data analysis for redox potential has not been prepared, since the effect of redox potential is a result of complex interactions between recycled water, soil, and in-situ waters and concentrations of oxidants and reactants and is not necessarily a direct result of the redox potential of recycled water. DO and ORP are ranked category B) Important Parameters, and should be included for monitoring in this study.

2.2.7. Silica

Silica concentrations in recycled water tend to be lower than those in groundwater (Appendix I-B). This is expected, since groundwater is in constant contact with silica-bearing sediments. Dissolved silica concentrations are typically temperature and pH controlled. Silica is not known to cause any adverse health effects in water, but it can cause scaling problems in industrial systems and groundwater wells. Since the observed concentrations of silica in recycled water sources are lower than those in groundwater, recycled water has very little potential to impact silica in groundwater. Hence, silica is ranked in category D) Minimal Potential for Impact, and is not recommended for monitoring in the study.

Summary Data for Silica (mg/l), Category D						
	Minimum	Median	Mean	Maximum	Count	Detect Frequency
Recycled Water	0.9	15.8	18.700	34.6	18	100%
Groundwater	0	25	25.6	244	4416	99.5%

2.3. Cations and Anions

Recycled water may contain several metals and other ions that include aluminum, boron, cadmium, calcium, chloride, copper, cyanide, fluoride, iron, lead, magnesium, manganese, nickel, sodium, sulfate, and zinc. The percentage of each of these constituents remaining after tertiary treatment will depend on the specific treatment train used.

2.3.1. Transition and Post-Transition Metals

Recycled water and groundwater samples have been analyzed for a group of metal ions. The group of transition and post-transition metals includes most of the metallic ions commonly dissolved in water, including aluminum, cadmium, copper, iron, lead, manganese, nickel, and zinc. Many of these metals do not warrant a full evaluation because concentrations in recycled water are similar to groundwater, and therefore pose little potential for groundwater impact. In the data analysis, concentrations of aluminum, manganese, and zinc were found to have similar distributions in recycled water and groundwater samples. Therefore, these metals are ranked in category D) Minimal Potential for Impact, and are not recommended for monitoring in the study. A few of the other metals detected in recycled water samples are discussed below.

Summary Data for Aluminum (µg/l), Category D						
	Minimum	Median	Mean	Maximum	Count	Detect Frequency
Recycled Water	0	0	39.6	174	18	33%
Groundwater	0	0	29.8	3800	1955	24%

Summary Data for Manganese (µg/l), Category D						
	Minimum	Median	Mean	Maximum	Count	Detect Frequency
Recycled Water	0	0	13.137	35	19	42%
Groundwater	0	0	28.4	1620	3830	36.8%

Summary Data for Zinc (µg/l), Category D						
	Minimum	Median	Mean	Maximum	Count	Detect Frequency
Recycled Water	0	0	32.263	130	19	42%
Groundwater	0	0	20.7	9400	3268	28.3%

2.3.1.1. Iron

Iron is ubiquitous in soil but is relatively insoluble in water except under reducing conditions. Iron concentrations in recycled water samples were generally lower and less frequently detected than in groundwater samples which probably reflects differences in redox conditions. Although there is no Maximum Contaminant Level (MCL) for iron, a secondary drinking water standard which is recommended but not enforced by USEPA is 300 micrograms per liter (µg/L). The maximum concentration observed in recycled water samples included in the data analysis was 120 µg/L. Iron is ranked in category D) Minimal Potential for Impact, and is not recommended for monitoring in the study.

Summary Data for Iron (µg/l), Category D						
	Minimum	Median	Mean	Maximum	Count	Detect Frequency
Recycled Water	0	0	6.700	120	18	6%
Groundwater	0	10	102	26000	4600	52.4%

2.3.1.2. Lead

Lead adsorbs strongly to soils, hence it does not typically migrate to groundwater from surface applications such as irrigation. The drinking water action level for lead is 15 µg/L (USEPA, 2003). In the data analysis, lead was detected in one of the 19 recycled water samples, at a concentration of 11 µg/L.

Detections of lead in groundwater are more frequent, and have shown higher concentrations. Therefore, lead concentrations in groundwater are not likely to be affected by recycled water use. Hence, lead is ranked in category D) Minimal Potential for Impact, and is not recommended for monitoring in the study.

Summary Data for Lead (µg/l), Category D						
	Minimum	Median	Mean	Maximum	Count	Detect Frequency
Recycled Water	0	0	0.579	11	19	5%
Groundwater	0	0	0.892	50	2556	12.4%

2.3.1.3. Nickel

Nickel is one of the most mobile metals. Nickel concentrations in groundwater are controlled by the partitioning between water and soil which is controlled by adsorption/desorption and precipitation/dissolution processes. Adsorption/desorption is dominant in soil with low pH. When pH is high or if nickel concentrations are high, precipitation/dissolution processes control the partitioning of nickel between water and soil. Nickel adsorption is dependent on the soil's cation exchange capacity, pH, texture, carbonate content, organic matter, sesquioxides, and chelating agents. Organic matter, layer silicates, hydrous oxides of silicon, aluminum, iron, and manganese, and carbonates are important adsorbents in soils (Selim and Iskandar, 1999). Groundwater in the Santa Clara and Llagas Subbasins may have elevated concentrations of nickel due to contact with serpentine bedrock. In the data analysis prepared for this study, nickel concentrations were found to have a similar distribution in recycled water samples and groundwater samples. Therefore, nickel concentrations in groundwater are not likely to be affected by recycled water use. Nickel is ranked in category D) Minimal Potential for Impact, and is not recommended for monitoring in the study. USEPA does not currently enforce a drinking water standard for nickel.

Summary Data for Nickel (µg/l), Category D						
	Minimum	Median	Mean	Maximum	Count	Detect Frequency
Recycled Water	0	0	3.105	47	19	11%
Groundwater	0	0	1.67	79	1648	14.9%

2.3.1.4. Cadmium

All compounds of cadmium are hazardous to both plants and animals. Accumulation of cadmium in the kidneys can lead to kidney dysfunction and it is a recognized carcinogen. The federal and state MCL is 5 µg/L for cadmium in drinking water (USEPA, 2003; State of California, 2007). Sorption/desorption, ion exchange and precipitation/dissolution are processes that affect the fate of cadmium. Cadmium interacts with soil through ion adsorption at surface sites, ion exchange with clay material, binding by organically coated particulate matter or organic colloidal material, or adsorption of metal ligand complexes. pH and ionic strength of the soil solution influence sorption of cadmium. Increasing the ionic strength in the soil solution tends to lower the sorption of cadmium. Sorption of cadmium increases as pH increases especially in the pH range from 5.5 to 6.5 where an adsorption edge occurs. Cadmium sorption will decrease in the presence of metals and cations competing for sorption sites (Selim and Iskandar, 1999).

Cadmium was detected in one of the recycled water samples included in the data analysis, from SJ/SC WPCP with a concentration of 12 µg/L. Higher concentrations have been observed in groundwater, although the relative detection frequency for groundwater is lower. Because cadmium is not detected in recycled water frequently, it is ranked in category D) Minimal Potential for Impact, and is not recommended for monitoring in the study.

Summary Data for Cadmium (µg/l), Category D						
	Minimum	Median	Mean	Maximum	Count	Detect Frequency
Recycled Water	0	0	0.632	12	19	5%
Groundwater	0	0	0.0841	21	2518	3.8%

2.3.1.5. Copper

Copper is a metal that is both essential to life and toxic at high or sustained concentrations. Copper retention in soil is intricate. Copper (II) can complex with a number of anions that are commonly found in natural water. At low copper concentrations such as those typically found in environmental samples (<32,000 µg/L), the presence of tartaric acid and fluvic acid decreases retention in soils. Tartaric acid is commonly introduced in the environment through plant roots and decomposing plant material. Observed increases in copper mobility have been related to binding with DOC (Selim and Iskandar, 1999).

USEPA has set a drinking water action level for copper of 1,300 µg/L, based on reducing the corrosiveness of drinking water (USEPA, 2003). Copper was detected in only one of the recycled water samples with a concentration of 61 µg/L. Concentrations of copper in groundwater are generally higher, and are detected more frequently. Therefore, it is unlikely that copper concentrations in groundwater will be significantly affected by use of recycled water. Hence, copper is ranked in category D) Minimal Potential for Impact, and is not recommended for monitoring in the study.

Summary Data for Copper (µg/l), Category D						
	Minimum	Median	Mean	Maximum	Count	Detect Frequency
Recycled Water	0	0	3.211	61	19	5%
Groundwater	0	0	6.15	2000	3058	17.5%

2.3.2. Other Ions

Recycled water commonly contains several other metallic and non-metallic ions of natural and anthropogenic origin.

2.3.2.1. Boron

Boron compounds are used in a wide range of industrial applications that eventually find their way into the water supply. In the environment, boric acid and borate ions are the most frequent form of boron. Boron has been shown to adsorb to soils, depending on the pH of the water. The World Health Organization has established a provisional guideline for boron in drinking water of 500 µg/L (World Health Organization, 1998b). The majority of boron concentrations in recycled water and groundwater samples included in the data analysis were lower than this value, although one sample collected from SJ/SC WPCP showed a concentration of 505 µg/L. Boron concentrations in the recycled water sources analyzed in this study fell within a fairly narrow range. Boron concentrations in groundwater have been observed as high as 5,200 µg/L within the study area. However, the median boron concentration in recycled water samples (416 µg/L) was higher than the median for groundwater samples (134 µg/L). Boron is toxic to some plants at lower concentrations than humans and therefore the use of recycled water for irrigation may be limited by the effects on plants rather than potential impacts to groundwater. Because the degree of boron adsorption to soils is dependent on pH, which may vary, boron is ranked in category C) Inconclusive, and should be included for monitoring in the study.

Summary Data for Boron (µg/l), Category C						
	Minimum	Median	Mean	Maximum	Count	Detect Frequency
Recycled Water	207	416	398	505	19	100%
Groundwater	0	134	196	5200	1815	85%

2.3.2.2. Cyanide

Generally, cyanide is not a persistent or stable constituent in water or soil. It volatilizes quickly and can biodegrade. Cyanide also does not accumulate in aquatic organisms. However, because cyanide does not bind to soils, it may leach to groundwater if it doesn't evaporate (USEPA, 2006b). The USEPA MCL in drinking water for cyanide is 200 µg/L (USEPA, 2003). The California MCL is 150 µg/L (State of California, 2007). Standards for cyanide in surface water bodies are more stringent than drinking water standards. Currently, the the RWQCB specifies a screening level of 1 µg/L for aquatic habitat goal based on California Toxics Rule (California Regional Water Quality Control Board, 2007). Cyanide has been detected in two of the recycled water sources included in the data analysis, SCRWA and SJ/SC WPCP. Both detections were below the California MCL (CA MCL) for drinking water, but above the cyanide aquatic habitat goal. Cyanide is detected infrequently in groundwater but the maximum is higher than the observed maximum in recycled water. Cyanide is ranked in category C) Inconclusive, and should be included for monitoring in the study.

Summary Data for Cyanide (µg/l), Category C						
	Minimum	Median	Mean	Maximum	Count	Detect Frequency
Recycled Water	0	0	4.5	58	14	14%
Groundwater	0	0	0.459	350	1059	0.6%

2.3.2.3. Fluoride

Fluoride is added to many drinking water sources as an additive for oral health. Due to fluoridation in the water supply from the San Francisco Public Utility Commission, some communities in Santa Clara County receive fluoridated drinking water. Drinking water for the Gilroy area is not currently fluoridated, but there is a low concentration of natural fluoride in the groundwater source for Gilroy's drinking water. As a result, the recycled water from SCRWA (located in Gilroy) has consistently lower fluoride concentrations (ranging 0.15 to 0.41 mg/L) than the other recycled water sources (ranging 0.55 to 1.69 mg/L). In general, fluoride concentrations in recycled water are higher than those in groundwater. The USEPA MCL drinking water standard for fluoride is 4.0 mg/L. Both the median concentrations for recycled water and groundwater are below the standard. Fluoride adsorbs strongly to soils, and at a low pH, can actually react directly with soil components. However, because fluoride is not harmful to human health or the environment at these concentrations, these effects may not be significant. Because fluoride concentrations in recycled and groundwater are below the drinking water standard, fluoride is ranked in category D) Minimal Potential for Impact, and is not recommended for monitoring in the study.

Summary Data for Fluoride (mg/l), Category D						
	Minimum	Median	Mean	Maximum	Count	Detect Frequency
Recycled Water	0.15	0.68	0.648	1.69	18	100%
Groundwater	0	0.13	0.518	721	5051	87.3%

2.3.2.4. Calcium, Magnesium, Sodium, Chloride, and Sulfate

Although not generally a health concern, concentrations of calcium, magnesium, sodium, chloride, and sulfate in recycled water have been shown to impact groundwater. USEPA does not currently enforce drinking water standards for these ions, but recommends secondary drinking water standards for chloride and sulfate, both at 250 mg/L. One study in Florida using recycled water for irrigation of several golf courses found that concentrations of calcium were lower in groundwater at golf courses irrigated with recycled water compared to those irrigated with local well water. Sodium concentrations were found to be higher in the groundwater at golf courses irrigated with recycled water than at golf courses irrigated with local well water (USGS, 1996).

High sodium concentrations relative to calcium and magnesium also have the potential to cause clay swelling and affect soil permeability (see Section 3: Soil Aquifer Plugging) but these effects can be partially reversed by salinity. Sodium affects soil when the proportion of sodium relative to calcium plus magnesium is high. When the soil water is highly saline and all constituents including sodium are present in high concentrations, the dispersing effects of sodium are mitigated by high concentrations of magnesium and calcium. When sodium is high and salinity including calcium and magnesium is low, the disruption of the soil can be extensive. Where use of recycled water produces significant increases in sodium, calcium, magnesium, sulfate, or chloride, groundwater salinity and TDS concentrations can also increase producing an adverse effect on water quality.

In the samples reviewed for the data analysis, calcium concentrations in groundwater and recycled water show a similar distribution. The median magnesium concentration was higher in recycled water samples, but the range of concentrations in recycled water was within the range for groundwater. Sodium, chloride, and sulfate concentrations are also higher in the recycled water sources relative to basin groundwater and therefore may affect soil as well as concentrations of these constituents in groundwater. Calcium, magnesium, sodium, chloride, and sulfate are ranked in category A) Significant Potential for Impact, and should be included for monitoring in the study. Special attention needs to be taken with calcium, magnesium, and sodium because of their potential to cause reduced soil permeability.

Summary Data for Calcium (mg/l), Category A

	Minimum	Median	Mean	Maximum	Count	Detect Frequency
Recycled Water	40.7	51	51.400	69.2	21	100%
Groundwater	0	56	61.5	916	5813	100.0%

Summary Data for Magnesium (mg/l), Category A

	Minimum	Median	Mean	Maximum	Count	Detect Frequency
Recycled Water	26.7	31.7	32.900	42.2	19	100%
Groundwater	0	25	30.7	370	5785	99.9%

Summary Data for Sodium (mg/l), Category A

	Minimum	Median	Mean	Maximum	Count	Detect Frequency
Recycled Water	118	148.95	161.600	230	20	100%
Groundwater	0	29	39.7	3570	5798	100.0%

Summary Data for Chloride (mg/l), Category A

	Minimum	Median	Mean	Maximum	Count	Detect Frequency
Recycled Water	119	196	207.700	320	20	100%
Groundwater	0	34	61.9	20000	6837	99.7%

Summary Data for Sulfate (mg/l), Category A

	Minimum	Median	Mean	Maximum	Count	Detect Frequency
Recycled Water	60.1	96.6	99.800	247	19	100%
Groundwater	0	42.3	54.1	1500	5915	99.8%

2.4. Nutrients

Wastewaters can often contain significant concentrations of organic and inorganic nutrients. Concentrations of these nutrients are also found in recycled water. Some studies have suggested that the presence of these nutrients can provide benefits as a supplemental fertilizer source when used for agricultural irrigation (Toze, 2004). Two of the most common nutrients present in recycled water are phosphate and nitrate.

2.4.1. Phosphate

Generally, phosphorus is a limiting nutrient for plant growth. One of the most common attenuation pathways for phosphate is crop uptake. Past the root uptake zone, phosphate can be attenuated by precipitation. When soluble phosphate is added to acidic soils, the majority of the phosphate turns into iron and aluminum phosphates which are insoluble. In calcareous soils, soluble phosphate forms calcium phosphate (Chang and Chu, 1961). Anaerobic soils have a higher capacity to sorb and release phosphate than aerobic soils. In anaerobic conditions, reduced ferrous compounds have a higher surface area allowing for phosphate to be more readily sorbed or released (Patrick and Khalid, 1974). Sinaj et al. (2002) found that phosphate is highly mobile in the top soil. In the subsoil, phosphate mobility is restricted due to the higher phosphorus-fixing capacity.

Phosphate was detected in every recycled water sample reviewed for this study. The median concentration found in recycled water was 9.2 mg/L. It was also detected in 37% of the groundwater samples, although the maximum groundwater concentration is lower than the minimum recycled water concentration observed. However, because of this difference and because phosphate's transport characteristics are not well known, phosphate is ranked in category C) Inconclusive, and should be included for monitoring in the study.

Summary Data for Phosphate (mg/l), Category C						
	Minimum	Median	Mean	Maximum	Count	Detect Frequency
Recycled Water	0.45	9.205	7.943	14	18	100%
Groundwater	0	0	0.0395	0.21	19	37%

2.4.2. Nitrate and Nitrite

Nitrate is a common constituent in recycled water. Fertilizers and degradation of biomass also provide sources to surface and eventually groundwater. Nitrate is a concern for groundwater because parts of the Santa Clara Valley have groundwater concentrations above the USEPA MCL, which is 10 mg/L as N (44.3 mg/L as NO_3). The CA MCL for nitrate in drinking water is 45 mg/L as NO_3. Nitrate is known to cause short term health effects such as "blue baby syndrome" among infants (USEPA, 2007a).. Concentrations above the federal MCL have been observed in samples from groundwater wells within the Llagas Subbasin. The California DPH has set the draft maximum allowable nitrogen concentration for recycled water in groundwater recharge projects as 5 mg/L as N (22.1 mg/L as NO_3) (SCVWD, 2004).

Nitrate can leach through the soil into the groundwater over time, but there are several attenuation factors that reduce the potential impact, such as denitrification, crop uptake, and volatilization into nitrogen gas. Hence, the amount of nitrate that reaches groundwater is typically less than the amount applied (SCVWD, 2004). The effect of denitrification can vary from 0 to 90 percent of the total nitrogen concentration. Crop uptake can cause up to 50 percent attenuation. Due to these processes, the travel time for nitrate from the vadose zone to groundwater can be as much as 10 to 100 years (SCVWD, 2004).

In the environment, nitrate is converted into nitrite through microbial degradation. By a similar microbial process, nitrate can be produced from ammonia. Due to this generation mechanism, the ARWT Feasibility Project recommended the review of ammonia levels in recycled water sources. In a case study where groundwater was recharged to a basin through surface spreading using treated effluent, LACSD found that nitrate had increased with depth and ammonia decreased with depth. The case study also concluded that denitrification was not dominant at this site (SCVWD, 2004).

The ARWT Feasibility Project concluded that for agricultural purposes in the unconfined zone of the Santa Clara Subbasin, nitrate would not cause a significant impact to the groundwater because mass loading is expected to be low. For the Llagas Subbasin, the ARWT Feasibility Project determined that current groundwater concentrations of nitrate are higher than recycled water concentrations, and that recharging with recycled water may lead to improvement of the groundwater quality (SCVWD, 2004).

The data analysis shows that nitrate concentrations in recycled water frequently exceed the draft California DPH maximum allowable limit for the purpose of groundwater recharge (22.1 mg/L as NO_3). The median nitrate concentration in recycled water is 41 mg/L as NO_3. Nitrite concentrations in recycled water samples show a similar distribution and detection frequency to groundwater samples. Potential for nitrate in recycled water to affect nitrogen levels in groundwater exists. Nitrate and nitrite are ranked in category C) Inconclusive, because it is not clear how effective the attenuation factors will be in reducing these constituents. These parameters should be included for monitoring in the study.

Summary Data for Nitrate as NO_3 (mg/l), Category C						
	Minimum	Median	Mean	Maximum	Count	Detect Frequency
Recycled Water	2.1	41.3	44.500	122	20	100%
Groundwater	0	20	23.5	429	14772	97.3%

Summary Data for Nitrite (As N) (µg/l), Category C						
	Minimum	Median	Mean	Maximum	Count	Detect Frequency
Recycled Water	0	0	20.000	400	18	6%
Groundwater	0	0	124	48000	1571	6.2%

2.5. Anthropogenic Compounds

Anthropogenic compounds are man-made chemicals which are not naturally occurring. Several anthropogenic compounds are also endocrine disrupting compounds (EDCs), which are substances that mimic, block, stimulate, or inhibit natural hormones in the endocrine system (Metcalf and Eddy, 2007). EDCs can include steroid hormones as well as synthetic organic compounds, including certain plasticizers and surfactants. Additional research is needed in fate and transport data, standardized analytical methodology, removal kinetics, predictive models, synergistic effects, and determination of the toxicological relevance of EDCs.

2.5.1. Disinfection By-Products (DBPs)

Disinfection by-products (DBPs) are primarily dissolved organohalogens from oxidative breakdown of organic substances during treatment with a chemical disinfectant. DBPs include trihalomethanes, haloacetonitriles, haloketones, haloacetic acids, chlorophenols, aldehydes, trichloronitromethane, chloral hydrate, and cyanogen chloride. DBPs, formed by chlorination, depend on pH, temperature, reaction time, free and combined chlorine concentrations, ammonia concentration, DBP precursor concentration, and precursor type. DBPs are not expected to accumulate in the soil. Considering the transient time of water and degradation of DBPs in the vadose zone, most, but not all, DBPs are unlikely to cause a significant threat to groundwater (Metcalf and Eddy, 2007).

2.5.1.1. Trihalomethanes (THMs)

Trihalomethanes (THMs) are a group of chemicals that include chloroform, bromodichloromethane, dibromochloromethane, and bromoform. THMs are formed during chlorine disinfection. During chlorination, hypochlorous acid (i.e. the active disinfectant) reacts with natural organic matter (NOM) to form THMs. In the presence of bromide, hypochlorous acid can be converted to hypobromous acid, which also reacts with NOM to produce brominated THMs. THM concentrations generally increase when the chlorine dose, concentration of NOM, chlorine contact time, pH, temperature, and/or concentration of bromide ion increase (Sadiq and Rodriquez, 2004). US EPA's maximum contaminant level for total THMs is 80 µg/L (USEPA, 2003).

THMs volatilize quickly so their potential impact on groundwater through irrigation is low, particularly if there is a significant vadose zone thickness. However, there is little degradation of THMs once they have reached the saturated zone (AWWA, 2001). Pavelic et al. (2005) found that for an aquifer storage and recovery system, THMs had half lives ranging from < 1 to 65 days. The rate of removal for chloroform was the lowest and the rate of removal for bromoform was the highest.

In the recycled water samples included in the data analysis, THMs were detected in every sample analyzed at levels above the USEPA MCL for total THMs. Bromoform is the only compound that was not detected in 100 percent of the recycled water samples. Each of the THMs was also detected in groundwater samples, with frequencies ranging from 0.3% to 1.3%. The median and maximum concentrations were higher for each THM in recycled water samples. THMs are ranked in category C) Inconclusive, and should be included for monitoring in the study. Although it is clear there is reduction in THMs through the vadose zone, it is unclear if groundwater will be impacted.

Summary Data for Trihalomethanes, Total (µg/l), Category C						
	Minimum	Median	Mean	Maximum	Count	Detect Frequency
Recycled Water	150	159.5	159.500	169	2	100%
Groundwater	0	0	0.0956	69	5491	1.7%

Summary Data for Bromoform (µg/l), Category C						
	Minimum	Median	Mean	Maximum	Count	Detect Frequency
Recycled Water	0	3	14.2684	61	19	79%
Groundwater	0	0	0.0192	20.6	7138	0.5%

Summary Data for Bromodichloromethane (µg/l), Category C						
	Minimum	Median	Mean	Maximum	Count	Detect Frequency
Recycled Water	6.1	45.5	46.39	95	20	100%
Groundwater	0	0	0.00959	12	10592	0.3%

Summary Data for Chloroform (µg/l), Category C						
	Minimum	Median	Mean	Maximum	Count	Detect Frequency
Recycled Water	2.7	54	50.216	95	19	100%
Groundwater	0	0	0.0491	54	7191	1.3%

Summary Data for Dibromochloromethane (µg/l), Category C						
	Minimum	Median	Mean	Maximum	Count	Detect Frequency
Recycled Water	2.4	32	42.458	115	19	100%
Groundwater	0	0	0.0142	14.4	7068	0.6%

2.5.1.2. Haloacetic Acids (HAA5)

Haloacetic acids are common disinfection by-products formed through a reaction of natural organic matter in the wastewater with hypochlorous or hypobromous acid. HAA5 is a specific group of five haloacetic acids: monochloroacetic acid, dichloroacetic acid, trichloroacetic acid, monobromoacetic acid, and dibromoacetic acid. US EPA’s maximum contaminant level for total HAA5 is 60 µg/L (USEPA, 2003). A sixth haloacetic acid, bromochloroacetic acid, is also frequently found in treated effluent, but is not included in the regulated HAA5 group. When bromochloroacetic acid is included with the other HAA5 compounds, they are referred to as the HAA6 group.

HAA5 compounds may degrade, but not completely, and the attenuation rates for HAA5 are low, especially in the saturated zone (SCVWD, 2004). Conversely, Pavelic et al. (2005) found that in an anoxic aquifer storage and recovery system, HAA5 were found to attenuate rapidly (half life < 1 day).

From the data analysis prepared for this study, all haloacetic acids appear in recycled water with greater frequency and higher concentrations than in groundwater. The median concentration for HAA5 in recycled water samples is slightly higher than the USEPA MCL (60 µg/L). Two haloacetic acids, dibromoacetic acid and bromochloroacetic acid, were detected in groundwater samples. Bromochloroacetic acid was detected in one third of the groundwater samples tested, although at much lower concentrations than those found in the recycled water samples. The maximum concentration of HAA5 observed in groundwater was 2.8 µg/L.

Because information on fate and transport of HAA5 is limited, HAA5 is ranked in category E) Insufficient Information, and should be included for monitoring in the study. Bromochloracetic acid should also be included in the analysis, since it has been observed in recycled water.

Summary Data for HAA5 (µg/l), Category E

	Minimum	Median	Mean	Maximum	Count	Detect Frequency
Recycled Water	1.7	62.45	83.361	232.3	18	100%
Groundwater	0	0	0.489	2.8	9	22%

Summary Data for Monochloroacetic Acid (µg/l), Category E

	Minimum	Median	Mean	Maximum	Count	Detect Frequency
Recycled Water	0	2.3	5.188	21.4	16	63%
Groundwater	0	0	0	0	9	0%

Summary Data for Dichloroacetic Acid (µg/l), Category E

	Minimum	Median	Mean	Maximum	Count	Detect Frequency
Recycled Water	0	15.65	29.100	80.4	18	94%
Groundwater	0	0	0	0	42	0.0%

Summary Data for Trichloroacetic Acid (µg/l), Category E

	Minimum	Median	Mean	Maximum	Count	Detect Frequency
Recycled Water	0	25.35	39.180	124	18	89%
Groundwater	0	0	0	0	42	0.0%

Summary Data for Monobromoacetic Acid (µg/l), Category E						
	Minimum	Median	Mean	Maximum	Count	Detect Frequency
Recycled Water	0	1.6	1.979	6.9	19	58%
Groundwater	0	0	0	0	9	0%

Summary Data for Dibromoacetic Acid (µg/l), Category E						
	Minimum	Median	Mean	Maximum	Count	Detect Frequency
Recycled Water	0	4.75	8.378	30.3	18	78%
Groundwater	0	0	0.0488	1	41	4.9%

2.5.1.3. N-Nitrosodimethylamine (NDMA)

N-nitrosodimethylamine (NDMA) is a polar, uncharged organic compound, and is known to be a potent carcinogen. In response to the health concern of NDMA, The California Department of Public Health has set a drinking water notification level of 0.01 µg/L (CDPH, 2007). NDMA was formerly used in the production of liquid rocket fuel, antioxidants, and softeners for copolymers; but NDMA is currently used only for research purposes (USEPA, 2008). In addition, NDMA may form during water treatment using chlorination. Research suggests that NDMA can be formed by the reaction from (1) monochloramine, which is a common form of chlorine when ammonia-containing water is disinfected, and (2) simple amines like dimethylamine. As a result of industrial processes (e.g. printed circuit board manufacturing and waste treatment), NDMA is also present in wastewater effluent prior to disinfection (Sedlak et al., 2005). Precursors of NDMA mainly consist of complex organic compounds that contain nitrogen (Pehlivanoglu-Mantas et al., 2006). The precursors are found to be difficult to remove by conventional and advanced treatment processes. Ultraviolet (UV) radiation has been shown to be an effective method of removing NDMA, however the process is expensive (Metcalf and Eddy, 2007; Deeb et al., 2006).

A Southern California field study evaluated the leaching potential of NDMA in turfgrass soils irrigated with recycled water. The study attributed the lack of NDMA in leachate water to several potential mechanisms including degradation, plant uptake, gas phase diffusion in soil, and volatilization at the soil surface (Gan et al., 2006). The conditions in this field study were typical of irrigated turf grass. This study suggests that irrigation of landscapes with water containing NDMA will have minimal potential to cause groundwater contamination. Data suggests that NDMA does not sorb or biodegrade well once it is in the saturated zone. Where NDMA has been detected in groundwater, it has been found to be persistent. NDMA precursors are resistant to biotransformation, but can be partially removed in saturated soil columns (Gan et al., 2006; WateReuse Foundation, 2006). In a recycled water irrigation study performed in Hawaii, concentrations of NDMA were observed to decrease between the irrigated recycled water and the infiltrated water at a 5 foot depth (Brown and Caldwell, 2005). The study concluded that approximately 94 percent of the NDMA in applied recycled water was removed in the vadose zone, and that the soil in Central Oahu had sufficient rention time and soil carbon to remove complex organics such as NDMA from infiltrated water prior to reaching groundwater. In other studies, (Bradley et al., 2005; Kaplan and Kaplan, 1985), NDMA was found to biodegrade in laboratory settings in unsaturated and saturated soil samples under both aerobic and anaerobic conditions. More recently, field evidence of in situ NDMA biodegradation in the subsurface was supported in a separate study (Zhou et. al., 2009).

As an emerging contaminant, there are few groundwater samples analyzed for NDMA within the SCVWD database for the study area. In the database, NDMA was not detected in any of the groundwater samples. From April through June 2007 the Ground-Water Ambient Monitoring and Assessment (GAMA) program investigated groundwater quality in the San Francisco Bay region, and did not find any detections of NDMA in groundwater within the Santa Clara County (Ray et al, 2009). In the recycled water samples analyzed for NDMA, it was detected in all except one sample, with detections up to 0.49 µg/L. NDMA is ranked in category C) Inconclusive, and should be included for monitoring in the study. Under conditions where there is minimal potential for volatilization, NDMA has potential to affect the groundwater.

Summary Data for N-Nitroso dimethylamine (NDMA) (µg/l), Category C						
	Minimum	Median	Mean	Maximum	Count	Detect Frequency
Recycled Water	0	0.026	0.091	0.49	15	93%
Groundwater	0	0	0	0	17	0%

2.5.1.4. Bromate

Bromate (BrO_3^-) in recycled water forms from disinfection using ozonation. The precursors to bromate formation are bromide and ammonia ion. The World Health Organization has labeled bromate as a possible human carcinogen (Butler et al., 2005b). Recently, bromate contamination has been discovered in groundwater aquifers in Japan and the United Kingdom (Butler et al., 2005b, Mihoko et al 2006). Bromate has also been found exceeding protective standards in groundwater near an ore processing facility in the United States (USEPA, 2006a). Many countries have set a drinking water standard for bromate ranging from 10 to 25 µg/L. The maximum contaminant level (MCL) for bromate in the U.S. is 10 µg/L (USEPA, 2003). Bromate is highly soluble and stable in water. Conventional treatment has proven difficult in removing bromate (Butler et al., 2005a).

In the recycled water samples included in the data analysis for this study, bromate was detected in 11% of the samples at concentrations up to 3 µg/L. Bromate was not detected in any of the groundwater samples reviewed for this study. Because concentrations of bromate in recycled water are less than drinking water standards, it is ranked in category D) Minimal Potential for Impact, and is not recommended for monitoring in the study.

Summary Data for Bromate (µg/l), Category D

	Minimum	Median	Mean	Maximum	Count	Detect Frequency
Recycled Water	0	0	0.333	3	18	11%
Groundwater	0	0	0	0	19	0%

2.5.2. Pesticides and Associated Chemicals

Pesticides can enter groundwater from direct application to crops or from a wastewater stream that may contain traces of pesticides. Some pesticides can be difficult to remove completely in wastewater treatment, particularly since laboratory analytical methods for pesticides are very sensitive. Although there are many pesticides with the potential to impact groundwater quality, this section discusses four that have been detected in recycled water sources within the study area. A few additional pesticides, such as atrazine and glyphosate, were analyzed in recycled water samples, but were not detected. Other pesticides, such as the pyrethroids allethrin and bifenthrin, were not analyzed in recycled water samples for this data analysis.

2.5.2.1. Lindane (Gamma-BHC)

Lindane (Gamma-BHC) is applied as a pesticide for insects including wood-inhabiting beetles and lice on pets and livestock. It is also used on fruit and nut trees, vegetables, and timber. In the environment, lindane can be degraded by soil microbes. Lindane can also evaporate from the surface or can leach slowly into groundwater (USEPA, 2006b). A study of recycled water irrigation on golf courses in Florida found lindane and other pesticides at trace levels in the recycled water. Pesticides were detected in 52 percent of the shallow groundwater samples collected during that study. However, the golf courses also used pesticides to maintain turf. Hence, the contribution of pesticides from the recycled water cannot be determined (USGS, 1996). The federal and California MCL for lindane is 0.2 µg/L (USEPA, 2003, State of California, 2007). Lindane was detected in one of the recycled water samples included in the data analysis, with a concentration of 0.01 µg/L. Lindane was not detected in any groundwater samples. Because lindane was detected in only one sample, at a concentration below the MCL, it is ranked in category D) Minimal Potential for Impact, and is not recommended for monitoring in the study.

Summary Data for Lindane (Gamma-BHC) (µg/l), Category D						
	Minimum	Median	Mean	Maximum	Count	Detect Frequency
Recycled Water	0	0	0.001	0.01	16	6%
Groundwater	0	0	0	0	222	0.0%

2.5.2.2. Heptachlor Epoxide

Heptachlor epoxide is not manufactured directly, but is formed through the chemical and biological degradation of heptachlor in the environment. Heptachlor, once used as a non-agricultural insecticide, is currently only permitted to be used for fire ant control in buried electric power transformers and in underground cable boxes for televisions and telephones. In soil, heptachlor degrades readily to heptachlor epoxide, which can persist in upper soil layers for many years because it adsorbs strongly to soil and is resistant to biodegradation. Heptachlor epoxide can also be introduced into the food chain through plant uptake, and will bioaccumulate in animals. The current federal drinking water standard for heptachlor epoxide is 0.2 µg/L (USEPA, 2006b). The CA MCL for heptachlor epoxide is 0.01 µg/L. Heptachlor epoxide was detected in one of the recycled water samples analyzed, at a concentration of 0.01 µg/L.

Although the data analysis included over 1000 groundwater samples analyzed for this chemical, it was not detected in any samples. Because heptachlor epoxide is detected infrequently and adsorbs strongly to soil, it is ranked in category D) Minimal Potential for Impact, and is not recommended for monitoring in the study.

Summary Data for Heptachlor Epoxide (µg/l), Category D						
	Minimum	Median	Mean	Maximum	Count	Detect Frequency
Recycled Water	0	0	0.001	0.01	15	7%
Groundwater	0	0	0	0	1079	0.0%

2.5.2.3. Aldicarb Sulfoxide

Aldicarb sulfoxide is a microbial degradation product of aldicarb, a common pesticide used for aphids, mites, and some species of flies. The most common use of aldicarb is for cotton farming, although it is approved for use with other crops as well. Aldicarb sulfoxide is a potent neurotoxin at sufficient concentrations. The transformation of aldicarb to aldicarb sulfoxide occurs relatively quickly in the environment. The degradation of aldicarb sulfoxide occurs more slowly, by nonbiological processes (USGS, 1995). Aldicarb sulfoxide was detected in four of the 18 recycled water samples analyzed. It was also detected in some groundwater samples, but at a much lower frequency (0.4%). Because of the limited information of fate and transport of aldicarb sulfoxide, it is ranked in category E) Insufficient Information, and should be included for monitoring in the study.

Summary Data for Aldicarb Sulfoxide (µg/l), Category E						
	Minimum	Median	Mean	Maximum	Count	Detect Frequency
Recycled Water	0	0	0.2778	1.5	18	22%
Groundwater	0	0	0.0122	3	738	0.4%

2.5.2.4. Terbuthylazine

Terbuthylazine is an herbicide that inhibits photosynthesis in plants. It is used to control algae, fungi, and bacteria in commercial and industrial water cooling systems. Discharge of water containing terbuthylazine to sewage systems is prohibited without first notifying the treatment plant authority. Terbuthylazine has been shown to degrade in soil, at varying rates depending on the temperature, moisture level, microbial activity, pH, and aeration state. Adsorption of terbuthylazine onto soil is dependent on the organic material content. Terbuthylazine is also degraded through exposure to sunlight, with a half-life of approximately three months (World Health Organization, 1998). Terbuthylazine was detected in two of the four recycled water samples analyzed, as shown in Appendix I-C. Data for terbuthylazine in groundwater were not available for the data analysis. For this reason, terbuthylazine is ranked in category C) Inconclusive, and should be included for monitoring in the study.

Summary Data for Terbuthylazine (µg/l), Category C						
	Minimum	Median	Mean	Maximum	Count	Detect Frequency
Recycled Water	0	0.05	0.050	0.1	4	50%
Groundwater	NA	NA	NA	NA	NA	NA

2.5.3. Hormones and Pharmaceutically Active Compounds (PhACs)

Hormones are EDCs, and can either be natural or synthetic. Concentrations of natural and synthetic hormones are generally low in recycled water. It is suspected that most of these hormone compounds absorb to soil and biodegrade quickly. One study found that estrone, an estrogenic hormone, degrades rapidly in aerobic soils. Anaerobic conditions resulted in little or no degradation of estrone (Ying, 2006). In a soil column study using three feet (one meter) soil columns operated under different conditions, gemfibrozil, ibuprofen, and noaproxen were believed to biotransform after 6 days of travel time as indicated by the lack of detection below the quantification limit under anoxic and oxic conditions. Biotransformation was identified as the main attenuation mechanism for these constituents under biotic conditions (Hoppe-Jones, et al, date unspecified). In the data analysis, estrone was detected in one groundwater sample and one recycled water sample, at concentrations of 0.0016 and 0.011 µg/L, respectively. Since it is detected infrequently, and has fate and transport characteristics that would limit the transport to groundwater, estrone can be classified in category D) Minimal Potential for Impact.

Pharmaceutically active compounds (PhACs) include antibiotics, anti-inflamatories, x-ray contrast media, and antidepressants. Some PhACs, like contraceptives and steroids, are also EDCs. The majority of PhACs are more hydrophilic than other anthropogenic compounds, which makes them less subject to adsorption, but possibly more biodegradable (Metcalf and Eddy, 2007). However, most steroids have a higher octanol-water partition coefficient and will sorb readily. In one study with steroidal hormones (17 beta-estradiol, estriol, and testosterone), adsorption to the porous media was the dominant removal mechanism. Further attenuation occurred in the presence of bioactivity regardless of the redox conditions whether the soil was aerobic or anoxic. Attenuation with bioactivity was not dependent on the type of organic carbon matrix (hydrophobic acids, hydrophilic carbon, or colloidal carbon) (Mansell et al., 2004).

Six compounds that can be classified as PhACs were detected in the recycled water samples included in the data analysis: caffeine, carbamazepine, carisoprodol, gemfibrozil, ibuprofen, and naproxen. Of these compounds, ibuprofen was detected most frequently, in 27% of recycled water samples analyzed. Caffeine, carisoprodol, and naproxen were each detected in only one sample. None of these compounds were detected in the groundwater samples. Due to the limited information on fate and transport characteristics, PhACs are ranked in category E) Insufficient Information, and should be included for monitoring in the study.

Summary Data for Ibuprofen (µg/l), Category E

	Minimum	Median	Mean	Maximum	Count	Detect Frequency
Recycled Water	0	0	0.061	0.7	15	27%
Groundwater	0	0	0	0	15	0%

Summary Data for Caffeine (µg/l), Category E

	Minimum	Median	Mean	Maximum	Count	Detect Frequency
Recycled Water	0	0	0.040	1	25	4%
Groundwater	0	0	0	0	18	0%

Summary Data for Gemfibrozil (µg/l), Category E

	Minimum	Median	Mean	Maximum	Count	Detect Frequency
Recycled Water	0	0	0.017	0.22	15	13%
Groundwater	0	0	0	0	15	0%

Summary Data for Carbamazepine (µg/l), Category E

	Minimum	Median	Mean	Maximum	Count	Detect Frequency
Recycled Water	0	0	0.017	0.2	15	13%
Groundwater	0	0	0	0	15	0%

Summary Data for Naproxen (µg/l), Category E

	Minimum	Median	Mean	Maximum	Count	Detect Frequency
Recycled Water	0	0	0.003	0.04	15	7%
Groundwater	0	0	0	0	15	0%

Summary Data for Carisoprodol (µg/l), Category E						
	Minimum	Median	Mean	Maximum	Count	Detect Frequency
Recycled Water	0	0	0.000	0.001	11	9%
Groundwater	0	0	0	0	10	0%

Summary Data for Estrone (µg/l), Category D						
	Minimum	Median	Mean	Maximum	Count	Detect Frequency
Recycled Water	0	0	0.001	0.011	18	6%
Groundwater	0	0	0.1067	1.6	15	7%

2.5.4. Industrial Chemicals

Removal of industrial chemicals (detergent compounds, their metabolites, and halogenated compounds) usually relies on photodegradation, affinity toward absorption to soil material, and biodegradability. Some of these chemicals degrade quickly while others may persist longer. Current research suggests that the soil environment can reduce most industrial chemicals to low levels. The ARWT Feasibility Project reported concentrations of detergent metabolites to decrease significantly as they migrate through the vadose zone, but reduction was not complete (SCVWD, 2004). Some industrial chemicals are also endocrine disruptors (Metcalf and Eddy, 2007).

2.5.4.1. Volatile Organic Compounds (VOCs)

Volatile organic compounds (VOCs) include a list of dozens of chemicals, which are frequently groundwater contaminants at industrial sites. Although recycled water samples have been analyzed for a comprehensive list of VOCs, only two of these chemicals were detected in the recycled water sources: carbon tetrachloride and xylenes.

Carbon tetrachloride is a clear heavy organic liquid used in fire extinguishers, nylon manufacturing, rubber cement, insecticides, and cleaning agents. Carbon tetrachloride evaporates quickly from surface water and soil. It does not adsorb well to soil, and hence may leach into groundwater. Carbon tetrachloride does not tend to accumulate in aquatic organisms (USEPA, 2006b). The federal MCL drinking water standard for carbon tetrachloride is 5 µg/L (USEPA, 2003). The CA MCL for carbon tetrachloride is 0.5 µg/L (State of California, 2007). In the data analysis for this study, carbon tetrachloride was detected in one of the nineteen recycled water samples tested, at a concentration of 0.69 µg/L, which is above the CA MCL. Carbon tetrachloride is detected infrequently in both recycled water and groundwater with 0.7% detection in groundwater and 6% in recycled water. The mean concentration of carbon tetrachloride in groundwater is 0.04 µg/L compared to 0.041 µg/L in recycled water. Because carbon tetrachloride was found in recycled water at similar concentrations to those of groundwater, carbon tetrachloride is ranked in category D) Minimal Potential for Impact, and is not recommended for monitoring in the study.

Xylenes are a group of similar compounds, used predominantly as a solvent. There are three isomers (meta-xylene, para-xylene, and ortho-xylene), which can be quantified individually but are more frequently reported cumulatively as total xylenes. In the environment, xylenes will evaporate when released into the soil or water. However, they can leach into the groundwater and persist there for several years. Xylenes tend not to accumulate in aquatic organisms (USEPA, 2006b). The federal and CA MCL drinking water standard for xylenes is 10,000 µg/L and 1,750 µg/L respectively (USEPA, 2003; State of California, 2007). Xylenes were detected in one of the recycled water samples included in the data analysis, at a concentration of 3.8 µg/L. Concentrations of xylenes have also been detected in groundwater, but those concentrations are most likely due to localized impacts with high concentrations. Xylenes were detected in only 1.1% of groundwater samples. Because xylenes were found in recycled water in low amounts and low frequency, xylenes are ranked in category D) Minimal Potential for Impact, and are not recommended for monitoring in the study.

Summary Data for Carbon Tetrachloride (µg/l), Category D

	Minimum	Median	Mean	Maximum	Count	Detect Frequency
Recycled Water	0	0	0.041	0.69	17	6%
Groundwater	0	0	0.0400	13.6	7069	0.7%

Summary Data for Xylenes, Total (µg/l), Category D

	Minimum	Median	Mean	Maximum	Count	Detect Frequency
Recycled Water	0	0	0.224	3.8	17	6%
Groundwater	0	0	0.698	580	6730	1.1%

2.5.4.2. 1,4-Dioxane

1,4-Dioxane is a solvent stabilizer compound commonly associated with VOCs, particularly 1,1,1-trichloroethane, and is a probable human carcinogen. It is a water contaminant that is used in a variety of industrial and commercial products. 1,4-Dioxane is highly soluble and resistant to biodegradation. 1,4 Dioxane can be successfully removed by advanced oxidation processes (Metcalf and Eddy, 2007). Although several samples of recycled water from the study area have been analyzed for 1,4-dioxane, it has not been detected in any samples. Hence, it is included in category D) Minimal Potential for Impact.

2.5.4.3. Plasticizers

Plasticizers are chemicals used to increase the plasticity of certain materials such as plastics and cement. Common plasticizers include di(2-ethylhexyl)phthalate (DEHP), N-butyl benzenesulfonamide (NBBS) and bisphenol-A (BPA). DEHP is widely used in the manufacture of polyvinyl chloride plastics. In the environment, DEHP does not evaporate, but it strongly adsorbs to soil, and has very low solubility in water. For these reasons, there is minimal potential for DEHP to leach into groundwater. In the presence of water, DEHPs can be biodegraded within weeks. However, in the food chain it can accumulate to elevated concentrations in aquatic organisms (USEPA, 2006b). DEHP was detected in two of the recycled water samples used for the data analysis. Concentrations have been observed in groundwater at much higher concentrations, although with much lower frequency. DEHP is ranked in category D) Minimal Potential for Impact. Monitoring for this constituent is not needed.

NBBS is a water-soluble compound used in nylon production. It enters the environment when water comes into contact with NBBS-containing plastics, such as leaching of landfills where NBBS-containing plastics have been disposed. In a previous SCVWD study, NBBS was detected in surface water, recycled water and groundwater. The study found levels of NBBS in samples of recycled water that are generally similar to those in surface water (SCVWD, 2006). Little information is available regarding the transport of NBBS through soil, although given its solubility and common presence in surface water and groundwater, it appears to have minimal, if any, attenuation through the vadose zone. NBBS was detected in two thirds of the samples included in the data analysis, and in one of the ten groundwater samples. Although detections were more frequent in recycled water samples, the highest observed concentration of NBBS was in the groundwater sample, at 0.5 µg/L. Because of the limited information in fate and transport, NBBS is ranked in category E) Insufficient Information, and should be included for monitoring in the study provided a laboratory capable of testing this constituent is identified.

BPA is used in polycarbonate plastic and epoxy resins. BPA is also classified as an estrogen-like EDC. In a laboratory batch equilibrium study of sorption on soils, BPA showed weak sorption characteristics, but showed rapid degradation in soils under aerobic conditions. Under anaerobic conditions, BPA showed very little degradation (Kookana and Ying, 2005). The 2006 SCVWD study detected BPA in one groundwater sample (SCVWD, 2006). In the data analysis conducted for this project, BPA was not observed in any recycled water sources. Hence, BPA is ranked in category D) Minimal Potential for Impact, and monitoring is not needed.

Summary Data for Di(2-Ethylhexyl)Phthalate (µg/l), Category D

	Minimum	Median	Mean	Maximum	Count	Detect Frequency
Recycled Water	0	0	0.093	0.7	15	13%
Groundwater	0	0	0.147	27.1	1552	2.1%

Summary Data for NBBS (µg/l), Category E

	Minimum	Median	Mean	Maximum	Count	Detect Frequency
Recycled Water	0	0.0075	0.032	0.27	12	67%
Groundwater	0	0	0.05	0.5	10	10%

2.5.4.4. Perfluorochemicals (PFCs)

Perfluorochemicals are a group of organic compounds that have hydrogen-based structures and are partially or fully fluorinated. PFCs are hydrophobic and oleophobic, which makes them useful in products such as non-stick surfaces and stain-resistant carpeting. PFCs include perfluorooctanesulfonate, perfluorooctanoate, perfluorononanoate, perfluorohexane sulfonate, and perfluorooctane sulfonamide (Nakata et al., 2006).

PFCs have a chemical structure that makes them very resistant to breakdown in the environment. PFCs are suspected to bioaccumulate, and they have been detected in fish, birds, marine mammals and humans (Luthy, 2007). Because PFCs are an emerging set of contaminants, information on fate and transport characteristics is limited. In a previous study conducted by SCVWD, PFCs were found in recycled water, surface water, and groundwater. However, the highest concentrations of PFCs were found in recycled water sources, particularly perfluorooctanesulfonate (PFOS) and perfluorooctanoate (PFOA), at concentrations of 340 and 110 ng/L, respectively. PFOS was also detected in groundwater at a concentration of 26 ng/L (SCVWD, 2006). In surface water, PFCs have been detected as high as 129 ng/L in Upper Silver Creek (SCVWD, 2006). Since only a few recycled water samples and one groundwater sample have been analyzed for PFCs, a full data analysis could not be performed. Because there is limited information on fate and transport of PFCs, they are ranked in category E) Insufficient Information and should be included for monitoring in the study.

2.5.4.5. Nitrilotriacetic acid (NTA) and Ethylenediaminetetraacetic Acid (EDTA)

Ethylenediaminetetraacetic acid (EDTA) and nitrilotriacetic acid (NTA) belong to aminopolycarboxylic acids which are multidentate synthetic organics (National Center for Sustainable Water Supply [NCSWS], 2001). Both EDTA and NTA are commonly present in domestic and industrial cleaning agents. They are found in laundry detergents, agricultural fertilizer, and pulp and paper production. Previous studies have shown that EDTA is relatively persistent in the subsurface, but has been shown to rapidly photodegrade when present in a complex with ferric iron. NTA has a relatively high susceptibility to biodegradation in soil and surface water (AWWA, 2001). A study of a recharge program at the Sweetwater Recharge Facility in Tucson, Arizona, showed EDTA removal of 0 and 80 percent at 3 meters and 38 meters below ground surface, respectively (Hyung, 2003). The same study showed NTA removals of 75% and 98% at the same respective depths. Similarly, another study found significant attenuation of NTA during river water infiltration and groundwater transport (Ding, 1999).

EDTA was detected in all recycled water samples, and over half of the groundwater samples. In general, EDTA concentrations in recycled water were much higher than groundwater concentrations. NTA results were not available for the data analysis. Both NTA and EDTA are ranked in category C) Inconclusive, and should be included for monitoring in the study.

Summary Data for EDTA (µg/l), Category C						
	Minimum	Median	Mean	Maximum	Count	Detect Frequency
Recycled Water	6	19.5	105.383	305	6	100%
Groundwater	0	5	4.736	13	11	55%

2.5.4.6. Naphthalenedicarboxylic Acids (NDCs)

Naphthalenedicarboxylic acids (NDCs) are industrial chemicals that are suspected to be an oxidative transformation product of polycyclic aromatic hydrocarbons (PAHs), a constituent of petroleum products. Previous studies have detected NDCs in recycled water sources. Limited information is available on the environmental fate of NDCs. A laboratory study found that some NDCs can be slowly degraded biologically, but the results showed poor reproducibility. A field-scale study of recycled water application in Tucson, Arizona showed that a large percentage of NDCs were removed within the first 10 feet of the subsurface, but below that, the degradation was significantly slower (AWWA, 2001). A laboratory study of microbial degradation has been performed on one form of NDC, which identified two strains of bacteria that may degrade NDCs, although slowly and inefficiently. The microbial study results also showed poor reproducibility (Lefèvre et al., 1999). Other than these studies, very little information is available regarding the fate of NDCs in the environment. Analytical results for NDCs were not available for the data analysis. NDCs are ranked in category E) Insufficient Information, and should be included for monitoring in the study provided a laboratory capable of testing for this constituent is identified.

2.5.4.7. Perchlorate

Perchlorate (ClO_4^-) is a highly oxidized chlorine oxyanion used as an oxidizer in solid propellants for rockets, missiles, explosives, and pyrotechnics. Perchlorate can also be distributed through the use of certain fertilizers which are derived from evaporite deposits. Once in the environment, perchlorate is highly soluble and adsorbs poorly to soil. For these reasons, when perchlorate reaches groundwater, it can spread over large distances. Anaerobic biological reactors and ion exchange are effective measures in removing perchlorate. There is also concern for perchlorate accumulation in food plants because it is a human exposure route (Metcalf and Eddy, 2007).

Groundwater in portions of the Llagas Subbasin has been impacted with perchlorate, with several drinking water source wells being shut down due to concentrations of perchlorate. The State of California has issued an MCL for perchlorate at 6 µg/L. Perchlorate has been detected in two recycled water sources included in this study: PARWQCP and SWPCP. The detection frequency for groundwater is higher than for recycled water, but that is likely due to the perchlorate impact on the Llagas Subbasin. Due to its transport characteristics and presence in recycled water, perchlorate is ranked in category A) Significant Potential for Impact, and should be included for monitoring in the study.

Summary Data for Perchlorate (µg/l), Category A						
	Minimum	Median	Mean	Maximum	Count	Detect Frequency
Recycled Water	0	0	0.922	12.3	18	11%
Groundwater	0	0	0.707	13	2223	13.0%

2.5.4.8. Hexachlorocyclopentadiene

Hexachlorocyclopentadiene is a semi-volatile compound used in multiple industrial processes, including manufacture of insecticides and flame retardants. In the environment, hexachlorocyclopentadiene sorbs strongly to soils, and once there, degrades quickly by either chemical hydrolysis or biodegradation. This chemical degrades even more quickly when exposed to sunlight, with a half-life in the range of a few minutes. In surface water, hexachlorocyclopentadiene is attenuated either through volatilization or photolysis (USEPA, 2006b). In the data analyzed for this study, hexachlorocyclopentadiene was detected in one of the 14 recycled water samples, with a concentration of 0.1 µg/L. The chemical was not detected in any groundwater samples. Due to strong attenuation of hexachlorocyclopentadiene, this constituent is ranked in category D) Minimal Potential for Impact. Monitoring for this constituent is not needed.

Summary Data for Hexachlorocyclopentadiene (µg/l), Category D						
	Minimum	Median	Mean	Maximum	Count	Detect Frequency
Recycled Water	0	0	0.007	0.1	14	7%
Groundwater	0	0	0	0	1127	0.0%

2.5.4.9. Methyl Tertiary-Butyl Ether (MTBE) and Other Oxygenates

Oxygenates like methyl tertiary-butyl ether (MTBE) are added to gasoline to achieve more complete combustion and to improve air quality. Widespread use of oxygenates has lead to contamination in the environment, and consequently, some drinking water sources. Oxygenates are polar compounds, hence they adsorb poorly to soils and can migrate through aquifers easily (Metcalf and Eddy, 2007). However, most oxygenates volatilize readily, and they have been shown to degrade biologically, although not under natural conditions (USEPA, 2004).

The oxygenates included in the data analysis are MTBE, tertiary amyl methyl ether, ethyl tertiary butyl ether, and diisopropyl ether. None of these oxygenates were detected in recycled water samples. Hence, there is limited potential to impact groundwater.

2.5.4.10. Organophosphates

Tris(3-chloropropyl)phosphate and tris(2,3-dichloropropyl)phosphate are organophosphates that are suspected to be carcinogenic. Trisphosphates are used primarily in flame retardants but can also be found in specialized rubber products, elastomers, fiberglass resins, industrial paints, surface coatings and sealants (National Industrial Chemicals Notification and Assessment Scheme [NICNAS], 2001). These chemicals have been detected in surface water, groundwater, and recycled water, with the highest concentrations in recycled water (SCVWD, 2006). The ARWT Feasibility Project found that the concentrations of these chemicals in recycled water pose no health risk (SCVWD, 2004).

A Stanford University study of effluent discharge to the Santa Ana River found that trisphosphates were detected regularly in recycled water. The study also found that under wetland treatment, trisphosphates were partially removed (Gross et al, 2004). Other than this study, little information is available regarding the fate and transport of trisphosphates in the environment.

In the data analysis prepared for this study, trisphosphates were detected in all recycled water samples except one, with maximum concentrations of 0.46 µg/L of tris(2,3-dichloropropyl)phosphate and 0.42 µg/L of tris(3-chloropropyl)phosphate. Trisphosphates were not detected in any groundwater samples.

Because of the limited information in fate and transport, trisphosphates are ranked in category E) Insufficient Information, and should be included for monitoring in the study provided a laboratory capable of testing this constituent is identified.

Summary Data for Tris(2,3-dichloropropyl)phosphate (µg/l), Category E						
	Minimum	Median	Mean	Maximum	Count	Detect Frequency
Recycled Water	0	0.01	0.084	0.46	12	92%
Groundwater	0	0	0	0	10	0%

Summary Data for Tris(3-chloropropyl)phosphate (µg/l), Category E						
	Minimum	Median	Mean	Maximum	Count	Detect Frequency
Recycled Water	0	0.0165	0.068	0.42	12	92%
Groundwater	0	0	0	0	10	0%

2.5.4.11. Surfactants

Surfactants are a common component of most detergents. In the environment, surfactants can form a surface film, which reduces oxygen transfer. They can also alter the hydraulic properties of soils. Surfactants are often monitored collectively as methylene blue active substances (MBAS). MBAS are a group of chemicals that react with methylene blue under specific testing conditions. A study in Florida found low concentrations of MBAS in recycled water. Although MBAS were also found at low concentrations in groundwater, the study concluded they were not attributable to recycled water use, but rather runoff from residential areas or nearby streets (USGS, 1996).

Alkylphenol ethoxylates (APEOs) are a specific type of nonionic surfactants used in domestic and industrial products. APEOs and some of their metabolites are suspected to be EDCs. During wastewater treatment and in the environment, APEOs degrade into alkylphenol ethoxycarboxylates (APECs), carboxyalkylphenol ethoxycarboxylates (CAPECs), alkylphenols (nonylphenol (NP) and octylphenol (OP)), alkylphenol mono-ethoxylate (AP1EO), alkylphenol di-ethoxylate (AP2EO), and alkylphenol tri-ethoxylate (AP3EO) (Ying et al., 2002). The biotransformation of APEOs to APECs occurs under aerobic conditions during wastewater treatment, and has also been shown to occur in the environment under wetland treatment (Gross et al, 2004). Halogenated APECs and halogenated APEOs, which have both been found in recycled water samples, are chlorinated or brominated forms of APECs and APEOs created during wastewater disinfection.

The physiochemical properties of APEOs, particularly the high octanol-water coefficients (K_{ow}), suggest that APEOs can partition effectively into the soil. Previous studies have shown concentrations of APEOs in treated wastewater effluents ranging from <0.1 to 369 µg/L, and in sediments from <0.1 to 13,700 µg/kg (Ying et al., 2002).

Compared to APEOs, the degradation products have higher toxicity and are more persistent than the parent compounds. The degradation products also sorb more readily to soils and sediments (Thiele et al., 1997). In one study of soil aquifer treatment in Arizona, APEOs were removed in both anoxic and oxic conditions. Generally, the length of ethoxycarboxylate chain has been found to decrease with depth as water percolates through the vadose zone. At depths greater than 3 meters only the alkylphenoxy acetic acids (AP1ECs), carboxyalkylphenoxy acetic acids (CAP1ECs), and alkylphenols (APs) remained. Under aerobic conditions, NP and OP were found to decrease by 80 percent within a three meter depth. Under anoxic conditions, APs were found to increase by 38 percent at 3 meters below ground surface, and APEC and CAPEC were found to decrease by more than 95 percent at the same depth. For treatment of APEOs in groundwater recharge applications, alternating flooding and drying cycles for recharge appears to enhance APEO removal (Montgomery-Brown et al., 2003).

At the Las Positas Golf Course in Livermore, CA, which was irrigated with recycled water from the Livermore Water Reclamation Plant, concentrations of NP, AP1EC, and AP2EC were observed to reduce substantially from the recycled water to the groundwater (Hudson et al, 2005; LLNL, 2006). The attenuation of APEO metabolites was attributed to sorption. In addition, estrogenic bioassay tests showed reduction in estrogenic response from the recycled water to the groundwater.

In Gilroy, where the South County Regional Wastewater Authority (SCRWA) provides water recycling for irrigation, five groundwater wells from a farm location, and three groundwater wells from Christmas Hill Park were monitored for trace organic compounds (LLNL, 2006). The groundwater at these locations occurs at depths of less than 20 feet below ground surface. NP, NP1EC, and NP2EC were detected in the shallow groundwater. Detections of low level NP may have been sampling artifacts.

A study of a recharge program at the Sweetwater Recharge Facility in Tucson, Arizona, showed APEC removals of 30% and 93% at 3 and 38 meters below ground surface, respectively (Hyung, 2003). Similarly, a different study found significant attenuation of APECs during river water infiltration and groundwater transport (Ding et al., 1999). A previous SCVWD study detected APEOs and their degradation products consistently in recycled water sources, but did not detect these compounds in the surface or groundwater (SCVWD, 2006).

Concentrations of total surfactants were detected in every recycled water sample included in the data analysis, with concentrations ranging from 94 to 357 µg/L. Individual surfactants were also occasionally detected in the groundwater samples, but with lower concentrations and lower frequency. However, the reporting limit for the total surfactants analysis is much higher than the reporting limits for individual surfactants.

In addition to the general analysis for surfactants, some samples were analyzed for specific APEOs and their metabolites. AP1EO, AP2EO, and AP3EO were each detected in 10% to 13% of the recycled water samples, and AP1EO was detected in one groundwater sample. Overall, APEOs were detected in 20% of recycled water samples. APECs were detected more frequently, in 64% of the recycled water samples, and in 40% of groundwater samples. Specific APECs, identified by their mass-charge ratio, were also analyzed, and detection frequencies ranged from 40% to 50% in recycled water samples. Halogenated AP/APEOs were detected in 17% of the recycled water samples and halogenated APECs were detected in 92%. The halogenated AP/APEOs and APECs were not detected in any groundwater samples. Concentrations of NP and OP were detected more frequently in groundwater samples than recycled water samples, with two thirds of the groundwater samples showing some detection. Because surfactants and their degradation products have significantly varying fate and transport characteristics, APEOs, APECs, NP, and OP are ranked in category C) Inconclusive, and should be included for monitoring in the study using MBAS to measure surfactants.

Summary Data for Surfactants (µg/l), Category C

	Minimum	Median	Mean	Maximum	Count	Detect Frequency
Recycled Water	94	131	162.000	357	14	100%
Groundwater	0	0	0.0856536	50	2356	7%

Summary Data for AP/APEO, Halogenated (µg/l), Category C

	Minimum	Median	Mean	Maximum	Count	Detect Frequency
Recycled Water	0	0	0.003	0.026	12	17%
Groundwater	0	0	0	0	10	0%

Summary Data for AP1EO (µg/l), Category C

	Minimum	Median	Mean	Maximum	Count	Detect Frequency
Recycled Water	0	0	0.019	0.14	15	13%
Groundwater	0	0	0.001067	0.016	15	7%

Summary Data for AP2EO (µg/l), Category C

	Minimum	Median	Mean	Maximum	Count	Detect Frequency
Recycled Water	0	0	0.048	0.48	10	10%
Groundwater	0	0	0	0	15	0%

Summary Data for AP3EO (µg/l), Category C

	Minimum	Median	Mean	Maximum	Count	Detect Frequency
Recycled Water	0	0	0.014	0.14	10	10%
Groundwater	0	0	0	0	15	0%

Summary Data for APEC m/z 235 (µg/l), Category C

	Minimum	Median	Mean	Maximum	Count	Detect Frequency
Recycled Water	0	0.27	2.044	9.2	10	50%
Groundwater	0	0	0.00253	0.018	15	20%

Summary Data for APEC m/z 249 (µg/l), Category C

	Minimum	Median	Mean	Maximum	Count	Detect Frequency
Recycled Water	0	0	0.494	2.8	10	40%
Groundwater	0	0	0.002267	0.014	15	40%

Summary Data for APEC m/z 279 (µg/l), Category C

	Minimum	Median	Mean	Maximum	Count	Detect Frequency
Recycled Water	0	0.745	1.952	7.6	10	50%
Groundwater	0	0	0.0024	0.019	15	13%

Summary Data for APEC Total (µg/l), Category C

	Minimum	Median	Mean	Maximum	Count	Detect Frequency
Recycled Water	0	1.35	3.599	18	14	64%
Groundwater	0	0	0.0072	0.039	15	40%

Summary Data for APEC, Halogenated (µg/l), Category C

	Minimum	Median	Mean	Maximum	Count	Detect Frequency
Recycled Water	0	1.45	3.145	14.8	12	92%
Groundwater	0	0	0	0	10	0%

Summary Data for NP/OP (µg/l), Category C						
	Minimum	Median	Mean	Maximum	Count	Detect Frequency
Recycled Water	0	0	0.027	0.163	15	40%
Groundwater	0	0.012	0.0323	0.15	15	67%

2.6. Pathogens

Microbiological contaminants, including bacteria and viruses, are occasionally present in recycled water sources. Some microbial species, such as *Clostridium perfringens*, have resistance to chlorine disinfection and are more frequently found in recycled water sources. These contaminants have also impacted groundwater at some locations where recycled water is used for groundwater recharge.

2.6.1. Bacteria and Parasites

In the laboratory, bacteria can be monitored using several techniques. Heterotrophic plate count is one of the simplest and most frequently used methods. The heterotrophic plate count is a measurement of the total number of bacteria present in a water sample. It is usually reported in colony-forming units per milliliter (CFU/mL). In the data analysis for this study, recycled water sources showed much higher maximum heterotrophic plate count than groundwater samples. However, the median values for recycled water and groundwater were similar.

Three coliform counts are frequently used to monitor bacteria presence: total coliforms, fecal coliforms, and *E. Coli* coliforms. Total coliforms include a large group of bacterial species. Fecal coliforms is a measurement that isolates a specific subgroup of coliforms originating in feces. *E. Coli* is a specific species that can be isolated and measured. In the data analysis for this study, total coliforms were detected in a third of recycled water samples, and in one groundwater sample. Fecal coliforms and *E. Coli* coliforms were below detection in all except one of the recycled water samples. Legionella, another bacterium known to cause lung and gastrointestinal infections, was detected in one of the samples from SWPCP, but no other recycled water or groundwater samples.

Using high-volume sampling techniques with low detection limits, a study of several water reclamation plants in the Los Angeles area found that total coliforms were detected regularly, although the concentrations were always below the California Title 22 limits for reuse. This study also found evidence of microbial impact in groundwater in the area where recycled water was being used for recharge. A similar study in Arizona found a direct correlation between bacterial indicators in groundwater and distance from the recharge point of recycled water. However, the coliform concentrations in the groundwater at both sites were below the detection limits for routine monitoring. The concentrations could only be quantified using high-volume sampling techniques (AWWA, 2001).

In addition to the coliform counts for bacteria, there are two protozoan parasites that have been monitored in recycled water sources: cryptosporidium and giardia. Both of these are genera of pathogens that cause intestinal disease. In water, these protozoa are often found in a spore-like phase as cysts (giardia) or oocysts (cryptosporidium). Giardia cysts and cryptosporidium oocysts can survive some wastewater disinfection processes like chlorination. In the recycled water samples examined for the data analysis, giardia and cryptosporidium were both detected at low concentrations. Giardia was detected more frequently, in 27% of the samples. Neither of these pathogens were detected in groundwater. There is not enough information concerning the fate and transport of bacteria and parasites to evaluate the impacts to groundwater. Hence, bacteria and parasites are ranked as category E) Insufficient Information, and should be included for monitoring in the study.

Summary Data for Giardia (cyst/L), Category E

	Minimum	Median	Mean	Maximum	Count	Detect Frequency
Recycled Water	0	0	0.313	3.8	15	27%
Groundwater	0	0	0	0	20	0%

Summary Data for Fecal Coliforms (MPN/100ml), Category E

	Minimum	Median	Mean	Maximum	Count	Detect Frequency
Recycled Water	0	0	0.722	13	18	6%
Groundwater	0	0	0	0	5	0%

Summary Data for E. Coli (MPN/100ml), Category E

	Minimum	Median	Mean	Maximum	Count	Detect Frequency
Recycled Water	0	0	0.444	8	18	6%
Groundwater	0	0	0	0	5	0%

Summary Data for Coliforms, Total (MPN/100ml), Category E

	Minimum	Median	Mean	Maximum	Count	Detect Frequency
Recycled Water	0	0	8.056	110	18	33%
Groundwater	0	0	1.211	23	19	5%

Summary Data for Cryptosporidium Oocysts (oocysts/L), Category E						
	Minimum	Median	Mean	Maximum	Count	Detect Frequency
Recycled Water	0	0	0.060	0.7	15	13%
Groundwater	0	0	0	0	20	0%

Summary Data for Heterotrophic Plate Count by R2A (CFU/ml), Category E						
	Minimum	Median	Mean	Maximum	Count	Detect Frequency
Recycled Water	0	117	4770.610	64000	18	83%
Groundwater	2	110	417.47	2000	19	100%

2.6.2. Viruses

Bacteria and parasites can be inactivated through death or dilution relatively quickly in the environment. However, the survival of viruses poses a concern (Metcalf and Eddy, 2007). There is less information available for the fate and transport of viruses than for bacteria. Although virus testing was a part of both the Los Angeles and Arizona studies discussed above, neither study found significant evidence of virus impacts caused by recycled water application. In other laboratory experiments, some viruses have been found to adsorb readily to soil particles, while others transport more quickly.

A field-scale experiment on virus transport in the environment was performed in Los Angeles County in 1997 (AWWA, 2001). The experiment included spiking recycled water with a concentrated stock solution of bacteriophage (a virus that targets bacteria) as well as a bromide tracer, and applying it within a large recharge facility. The bacteriophage used in this experiment was a surrogate for human viruses commonly found in recycled water. Groundwater concentrations at the site were monitored at depths of five and ten feet over a period of two days. Concentrations of the virus were detected within 4 hours at 5 feet below ground surface, and in 6 hours at 10 feet below ground surface. The maximum virus concentration observed in both wells was approximately two orders of magnitude less than the concentration discharged at the surface. Since the bromide concentrations did not change significantly over the 10-foot interval, it was determined that the reduction in concentrations was not caused by dilution, but the virus was attenuated by removal and/or inactivation. Below 10 feet, the virus was also detected, but not at quantitative levels (AWWA, 2001).

The data analysis for this study included results for total culturable virus assay. The results were below detection for all recycled water samples, but a value of 0.11 most-probable-number per 100 liters was found in one groundwater sample. Since viruses were not detected in any recycled water samples, viruses are ranked in category D) Minimal Potential for Impact, and do not need to be monitored.

2.7. Radioactives

Alpha emitters are radionuclides that give off alpha particles. An alpha particle is similar to a helium nucleus with two protons and two neutrons. Alpha emitters, which can be natural or anthropogenic, include americium-241, plutonium-236, uranium-238, thorium-232, radium-226, radon-222, and polonium-210. Alpha emitters are used in industry as static eliminators, in smoke detectors, and in cancer treatment (USEPA, 2007b).

Alpha particles do not travel far in the environment; their energy is quickly lost in the air, within a few centimeters. Once an alpha particle has lost its energy, it becomes helium. Generally, external exposure of alpha particles is less of a concern than internal exposure because they lack the energy to penetrate the outer layer of human skin. However, inhalation, ingestion, or absorption into blood stream can increase the risk of cancer. In particular, inhalation of alpha emitter has been known to cause lung cancer (USEPA, 2007b).

Beta emitters are radionuclides which give off beta particles. Beta particles are smaller than alpha particles, having 1/2000 of a proton's mass. Beta emitters, which can be natural or anthropogenic, include tritium, cobalt-60, strontium-90, carbon-14, technetium-99, iodine-129, iodine-131, cesium-137, and phosphorus-32. Beta emitters are used in medical diagnosis, imaging and treatment (USEPA, 2007b). Beta particles may travel several feet before they hit solid material. Beta radiation can have acute and chronic health effects. Direct exposure to beta particles is considered hazardous; strong sources of beta particles can redden or burn skin. Inhalation and ingestion are of greater concern because they damage living tissue (USEPA, 2007b).

In a previous SCVWD study, levels of gross alpha and beta emitters in surface water, groundwater, and recycled water were found below drinking water regulations or threshold values as determined by the laboratory (SCVWD, 2004). The USEPA and CA MCL for gross alpha particle activity are 15 picoCuries per liter. The MCL for beta particles is specified in millirems per year of exposure, but as a general guideline, gross beta emissions less than 50 picoCuries per liter are considered safe for drinking water (USEPA, 2003). Both alpha and beta radiation were found at higher levels in recycled water samples than in groundwater samples in the data analysis. However, the maximum detected values for both measurements were below the respective MCLs.

Radium-228, a beta-particle-emitting radioactive metal, was detected in one of the recycled water samples at 1.1 picoCuries per liter, but since only four samples were analyzed for radium-228, there is insufficient data to fully characterize it. A specific MCL has not been established for radium-228, but the MCL for combined radium-226 and radium-228 is 5 picoCuries per liter. Since radium-226 was not detected in any recycled water samples, all recycled water samples were below the MCL for radium-226 and radium-228. Because the radioactive concentrations in recycled water are less than drinking water standards, they are ranked as category D) Minimal Potential for Impact, and are not recommended for monitoring in the study.

Summary Data for Radium 228 (pci/l), Category D						
	Minimum	Median	Mean	Maximum	Count	Detect Frequency
Recycled Water	0	0	0.275	1.1	4	25%
Groundwater	0	0	0.0920	5.67	687	9.8%

Summary Data for Alpha, Gross (pci/l), Category D						
	Minimum	Median	Mean	Maximum	Count	Detect Frequency
Recycled Water	0	3.2	2.59	6.7	17	65%
Groundwater	0	0.72	1.49	470	3965	70%

Summary Data for Beta, Gross (pci/l), Category D						
	Minimum	Median	Mean	Maximum	Count	Detect Frequency
Recycled Water	5.2	11	11.83	19	17	100%
Groundwater	0	1.105	2.09	34	562	64%

2.8. Conclusions

The constituents of most concern that need to be monitored are those which are likely to affect groundwater, category A) Significant Potential for Impact. Constituents that belong to category A) are those that are likely to negatively impact groundwater resources based on the available information on the fate and transport pathways and the data analysis. Those that fall in this category include ions (e.g. magnesium, calcium, sodium, sulfate, chloride), DOC, TOC, TDS, and perchlorate. Magnesium, calcium, and sodium are especially of concern as they may potentially affect soil permeability.

In addition to constituents in category A), constituents that fall in categories C) Inconclusive and E) Insufficient Information should also be monitored. Constituents that belong to either of these categories have a potential to negatively impact groundwater. However, there are too many unknowns with these constituents to determine with confidence whether or not there will be negative impacts. Constituents in category C) include boron, surfactants (represented by MBAS), THMs, terbuthylazine, cyanide, phosphate, nitrate, nitrite, EDTA, NTA, and NDMA. Constituents in category E) include aldicarb sulfoxide, HAA5, bromochloroacetic acid, PHaCs, NDCs, bacteria and parasites, NBBS, PFCs, and trisphosphates. More studies are needed of the constituents in category E) to properly evaluate their effects on groundwater.

Category D) are constituents that are not expected to impact groundwater resources either because 1) constituent concentrations in recycled water are less than or similar to those in groundwater or drinking water standards or 2) fate and transport mechanisms suggest that constituents will be attenuated before reaching groundwater. Constituents in these categories include bromate, radioactives, hardness, TSS, silica, metals (aluminum, cadmium, copper, iron, lead, manganese, nickel, zinc), fluoride, lindane, heptachlor epoxide, 1,4-dioxane, DEHP, BPA, hexachlorocyclopentadiene, VOCs (xylenes and carbon tetrachloride), oxygenates (MTBE, tertiary amyl methyl ether, ethyl tertiary butyl ether, diisopropyl ether), turbidity, viruses, and estrone.

Category B) includes alkalinity, DO, ORP and pH. These constituents are important to monitor as they provide insight to how other constituents in recycled water will behave through soil.

3. SOIL AQUIFER PLUGGING

In addition to the potential effects recycled water use can have on groundwater, some characteristics of recycled water have been shown to cause reductions in hydraulic conductivity in surface soils. Over time, this effect may actually cause a change in the quantity of water that percolates from the surface and recharges groundwater. Aquifer soil plugging can originate from three mechanisms: chemical plugging due to clay expansion/dispersion and/or mineral precipitation, physical plugging due to particulate matter, and biological plugging due to bacterial growth (SCVWD, 2004).

3.1. Clay Expansion / Dispersion

The potential for clay expansion and dispersion caused by contact with recycled water has been investigated extensively in a previous study conducted on behalf of SCVWD (Geologica, 2003). In soils with expansive clays, hydraulic conductivity can be reduced as a result of cation exchange resulting in swelling from increased interparticle spaces between clay layers, effects of dispersion, or destruction of structural aggregates.

Hydraulic conductivity changes are caused by changes in the size of the intra-particle spacing, which separates clay layers or inter-particle spaces. When this space expands, the pore sizes are reduced, which reduces the hydraulic conductivity. Clay surfaces are negatively charged, and cations such as sodium, magnesium, and calcium are attracted to this space. When sodium is adsorbed to the inter-particle surfaces, replacing calcium and magnesium ions, the spacing expands and the clay swells. Hence, recycled water with high sodium concentrations (or high TDS levels) and a high sodium adsorption ratio (SAR) can reduce hydraulic conductivity. SAR describes the concentration of sodium relative to calcium and magnesium. Table I-2-3 of this report includes calculated SAR values prepared using the analyses for the recycled water samples included in the data analysis. Expansion is also dependent on the exchangeable sodium percentage which characterizes the relative proportions of cations on the clay surfaces.

Of the common types of clay, montmorillonite has been observed to expand the most because it has the highest base exchange capacity. The effect is less prominent in soils with illite-vermiculite clay and even less prominent in kaolinite clays. Montmorillonite clays are known to exist throughout Santa Clara County soils. The coefficient of linear expansion, liquid limit, plasticity index, and percentage of montmorillonite by x-ray diffraction are measurable physical parameters of the soil that can be correlated to the potential change in hydraulic conductivity (Geologica, 2003).

The study also determined that recycled water irrigation could be used without adverse reaction at locations within Santa Clara County with low clay and/or low expansive clay content. Gypsum-treatment of soils can reduce the adverse impacts of recycled water on permeability. Similarly, recycled water sources can be treated with gypsum, sodium removal, or blending with other water sources to reduce the potential for affecting hydraulic conductivity (Geologica, 2003). However, this could potentially increase the transport of constituents of concern in groundwater.

In terms of water chemistry, the study found that recycled water had greater ion exchange of calcium and magnesium with the soils compared to other irrigation sources. The study concluded that additional testing is warranted to evaluate the impacts of recycled water on groundwater by focusing on ion exchange and percolating water chemistry. Additional hydraulic testing on a range of soils and waters can be used to determine the range of SAR and salinity that is safe from adverse impacts on permeability. It may also be important to evaluate what effect cycling between rainwater and recycled water due to seasonal changes will have on hydraulic conductivity (Geologica, 2003).

3.2. Other Plugging Mechanisms

3.2.1. Mineral Precipitation

Mineral precipitation depends on pH, temperature, and availability of large surface areas for precipitate deposition. Calcium carbonate, iron oxides, and manganese oxides are examples of insoluble compounds which may form. The ARWT Feasibility Project determined that mineral precipitation does not significantly alter hydraulic conductivity because precipitation kinetics are slow and it occurs in isolated pore spaces. In addition, the total volume of precipitation is not significant enough to change hydraulic conductivity (SCVWD, 2004). The correlation between expansive clay content of soils and change in hydraulic conductivity as a result of irrigation with recycled water also suggests that mineral precipitation in the short term is not a predominant process changing hydraulic conductivity in this situation (Geologica, 2003).

3.2.2. Physical Plugging

Physical plugging can be caused by accumulation of suspended solids from recycled water. Suspended solids can be inorganic such as silt, clay, fine sands, or flocs, or can be organic such as algal cells or decaying organic matter. The ARWT Feasibility Project determined based on past experiments that a total suspended solids (TSS) level less than 2,000 µg/L will not cause significant physical plugging. However, other research in the same aquifer system has shown that a level as high as 25,000 µg/L will not have adverse effects (SCVWD, 2004). Although the effect of the accumulation of solids may vary depending on soil permeability and porosity, it is most likely that the soil that is currently irrigated will be able to accommodate the range of suspended solids found in recycled water, as they are less than the range of storm water runoff which is mitigated by natural infiltration.

3.2.3. Biological Plugging

Biological plugging occurs due to in-situ bacterial growth. The accumulation of cells and waste products contribute to plugging of soil pores. The presence of biological contaminants in recycled water may contribute to this issue, but biological plugging can be effectively managed with disinfection of recycled water. The growth of biological material requires an energy and nutrient source. Growth is enhanced by warmer temperatures, sunlight, and greater concentrations of nutrients, of which at least the first two are not present in the subsurface (SCVWD, 2004).

3.3. Conclusions

Further investigation of soil aquifer plugging via clay expansion and dispersion is recommended. Recycled water with high SAR levels can affect the hydraulic conductivity of soil and hence the rate of percolation to groundwater resources. This effect is most commonly seen with soils that have high base exchange capacity like montmorillonite clays. Because Santa Clara County has such clays in its soil, aquifer plugging is a concern.

Further investigation of soil aquifer plugging due to mineral precipitation, physical plugging, and biological plugging is not recommended. These other mechanisms are not as likely to significantly affect groundwater resources.

4. MODELING TOOLS

The next phase of this project is the fate and transport evaluation, which will include use of a model to simulate the migration of recycled water constituents through the vadose zone. During the literature review, four of these analytical models were identified: PHREEQ, HYDRUS, MINTEQA2, and Soil Attenuation Model (SAM). The four modeling programs can potentially be used to characterize fate and transport of recycled water constituents.

4.1. PHREEQ

PHREEQ is a modeling program developed by USGS to characterize speciation, batch-reaction, one dimensional transport, and perform inverse geochemical calculations. PHREEQC is the latest version of PHREEQ written in the C programming language. PHREEQC is capable of performing a range of low-temperature aqueous geochemical calculations.

Version 2 of PHREEQC includes features for dispersion/diffusion and stagnant zones in one-dimensional transport calculations, kinetic reactions with user-defined rate expressions, formation/dissolution of ideal/multicomponent/nonideal binary solid solutions, fixed volume or fixed pressure phases, variation in the number of surface or exchange sites with the dissolution/precipitation of minerals or kinetic reactions, isotope mole balances in inverse modeling calculations, and multiple sets of convergence parameters. Version 2 also allows users to print user-defined quantities to a primary output file or to a spreadsheet-compatible file (USGS, 2005).

Advantages

Based on an ion-association aqueous model, PHREEQ is capable of speciation and saturation-index calculations. It can perform one-dimensional transport calculations involving reversible reactions. It can model transformation in the aqueous phase, gas phase, and solid-solution. The model can also address transformation involving mineral, surface-complexation, and ion-exchange equilibria. It can also account for irreversible reactions, which include specified mole transfers of reactants, kinetically controlled reactions, mixing of solutions, and temperature changes. In addition, it is capable of inverse modeling, which finds sets of mineral and gas mole transfers that account for differences in composition between waters, within specified compositional uncertainty limits (USGS, 2005).

Disadvantages

PHREEQ requires a lot of input data that is very specific to the soil type, including the concentrations of every ion present that may react with the water constituents. Since this information will be very location-specific, the model results may not be applicable over a larger area, such as the entire Santa Clara and Llagas Subbasins.

4.2. HYDRUS

HYDRUS is a finite element model that simulates movement of water, heat, and multiple solutes in a media that is variably saturated. The model was developed jointly by scientists at the University of California at Riverside and the Agricultural Research Service division of the US Department of Agriculture. HYDRUS-1D is a one-dimensional public domain version of the HYDRUS model. HYDRUS has also been developed in two- and three-dimensional versions. In HYDRUS-1D, the Richards equation is used for saturated-unsaturated water flow and the Fickian advection/dispersion equations are used for heat and solute transport (Šimunek et al., 2005b).

The program can account for unsaturated flow, water uptake and transpiration by plants, evaporation from soil surface, solute adsorption by the solid phase, and solute degradation. The current version 3.0 includes simulation of preferential flow of water and dissolved constituents through the unsaturated zone using a hierarchy of modules of increasing complexity. The modules account for the presence of immobile water, exchange of water or solutes between solid macropores and the soil matrix, and possible water flow and solute transport in both the macropores and micropores. Version 3.0 also includes options to simulate the transport of viruses, bacteria, and colloids in the soil. Simulation includes provisions for kinetic attachment/detachment of colloid or pathogens to the solid phase, physical straining of colloid particles by the solid phase, and possible accumulation at air-water interfaces when the soil becomes unsaturated (Šimunek et al., 2005a).

A review of three projects conducted by the Agricultural Research Service confirmed that HYDRUS is a valuable tool in for analyzing and designing irrigated agricultural systems. The three projects included in the review included analyzing drip irrigation systems, simulating the effects of salinity and drought stress on root water uptake, and using inverse modeling to assess upward water flow from shallow groundwater (Skaggs et al., 2005).

HYDRUS can also be coupled with other software packages. Šimunek et al. (2005) coupled HYDRUS to several other packages including UNSATCHEM, the PHREEQ biogeochemical code, and Constructed Wetlands 2D (CW2D). The coupled model of HYDRUS and UNSATCHEM has been used to make quantitative predictions on the effects of salinity on plant growth and the amount of water and amendment required to reclaim salt-affected soil profiles. HP1, a coupling of HYDRUS and PHREEQC, accounts for complexation, cation exchange, surface complexation, precipitation-dissolution and redox reactions. The combined model of CW2D and the two-dimensional version of HYDRUS characterizes biochemical transformation and degradation processes in subsurface flows in constructed wetlands and includes biochemical degradation and transformation process for organic matter, nitrogen, and phosphorus. Biochemical components in the CW2D program are dissolved oxygen, organic matter (readily biodegradable, slowly biodegradable, inert), nitrogen compounds (ammonium, nitrite, nitrate, dinitrogen), inorganic phosphorus, and microorganisms (heterotrophic, autotrophic). The model assumes that heterotrophic bacteria are responsible for hydrolysis, mineralization of organic matter and denitrification, and autotrophic bacteria are responsible for nitrification (Šimunek et al., 2005a).

The Agricultural Research Services recently performed a research project to improve HYDRUS by implementing new processes and by testing the software against experimental data. The project plan included improved capabilities for simulating 3D transport problems, preferential flow as modeled with alternative dual-permeability models, multicomponent solute transport as applied to toxic trace elements, energy balance at the soil service, overland flow to improve the design of surface irrigation systems, and colloid and colloid-facilitated transport.

Advantages

HYDRUS-1D is capable of one dimensional transport of multiple solutes. Transport equations can account for nonlinear and non equilibrium reactions between the solid and liquid phases, linear equilibrium reactions between the liquid and gaseous phases, zero order production, and two first-order degradation reactions: one which is independent of other solutes, and one which provides coupling between solutes involved in sequential first-order decay reactions. Also, HYDRUS-1D provides the option of choosing different methods to represent parts of the model.

Disadvantages

HYDRUS-1D does not directly consider geochemical reactions; however degradation rates can be input to represent geochemical transformations. HYDRUS-1D results may also be very sensitive to parameters which are variable across the entire Santa Clara and Llagas groundwater subbasins, such as soil characteristics.

4.3. MINTEQA2

MINTEQA2 is a model developed by USEPA for geochemical equilibrium speciation for dilute aqueous systems. Adsorption data are not included in the database as they are left to the user to select for each specific problem. Seven adsorption models are available to match the adsorption input data. An associated program called PRODEFA2 has been incorporated into MINTEQA2 to assist with creating the input files (USEPA, 1991).

A Windows-based implementation of MINTEQA2, Visual MINTEQ, is available for free download. Visual MINTEQ includes ion speciation using equilibrium constants, solubility calculations involving solid phases, adsorption calculations with adsorption isotherms, ion exchange calculations using the

Gaines-Thomas formalism, metal-humic complexation, calculations for redox couples and gases, sweep runs in which one parameter is varied, and titrations (KTH, 2007).

Advantages

The model is useful for characterizing equilibrium mass distribution for dissolved species, adsorbed species, and multiple solid phases. MINTEQA2 includes a comprehensive thermodynamic database of equilibrium constants which can be modified if data are incomplete or inadequate to a specific problem.

Disadvantages

MINTEQA2 does not model the transport of constituents, only physical and chemical equilibrium. Hence, it cannot be used to estimate transport of constituents to groundwater.

4.4. Soil Attenuation Model (SAM)

SAM provides conservative estimates soil to groundwater contaminant releases based on annual rainfall, soil type, depth to groundwater and hydrogeological properties.

Advantages

SAM is a very simple model to implement, requiring minimal data input compared to other models. SAM can predict the upperbound constituent concentrations in groundwater based on soil concentrations. It can also back-calculate a lower bound soil site specific target level based on the applicable risk-based screening level at the groundwater point of exposure. SAM can be used for porous media soils impacted by either organic or inorganic constituents, in the absence of mobile non-aqueous phase liquids (Connor et al., 1997).

Disadvantages

The lack of consideration for geochemical reactions makes SAM inaccurate for many constituents. Furthermore, in the base version of this model, volatilization and biodegradation processes are neglected for simplicity. As discussed in Section 2, there are several recycled water constituents where these processes are expected to have a significant effect.

4.5. Recommendations

Based on the advantages and disadvantages of each model, HYDRUS-1D is recommended as the most suitable model for soil attenuation modeling. HYDRUS-1D can model the transport of multiple solutes in one dimension. It can account for solute transformation in the solid-aqueous phase, gas-aqueous phase, zero and first order degradation. Although HYDRUS-1D does not account specifically for geochemical reactions, inputs for degradation rates can be used which will serve the purpose of this study. The issue of sensitivity to input parameters can be accounted for by testing the model using a range of potential inputs. For more detailed investigations, the 2D or 3D versions of HYDRUS could be implemented, but since this modeling is intended to apply generally to the entire Santa Clara and Llagas subbasins, the 1D version is more suitable.

The other models discussed above have significant drawbacks which make them less valuable for this study. SAM is not suitable for modeling because of the lack of attenuation mechanisms such as volatilization and biodegradation. MINTEQA is not suitable because it does not model solute transport. PHREEQ can account for multiple physical and chemical processes that affect solute transport, but the results cannot be applied to a large area, since the input data is very specific to soil characteristics which are variable across the study area.

REFERENCES

American Water Works Association (AWWA) Research Foundation, 2001, Soil Aquifer Treatment for Sustainable Water Reuse, prepared by Fox, P.; Houston, S.; Westerhoff, P.; Drewes, J.; Nellor, M.; Yanko, W.; Baird, R.; Rincon, M.; Arnold, R.; Lansey, K.; Bassett, R.; Gerba, C.; Karpiscak, M.; Amy, G.; and Reinhard, M.; published by AWWA Research Foundation, Denver, CO.

Asano, T., Burton, F.L., Leverenz, H.L., Tsuchihashi, R., and Tchobanoglous, G., 2007, Water Reuse: Issues, Technologies, and Applications, MetCalf & Eddy | AECOM.

Bradley, P.M., Carr, S.A., Baird, R.B., Chapell, F.H., 2005, Biodegradation of n-Nitrosodimethylamine in soil from a water reclamation facility, Bioremdiat, J, 9(2), 115-120.

Butler, R., Godley, A., Lytton, L., and Cartmell, E., 2005a, Bromate Environmental Contamination: Review of Impact and Possible Treatment, Critical Reviews in Environmental Science and Technology, Vol. 35, Issue 3, pp. 193-217.

Butler, R., Lytton, L., Godley, A., Tothill, I., and Cartmell, E., 2005b, Bromate Analysis in Groundwater and Wastewater Samples, Journal of Environmental Monitoring.

Brown and Caldwell, May 2005. Assessment Of Recycled Water Irrigation In Central Oahu by Crites, R.W., Kawata, E.M., Muirhead, W.M

California Department of Public Health (CDPH), 2007, Drinking Water Notification Levels and Response Levels: An Overview, Drinking Water Program, Last update: December 14, 2007, URL: http://www.cdph.ca.gov/certlic/drinkingwater/Pages/default.aspx.

California Regional Water Quality Control Board, San Francisco Bay Region, 2007, Screening for Environmental Concerns at Sites with Contaminated Soil and Groundwater, Interim Final November 2007, Revised May 2008..

Chang, S.C., Chu, W.K., 1961, The Fate of Soluble Phosphate Applied to Soils, European Journal of Soil Science, Volume 12, Issue 2, Page 286-293.

Connor, J.A., Bowers, R.L., Paquette, S.M., and Newell, C.J., 1997, Soil Attenuation Model for Derivation of Risk-Based Soil Remediation Standards, Groundwater Services Inc., July.

Deeb, R., Hawley, E., Sedlak, D., Loveland, J., and Kavanaugh, M., 2006, Removal and Destruction of NDMA and Precursors During Wastewater Treatment, Water Environment Foundation Technical Exhibition and Conference, 2006 Proceedings.

Ding, W., Wu, J., Semandeni, M., Reinhard, M., 1999, Occurrence and Behavior of Wastewater Indicators in the Santa Ana River and the Underlying Aquifers, Chemosphere, Vol. 39, Issue 11, pp 1781-1794.

Gan, J., Bondarenko, S., Ernst, F., Yang, W., Ries, S.B., and Sedlak, D.L., 2006, Leaching of N-nitrosodimethylamine (NDMA) in Turfgrass Soils During Wastewater Irrigation, Journal of Environmental Quality, 2006, Vol. 35, No. 1, pp. 277-284, doi: 10.2134/jeq2005.0264.

Gan, J., Green, J., Sedlak, D., date unspecified, Irrigation with Recycled Wastewater: The NDMA Story, University of California Riverside, University of California Berkeley.

Geologica, 2003, Final Report: Evaluation of Potential Geochemical Reactions with Recycled Water, prepared for Santa Clara Valley Water District, 20 August.

Gross, B., Montegomery-Brown, J., Naumann, A., Reinhard, M., 2004, Occurrence and Fate of Pharmaceuticals and Alkylphenol Ethoxylate Metabolites in an Effluent-dominated River and Wetland, Environmental Toxicology and Chemistry, Vol. 23, Issue 9, pp. 2074-2083.

Hoppe-Jones, C., Dickenson, E.R.V, Drewes, J.E., date unspecified, Factors Effecting the Attenuation of Trace Organic Contaminants during Riverbank Filtration (RBF) and Soil-Aquifer Treatment (SAT), Colorado School of Mines, Golden, CO.

Hudson, G.B, Beller, H., Moody Bartel, C., Kane, S., Campbell, C., Grayson, A., Liu, N., Baurastero, S., 2005, Environmental Transport and Fate of Endocrine Disruptors from Non-Potable Reuse of Municipal Wastewater, Lawrence Livermore National Laboratory, UCLR-TR-217159, 16 November.

Hyung, S.Y., 2003, Denitrification of Ethylenediaminetetraacetic Acid (EDTA) and Fate of Other Wastewater Organics in a Vadose Zone During Soil-Aquifer Treatment (SAT), Thesis submitted to Department of Civil and Environmental Engineering, Stanford University.

Kaplan, D.L, Kaplan, A.M., Biodegradation of N-Nitrosodimethylamine in Aqueous and Soil Systems, Sciene and Advanced Technology Laboratory, U.S. Army Natick Research and Development Center, Applied and Environmental Microbiology, Vol. 50, No. 4, 1077-1086.

Kungliga Tekniska Högskolan (KTH), 2007, Department of Land and Water Resources Engineering, Visual MINTEQ ver 2.52, http://www.lwr.kth.se/English/OurSoftware/vminteq/, last updated: 7 May 2007.

Kookana, R. and Ying, G., 2005, Sorption and Degradation of Estrogen-Like-Endocrine Disrupting Chemicals in Soil, Environmental Toxicology and Chemistry, 24:2640-2645.

Lawrence Livermore National Laboratory (LLNL), 2006, California GAMA Program: Fate and Transport of Wastewater Indicators: Results from Ambient Groundwater and from Groundwater Directly Influenced by Wastewater, prepared in cooperation with the California State Water Resource Control Board, UCRL-TR-222531, June.

Lefèvre, C., Mathieu, C., Tidjani, A., Dupret, I., VanderWauven, C., DeWinter, W., and David, C., 1999, Comparative Degradation by Micro-Organisms of Terephthalic Acid, 2,6-Naphthalene Dicarboxylic Acid, Their Esters, and Polyesters, Polymer Degradation and Stability, 64:9-16.

Luthy, R., 2007, Research: Environmental Fate, Toxicity, and Bioaccumulation of Perfluorinated Chemicals, Richard G. Luthy Research Group, Department of Civil & Environmental Engineering, Stanford University, http://www.stanford.edu/group/luthygroup/PFC%20Research.htm, reviewed 10 September 2007.

Mansell J., Drewes J.E., Rauch, T., 2004, Removal Mechanisms of Endocrine Disrupting Compounds (Steroids) during Soil Aquifer Treatment, Water Science and Technology, Vol. 50, Issue 2, pp. 229-237.

Mihoko, U.,Toshinari, S., Kumiko, Y., Kazuo, Y., Toshihiro, N., 2006, Survey of Bromate Ions Potable Groundwater in Tama District, Tokyo, Journal of Japan Society on Water Environment, Vol. 29, No. 5, pp 281-285.

Montgomery-Brown, J., Drewes, J.E., Fox, P., Reinhard, M., 2003, Behavior of Alkylphenol Polyethoxylate Metabolites during Soil Aquifer Treatment, Water Research, Vol. 37, Issue 15, pp. 3672-3681.

Nakata, H., Kannan, K., Nasu, T., Cho, H.S., Sinclair, E., Takemuari, A., 2006, Perfluorinated Contaminants in Sediments and Aquatic Organisms Collected from Shallow Water and Tidal Flat Areas of the Ariake Sea, Japan: Environmental Fate of Perfluorooctane Sulfonate in Aquatic Ecosystems, Environmental Science and Technology, Vol. 40, Issue 16, pp. 4916 – 4921.

National Center for Sustainable Water Supply, 2001, White Paper: An Investigation of Soil-Aquifer Treatment for Sustainable Water Reuse, Leading Researchers: Fox, P.; Houston, S.; Westerhoff, P.; Drewes, J.E.; Nellor, M.; Yanko, W.; Baird, R.; Rincon, M.; Arnold, R.; Lansey, K.; Bassett, R.; Gerba, C.; Karpiscak, M.; Quanrud, D.; Amy, G.; Reinhard, M, Arizona State University, Tempe, Arizona.

National Industrial Chemicals Notification and Assessment Scheme (NICNAS), 2001, Safety Info Sheet No. 17: Trisphosphates.

Patrick Jr. W.H., Khalid, R.A., 1974, Phosphate Release and Sorption by Soil and Sediments: Effects of Aerobic and Anaerobic Conditions, Science, Vol. 186., no. 4158, pp. 53-55.

Pavelic, P., Nicholson, B.C., Dillon, P.J., Barry, K.E., 2005, Fate of Disinfection By-products in Groundwater during Aquifer Storage and Recovery with Recycled Water, Journal of Contaminant Hydrology, Vol. 77, Issue 4, pp. 351-3713.

Pehlivanoglu-Mantas, E., Hawley, E., Deeb, R., and Sedlak, D., 2006, Formation of Nitrosodimethylamine (NDMA) During Chlorine Disinfection of Wastewater Effluents Prior to Use in Irrigation Systems, Water Research, Vol. 40, Issue 2, pp. 341-347.

Pitt, R., Clark, S., Parmer, K., and Field, R., 1996, Groundwater Contamination from Stormwater Infiltration, CRC Press.

Ray, M.C., Kulongoski, J.T., Belitz, Kenneth, 2009, Groundwater Quality Data in the San Francisco Bay Study Unit, 2007: Results from the California GAMA program: US Geological Survey Data Series 396, 92 p. Available at http://pubs.usgs.gov/ds/396.

Sadiq, R., Rodriguez, M.J., 2004, Disinfection By-products (DBPs) in Drinking Water and the Predictive Models for their Occurrence: A Review, National Research Council Canada, NRCC-44499.

Santa Clara Valley Water District, 2004, Technical Documents, Technical Memoranda 1-6: Advanced Recycled Water Treatment (ARWT) Feasibility Project, prepared by Black & Veatch Corporation.

Santa Clara Valley Water District, 2006, Stream Flow Augmentation Project Upper Silver Creek and Coyote Creek, Initial Study / Mitigated Negative Declaration, Draft, prepared by Thomas Reid Associates.

Sedlak, D.L., Deeb, R.A., Hawley, E.L., Mitch, W.A., Durbin, T.D., Mowbray, S., and Carr, S., Sources and Fate of Nitrosodimethylamine and its Precursors in Municipal Wastewater Treatment Plants, Water Environment Research, January 2005, Vol. 77, No. 1, pp. 32-39.

Selim, H.M., and Iskandar, I.K., 1999, Fate and Transport of Heavy Metals in the Vadose Zone, Lewis Publishers, Boca Raton, FL.

Skaggs, T.H., Trout, T.J., Kelleners, T.J., Shouse, P.J., and Ayars, J.E., 2005, Recent Applications of Hydrus in Irrigated Agriculture. In: S. Torkzaban and S. Mjaid Hassanizadeh (eds.), Proceedings of Workshop on HYDRUS Applications. October 19, 2005, ISBN 90-39341125, Department of Earth Sciences, Utrecht University, Utrecht, The Netherlands. p: 69-72.

Šimunek, J., Van Genunchten, M.T., Bradford, S.A., and Lenhard, R.J., 2005a, New Features of HYDRUS-1D, Version 3.0. In: S. Torkzaban and S. Majid Hassanizadeh (eds.), Proceedings of Workshop on HYDRUS Applications, p. 86-89, October 19, 2005, ISBN 90-39341125, Department of Earth Sciences, Utrecht University, Utrecht, The Netherlands.

Šimunek, J., Jacques, D., Langergraber, G., Van Genuchten, M.T., and Mallants, D., 2005b, Multicomponent biogeochemical transport modeling using the HYDRUS computer software packages. ASA-CSSA-SSSA Annual Meetings Abstracts. Nov. 6-10, Salt Lake City, UT. CD-ROM. Paper No 316-6).

Sinaj, S., Stamm, C., Toor, G.S., Condron, L.M., Hendry, T., Di, H.J., Cameron, K.C., Frossard, E., 2002, Vadose Zone Processes and Chemical Transport, Phosphorus Exchangeability and Leaching Losses from Two Grassland Soils, Journal of Environmental Quality, 31:319-330.

State of California, Title 22 California Code of Regulations, Section 64431, 64672.3, 64441, 64443 64444, http://www.oal.ca.gov/, 2007.

Sun, W., Ni, J., O'Brien, K., Hao, P., and Sun, L., 2005, Adsorption of Bisphenol A on Sediments in the Yellow River, Water, Soil, & Air Pollution, 167:353-364, October.

Thiele, B., Gunther, K., and Schwuger, M., 1997, Alkylphenol Ethoxylates: Trace Analysis and Environmental Behavior, Chemical Reviews, Volume 97, 8:3247-3272, September.

Toze, Simon, 2004, Reuse of Effluent Water – Benefits and Risks, Commonwealth Scientific and Industrial Research Organization, Centre for Environmental and Life Sciences, from proceedings of the 4th International Crop Science Congress, Brisbane, Australia.

US Environmental Protection Agency, 1991, MINTEQA2/PROFEDA2, A Geochemical Assessment Model for Environmental Systems: Version 3.0 User’s Manual, EPA/600/3-91/021, March.

US Environmental Protection Agency, 2003, National Primary Drinking Water Standards, EPA 816-F-03-016.

US Environmental Protection Agency, 2004, Technologies for Treating MtBE and Other Fuel Oxygenates, May.

US Environmental Protection Agency, 2006a, EPA Superfund Record of Decision: EPA ID# PAD077087989, Foote Mineral Company, East Whiteland Township, Pennsylvania, 31 March.

US Environmental Protection Agency, 2006b, Ground Water and Drinking Water: Drinking Water Contaminants, http://www.epa.gov/safewater/hfacts.html, last updated November 2006.

US Environmental Protection Agency, 2007a, Nitrates and Nitrites, TEACH Chemical Summary, U. S. EPA, Toxicity and Exposure Assessment for Children’s Health, Last revised updated May 22 2007.

US Environmental Protection Agency, 2007b, Radiation Topics: Understanding Radiation, http://www.epa.gov/radiation/understand/index.html, last updated July 2007.

US Environmental Protection Agency, 2008, Emerging Contaminant – N-Nitrosodymethylamine (NDMA) Fact Sheet, EPA 505-F-07-006, April 2008.

US Geological Survey, 1995, Pesticide Movement in Soils: A Comparison of No-Tillage and Conventional Tillage in the Beaver Creek Watershed in West Tennessee, Open File Report 95-329, written by Olsen, L.

US Geological Survey, 1996, Water Quality, Pesticide Occurrence, and Effects of Irrigation with Recycled Water at Golf Courses in Florida, written by Swancar, A., Water-Resources Investigations Report 95-4250, Tallahassee, Florida.

US Geological Survey, 2005, PHREEQC (Version 2) – A Computer Program for Speciation, Batch-Reaction, One-Dimensional Transport, and Inverse Geochemical Calculations, http://wwwbrr.cr.usgs.gov/projects/GWC_coupled/phreeqc/, last updated November 2005.

WateReuse Foundation, 2006, Investigation of N-Nitrosodimethylamine (NDMA) Fate and Transport, Principle Investigator: Sedlak, D., Alexandria, VA, July.

World Health Organization, 1998a, Terbuthylazine (TBA) in Drinking Water, Background Document for Development of WHO Guidelines for Drinking-Water Quality, Guidelines for Drinking-Water Quality, 2nd. Ed., Addendum to Vol. 2.

World Health Organization, 1998b, Boron in Drinking Water, Background Document for Development of WHO Guidelines for Drinking-Water Quality, Guidelines for Drinking-Water Quality, 2nd. Ed., Addendum to Vol. 2.

Ying, G., Williams, B., Kookana, R., 2002, Environmental Fate of Alkylphenols and Alkylphenol Ethoxylates – A Review, Environment International, Vol. 28, Issue 3, pp. 215-226.

Ying, G. and Kookana, R.S., 2006, Environmental Fate of Endocrine Disrupting Chemicals in Soil, 5th International Conference on Pharmaceuticals and Endocrine Disrupting Chemicals in Water, National Ground Water Association.

Zhou, Q., McCraven, S., Garcia, J., Gasca, M., Johnson, T.A., Motzer, W.E., 2009, Field evidence of biodegradation of N-Nitrosodimethylamine (NDMA) in groundwater with incidental and active recycled water recharge, Water Research 43, 793-805.

TABLES

TABLE I-2-1
LIST OF CHEMICALS ANALYZED IN RECYCLED WATER SAMPLES

Constituent	Data Presented in	Category
1,1,1,2-Tetrachloroethane	No detections, not plotted	
1,1,1-Trichloroethane	No detections, not plotted	
1,1,2,2-Tetrachloroethane	No detections, not plotted	
1,1,2-Trichloroethane	No detections, not plotted	
1,1-Dichloroethane	No detections, not plotted	
1,1-Dichloroethene	No detections, not plotted	
1,1-Dichloropropane	No detections, not plotted	
1,1-Dichloropropene	No detections, not plotted	
1,2,3-Trichlorobenzene	No detections, not plotted	
1,2,3-Trichloropropane	No detections, not plotted	
1,2,4-Trichlorobenzene	No detections, not plotted	
1,2,4-Trimethylbenzene	No detections, not plotted	
1,2-Dichlorobenzene	No detections, not plotted	
1,2-Dichloroethane	No detections, not plotted	
1,2-Dichloropropane	No detections, not plotted	
1,3,5-Trimethylbenzene	No detections, not plotted	
1,3-Dichlorobenzene	No detections, not plotted	
1,3-Dichloropropane	No detections, not plotted	
1,3-Dichloropropene	No detections, not plotted	
1,4-Dichlorobenzene	No detections, not plotted	
1,4-Dioxane	No detections, not plotted	
17β-Estradiol	No detections, not plotted	
2,2-Dichloropropane	No detections, not plotted	
2,3,7,8-TCDD	No detections, not plotted	
2,4,5-TP	No detections, not plotted	
2,4-D	No detections, not plotted	
2,4-Dinitrotoluene	No detections, not plotted	
2,6-Dinitrotoluene	No detections, not plotted	
2-Chlorotoluene	No detections, not plotted	
3-Hydroxycarbofuran	No detections, not plotted	
4,4'-DDD	No detections, not plotted	
4,4'-DDE	No detections, not plotted	
4,4'-DDT	No detections, not plotted	
4-Chlorotoluene	No detections, not plotted	
4-Isopropyltoluene	No detections, not plotted	
Acenaphthene	No detections, not plotted	
Acenaphthylene	No detections, not plotted	
Acetaminophen	No detections, not plotted	
Acetochlor	No detections, not plotted	
Aciflurfen	No detections, not plotted	
Alachlor	No detections, not plotted	
Aldicarb (Temik)	No detections, not plotted	
Aldicarb sulfone	No detections, not plotted	
Aldicarb sulfoxide	Appendix A	E
Aldrin	No detections, not plotted	
Alkalinity, Total	Appendix A	B
Alkylphenol Di-ethoxylate (AP2EO)	Appendix B	C
Alkylphenol Ethoxycarboxylate (APEC) m/z 235	Appendix B	C
Alkylphenol Ethoxycarboxylate (APEC) m/z 249	Appendix B	C
Alkylphenol Ethoxycarboxylate (APEC) m/z 279	Appendix B	C
Alkylphenol Ethoxycarboxylate (APEC), Halogenated	Appendix B	C
Alkylphenol Ethoxycarboxylate (APEC), Total	Appendix B	C
Alkylphenol ethoxylate (APEO), Total	Appendix B	C
Alkylphenol Mono-ethoxylate (AP1EO)	Appendix B	C
Alkylphenol Tri-ethoxylate (AP3EO)	Appendix B	C

TABLE I-2-1
LIST OF CHEMICALS ANALYZED IN RECYCLED WATER SAMPLES

Constituent	Data Presented in	Category
Alkylphenol/Alkylphenolethoxylates (AP/APEO), Halogenated	Appendix B	C
Alpha, Gross	Appendix A	D
Alpha-BHC	No detections, not plotted	
Alpha-chlordane	No detections, not plotted	
Aluminum	Appendix A	D
Anthracene	No detections, not plotted	
Antimony	No detections, not plotted	
Arsenic	No detections, not plotted	
Atrazine	No detections, not plotted	
Barium	No detections, not plotted	
Baygon (Propoxur)	No detections, not plotted	
Bentazon	No detections, not plotted	
Benz(a)Anthracene	No detections, not plotted	
Benzene	No detections, not plotted	
Benzo(a)pyrene	No detections, not plotted	
Benzo(b)Fluoranthene	No detections, not plotted	
Benzo(g,h,i)Perylene	No detections, not plotted	
Benzo(k)Fluoranthene	No detections, not plotted	
Beryllium	No detections, not plotted	
Beta, Gross	Appendix A	D
Beta-BHC	No detections, not plotted	
Bicarbonate Alkalinity	Appendix A	B
Bisphenol-A (BPA)	No detections, not plotted	
Boron	Appendix A	C
Bromacil	No detections, not plotted	
Bromate	Appendix B	D
Bromobenzene	No detections, not plotted	
Bromochloroacetic Acid	Appendix B	E
Bromochloromethane	No detections, not plotted	
Bromodichloromethane	Appendix A	C
Bromoform	Appendix A	C
Bromomethane	No detections, not plotted	
Butachlor	No detections, not plotted	
Butylbenzylphalate	No detections, not plotted	
Cadmium	Appendix A	D
Caffeine	Appendix B	E
Calcium	Appendix A	A
Carabaryl	No detections, not plotted	
Carbamazepine	Appendix B	E
Carbofuran (Furadan)	No detections, not plotted	
Carbon Tetrachloride	Appendix A	D
Carbonate Alkalinity	No detections, not plotted	
Carisoprodol	Appendix B	E
Chlordane	No detections, not plotted	
Chloride	Appendix A	A
Chlorine, Total	Appendix C	E
Chlorobenzene	No detections, not plotted	
Chlorobenzilate	No detections, not plotted	
Chloroethane	No detections, not plotted	
Chloroform	Appendix A	C
Chloromethane	No detections, not plotted	
Chloroneb	No detections, not plotted	
Chlorpyrifos (Dursban)	No detections, not plotted	
Chlorthalonil (Draconil, Bravo)	No detections, not plotted	
Chromium	No detections, not plotted	

TABLE I-2-1
LIST OF CHEMICALS ANALYZED IN RECYCLED WATER SAMPLES

Constituent	Data Presented in	Category
Chromium, Hexavalent	No detections, not plotted	
Chrysene	No detections, not plotted	
cis-1,2-Dichloroethene	No detections, not plotted	
cis-1,3-Dichloropropene	No detections, not plotted	
Clostridium Perfringens	No data, not tested for	E
Coliforms, Total	Appendix B	E
Conductivity	Not enough data, not plotted	
Copper	Appendix A	D
Cryptosporidium Oocysts	Appendix B	E
Cyanide	Appendix A	C
Dalapon	No detections, not plotted	
Delta-BHC	No detections, not plotted	
Di(2-ethylhexyl)adipate	No detections, not plotted	
Di(2-ethylhexyl)phthalate (DEHP)	Appendix A	D
Diazinon	No detections, not plotted	
Dibenz(a,h)Anthracene	No detections, not plotted	
Dibromoacetic Acid	Appendix A	E
Dibromochloromethane	Appendix A	C
Dibromochloropropane (DBCP)	No detections, not plotted	
Dibromomethane	No detections, not plotted	
Dicamba	No detections, not plotted	
Dichloroacetic Acid	Appendix A	E
Dichlorodifluoromethane	No detections, not plotted	
Dichlorovos (DDVP)	No detections, not plotted	
Dieldrin	No detections, not plotted	
Diethylphthalate	No detections, not plotted	
Diisopropyl Ether (DIPE)	No detections, not plotted	
Dimethoate	No detections, not plotted	
Dimethylphthalate	No detections, not plotted	
Di-N-Butylphthalate	No detections, not plotted	
Di-N-Octylphthalate	No detections, not plotted	
Dinoseb	No detections, not plotted	
Diquat	No detections, not plotted	
Dissolved Organic Carbon	Appendix C	A
Dissolved Oxygen	No data, not tested for	B
E. Coli	Appendix B	E
Endosulfan I (alpha)	No detections, not plotted	
Endosulfan II (beta)	No detections, not plotted	
Endosulfan sulfate	No detections, not plotted	
Endothall	No detections, not plotted	
Endrin	No detections, not plotted	
Endrin Aldehyde	No detections, not plotted	
Estradiol	No detections, not plotted	
Estriol	No detections, not plotted	
Estrone	Appendix B	D
Ethyl tert-Butyl Ether (ETBE)	No detections, not plotted	
Ethylbenzene	No detections, not plotted	
Ethylene Dibromide (EDB)	No detections, not plotted	
Ethylenediaminetetraacetic acid (EDTA)	Appendix B	C
Ethynylestradiol	No detections, not plotted	
Fecal Coliforms	Appendix B	E
Fluorene	No detections, not plotted	
Fluoride	Appendix A	D
Fluoroanthene	No detections, not plotted	
gamma-Chlordane	No detections, not plotted	

TABLE I-2-1
LIST OF CHEMICALS ANALYZED IN RECYCLED WATER SAMPLES

Constituent	Data Presented in	Category
Gemfibrozil	Appendix B	E
Giardia	Appendix B	E
Glyphosate	No detections, not plotted	
Haloacetic Acids (5), Total	Appendix B	E
Hardness	Appendix A	D
Heptachlor	No detections, not plotted	
Heptachlor Epoxide	Appendix A	D
Heptachlor Epoxide (isomer A)	No detections, not plotted	
Heptachlor Epoxide (isomer B)	No detections, not plotted	
Heterotrophic Plate Count	Appendix B	E
Hexachlorobenzene	No detections, not plotted	
Hexachlorobutadiene	No detections, not plotted	
Hexachlorocyclopentadiene	Appendix A	D
Hydroxide Alkalinity	No detections, not plotted	
Ibuprofen	Appendix B	E
Iminostilbene	No detections, not plotted	
Indeno(1,2,3,c,d)pyrene	No detections, not plotted	
Iron	Appendix A	D
Isophorone	No detections, not plotted	
Isopropylbenzene	No detections, not plotted	
Ketoprofen	No detections, not plotted	
Lead	Appendix A	D
Legionella Direct Isolation	No quantifiable results	
Lindane (gamma-BHC)	Appendix A	D
Magnesium	Appendix A	A
Malathion	No detections, not plotted	
Manganese	Appendix A	D
Medroxyprogesterone	No detections, not plotted	
Mercury	No detections, not plotted	
Methiocarb	No detections, not plotted	
Methomyl	No detections, not plotted	
Methoxychlor	No detections, not plotted	
Methyl Ethyl Ketone (MEK)	No detections, not plotted	
Methyl Isobutyl Ketone	No detections, not plotted	
Methyl tert-Butyl Ether (MTBE)	No detections, not plotted	
Methylene Chloride	No detections, not plotted	
Metolachlor	No detections, not plotted	
Metribuzin	No detections, not plotted	
Molinate	No detections, not plotted	
Monobromoacetic Acid	Appendix B	E
Monochloroacetic Acid	Appendix B	E
Naphthalene	No detections, not plotted	
Naphthalenedicarboxylic acids (NDCs)	No data, not tested for	E
Naproxen	Appendix B	E
N-Butyl Benzenesulfonamide (NBBS)	Appendix B	E
N-Butylbenzene	No detections, not plotted	
Nickel	Appendix A	D
Nitrate	Appendix A	C
Nitrilotriacetic acid (NTA)	No data, not tested for	C
Nitrite	Appendix A	C
Nitrobenzene	No detections, not plotted	
N-Nitroso Dimethylamine (NDMA)	Appendix B	C
Nonylphenol/Octylphenol (NP/OP)	Appendix B	C
ORP	No data, not tested for	B
Oxamyl (Vydate)	No detections, not plotted	

TABLE I-2-1
LIST OF CHEMICALS ANALYZED IN RECYCLED WATER SAMPLES

Constituent	Data Presented in	Category
Paraquat	No detections, not plotted	
Parathion	No detections, not plotted	
PCB 1016 Aroclor	No detections, not plotted	
PCB 1221 Aroclor	No detections, not plotted	
PCB 1232 Aroclor	No detections, not plotted	
PCB 1242 Aroclor	No detections, not plotted	
PCB 1248 Aroclor	No detections, not plotted	
PCB 1254 Aroclor	No detections, not plotted	
PCB 1260 Aroclor	No detections, not plotted	
PCBs, Total	No detections, not plotted	
Pendimethalin	No detections, not plotted	
Pentachlorophenol	No detections, not plotted	
Perchlorate	Appendix A	A
Perfluorochemicals	No data, not tested for	E
Permethrin (mixed isomers)	No detections, not plotted	
pH	Appendix A	B
Phenanthrene	No detections, not plotted	
Phosphate	Appendix B	C
Picloram	No detections, not plotted	
p-Isopropyltoluene	No detections, not plotted	
Primidone	No detections, not plotted	
Prometryn	No detections, not plotted	
Propachlor	No detections, not plotted	
Propanolol	No detections, not plotted	
Propylbenzene	No detections, not plotted	
Pyrene	No detections, not plotted	
Radium 226	No detections, not plotted	
Radium 228	Appendix A	D
Radon 222	No detections, not plotted	
sec-Butylbenzene	No detections, not plotted	
Selenium	No detections, not plotted	
S-Ethyl dipropylthiocarbamate (EPTC)	No detections, not plotted	
Silica	Appendix A	D
Silver	No detections, not plotted	
Simazine	No detections, not plotted	
Sodium	Appendix A	A
Strontium 90	No detections, not plotted	
Styrene	No detections, not plotted	
Sulfate	Appendix A	A
Surfactants	Appendix B	C
Terbacil	No detections, not plotted	
Terbuthylazine	Appendix C	C
tert-Amyl Methyl Ether (TAME)	No detections, not plotted	
tert-Butyl Alcohol	No detections, not plotted	
tert-Butylbenzene	No detections, not plotted	
Testosterone	No detections, not plotted	
Tetrachloroethene	No detections, not plotted	
Thallium	No detections, not plotted	
Thiobencarb	No detections, not plotted	
Toluene	No detections, not plotted	
Total Culturable Virus Assay	No detections, not plotted	
Total Filterable Residue at 180C (TDS)	Appendix B	A
Total Organic Carbon (TOC)	Appendix B	A
Total Suspended Solids (TSS)	Appendix B	D
Toxaphene	No detections, not plotted	

TABLE I-2-1
LIST OF CHEMICALS ANALYZED IN RECYCLED WATER SAMPLES

Constituent	Data Presented in	Category
trans-1,2-Dichloroethene	No detections, not plotted	
trans-1,3-Dichloropropene	No detections, not plotted	
trans-Nonachlor	No detections, not plotted	
Trichloroacetic Acid	Appendix A	E
Trichloroethene	No detections, not plotted	
Trichlorofluoroethane	No detections, not plotted	
Trichlorofluoromethane	No detections, not plotted	
Trifluralin	No detections, not plotted	
Trihalomethanes, Total	Appendix A, plotted individually	C
Tris(2,3-dichloropropyl)phosphate	Appendix B	E
Tris(3-chloropropyl)phosphate	Appendix B	E
Turbidity	Appendix A	D
Uranium	No detections, not plotted	
UV-254	Appendix B	A
Vinyl Chloride	No detections, not plotted	
Viruses	No detections, not plotted	D
Xylenes, Total	Appendix A	D
Zinc	Appendix A	D

Notes:
A - Significant Potential for Impact; Include for Monitoring
B - Important Parameter; Include for Monitoring
C - Inconclusive; Include for Monitoring
D - Minimum Potential for Impact; Omit from Monitoring
E - Insufficient Information; Include for Monitoring

Table I-2-2
RECLAIMED WATER CHEMISTRY

	Location	PARWQCP	PARWQCP	PARWQCP	PARWQCP	PARWQCP	PARWQCP	PARWQCP	SCRWA	SCRWA
	Date	30-Jul-2002	14-Nov-2002	25-Jan-2005	26-Jan-2005	5-Apr-2005	26-Jun-2007	2-Jul-2007	29-Nov-2001	3-Dec-2001
Parameter	Units									
Cations and Anions										
Boron	µg/L	321	NT	NT	344	NT	328	NT	207	NT
Calcium as CaCO3	mg/L	112	NT	NT	126	NT	109	NT	102	NT
Calcium	mg/L	45	NT	NT	51	NT	45	NT	41	NT
Chloride	mg/L	270	NT	NT	320	NT	274	NT	170	NT
Chlorine Total by DPD	mg/L	NT	NT	NT	NT	3.8	NT	NT	170	NT
Cyanide	µg/L	ND	NT	NT	NT	NT	ND	NT	NT	NT
Fluoride	mg/L	0.77	NT	NT	0.65	NT	0.87	NT	NT	NT
Sodium	mg/L	209	NT	NT	230	NT	206	NT	147	NT
Sulfate	mg/L	91	NT	NT	104	NT	95	NT	73	NT
Disinfection Byproducts										
Bromate	µg/L	ND	NT	NT	ND	NT	ND	NT	NT	NT
N-Nitroso dimethylamine (NDMA)	µg/L	0.49	0.23	NT	NT	NT	0.063	NT	NT	NT
General Water Quality										
Alkalinity, Total	mg/L	88	NT	NT	110	NT	65	NT	226	NT
Bicarbonate Alkalinity	mg/L	107	NT	NT	110	NT	77	NT	226	NT
Dissolved Organic Carbon	mg/L	NT	NT	NT	NT	NT	6.3	NT	NT	NT
Hardness as CaCO3	mg/L	232	NT	NT	261	NT	244	NT	NT	NT
pH	pH units	7.0	NT	NT	6.7	7.1	7.6	NT	7.4	NT
Silica	mg/L	7.0	NT	NT	15	NT	14	NT	NT	NT
Total Filterable Residue at 180C	mg/L	840	NT	NT	890	NT	862	NT	660	NT
Total Organic Carbon	mg/L	7.1	NT	NT	5.9	NT	5.6	NT	NT	NT
Total Suspended Solids	mg/L	0.0	NT	NT	0.0	NT	1.0	NT	NT	NT
Turbidity	NTU	0.67	NT	NT	0.89	NT	0.51	NT	NT	NT
UV-254	ABS	0.11	NT	NT	0.12	NT	0.11	NT	NT	NT

Notes:

ND - denotes result was below the detection limit
NT - sample not tested for the given parameter
PARWQCP - Palo Alto Regional Water Quality Control Plant
SCRWA - South County Regional Wastewater Authority
SJ/SC WPCP - San Jose/Santa Clara Water Pollution Control Plant
SWPCP - Sunnyvale Water Pollution Control Plant

Table I-2-2

RECLAIMED WATER CHEMISTRY

Parameter	Location Date Units	PARWQCP 30-Jul-2002	PARWQCP 14-Nov-2002	PARWQCP 25-Jan-2005	PARWQCP 26-Jan-2005	PARWQCP 5-Apr-2005	PARWQCP 26-Jun-2007	PARWQCP 2-Jul-2007	SCRWA 29-Nov-2001	SCRWA 3-Dec-2001
Haloacetic Acids										
Bromochloroacetic Acid	µg/L	30	NT	NT	12	NT	NT	NT	NT	ND
Dibromoacetic Acid	µg/L	30	NT	NT	21	NT	23	NT	NT	ND
Dichloroacetic Acid	µg/L	23	NT	NT	7.0	NT	14	NT	NT	1.0
Haloacetic Acids (5)	µg/L	91	NT	NT	33	NT	58	NT	NT	61
Monobromoacetic Acid	µg/L	6.9	NT	NT	1.7	NT	3.8	NT	NT	ND
Monochloroacetic Acid	µg/L	2.2	NT	NT	ND	NT	NT	NT	NT	ND
Trichloroacetic Acid	µg/L	29	NT	NT	3.1	NT	18	NT	NT	60
Hormones										
Estrone	µg/L	NT	NT	NT	NT	NT	NT	NT	NT	NT
Estrone	µg/L	NT	NT	NT	ND	NT	NT	ND	NT	NT
Industrial Chemicals										
Carbon Tetrachloride	µg/L	ND	NT	NT	ND	ND	ND	NT	NT	NT
Di (2-Ethylhexyl) phthalate	µg/L	ND	NT	NT	NT	NT	ND	NT	NT	NT
EDTA	µg/L	NT	NT	NT	NT	NT	NT	NT	NT	NT
Hexachlorocyclopentadiene	µg/L	ND	NT	NT	NT	NT	ND	NT	NT	NT
NBBS	µg/L	NT	NT	NT	0.010	NT	NT	ND	NT	NT
Perchlorate	µg/L	ND	NT	NT	4.3	NT	ND	NT	NT	NT
Xylenes, Total	µg/L	ND	NT	NT	ND	0.0	ND	NT	NT	NT
Metals										
Aluminum	µg/L	83	NT	NT	ND	NT	ND	NT	NT	NT
Cadmium	µg/L	ND	NT	NT	ND	NT	ND	NT	NT	NT
Copper	µg/L	ND	NT	NT	ND	NT	ND	NT	NT	NT
Iron	µg/L	ND	NT	NT	ND	NT	ND	NT	NT	NT
Lead	µg/L	ND	NT	NT	ND	NT	ND	NT	NT	NT
Magnesium	mg/L	33	NT	NT	40	NT	31	NT	27	NT
Manganese	µg/L	ND	NT	NT	ND	NT	26	NT	NT	NT

Notes:

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NT - sample not tested for the given parameter
PARWQCP - Palo Alto Regional Water Quality Control Plant
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Table I-2-2
RECLAIMED WATER CHEMISTRY

Parameter	Location Date Units	PARWQCP 30-Jul-2002	PARWQCP 14-Nov-2002	PARWQCP 25-Jan-2005	PARWQCP 26-Jan-2005	PARWQCP 5-Apr-2005	PARWQCP 26-Jun-2007	PARWQCP 2-Jul-2007	SCRWA 29-Nov-2001	SCRWA 3-Dec-2001
Metals										
Nickel	µg/L	ND	NT	NT	ND	NT	ND	NT	NT	NT
Zinc	µg/L	ND	NT	NT	ND	NT	ND	NT	NT	NT
Nutrients										
Nitrate as NO3	mg/L	85	NT	NT	106	NT	122	NT	2.1	NT
Nitrite as N	mg/L	0.0	NT	NT	ND	NT	ND	NT	NT	NT
Phosphate	mg/L	11	NT	NT	14	NT	14	NT	NT	NT
Organophosphates										
Tris(2,3-dichloropropyl)phosphate	µg/L	NT	NT	NT	0.010	NT	NT	0.15	NT	NT
Tris(3-chloropropyl)phosphate	µg/L	NT	NT	NT	0.050	NT	NT	0.42	NT	NT
Pathogens										
Coliforms, Total	MPN/100ml	0.0	NT	NT	2.0	NT	4.0	NT	NT	NT
Cryptosporidium Oocysts	oocysts/L	0.20	NT	NT	0.70	NT	ND	NT	NT	NT
E. Coli	MPN/100ml	0.0	NT	NT	0.0	NT	ND	NT	NT	NT
Fecal Coliforms	MPN/100ml	0.0	NT	NT	0.0	NT	ND	NT	NT	NT
Giardia	cysts/L	0.0	NT	NT	3.8	NT	ND	NT	NT	NT
Heterotrophic Plate Count by R2A	CFU/mL	2.0	NT	NT	170	NT	5700	NT	NT	NT
Legionella	NA	NT	NT	NT	NT	NT	NT	NT	NT	NT
Total Culturable Virus Assay	MPN/100 L	ND	NT	NT	NT	NT	NT	NT	NT	NT
Pesticides										
Aldicarb Sulfoxide	µg/L	ND	NT	NT	NT	NT	ND	NT	NT	NT
Heptachlor Epoxide	µg/L	ND	NT	NT	NT	NT	ND	NT	NT	NT
Lindane (gamma-BHC)	µg/L	ND	NT	NT	NT	NT	ND	NT	NT	NT
Terbuthylazine	µg/L	NT	NT	NT	NT	NT	0.10	NT	NT	NT

Notes:

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Table I-2-2
RECLAIMED WATER CHEMISTRY

Parameter	Location Date Units	PARWQCP 30-Jul-2002	PARWQCP 14-Nov-2002	PARWQCP 25-Jan-2005	PARWQCP 26-Jan-2005	PARWQCP 5-Apr-2005	PARWQCP 26-Jun-2007	PARWQCP 2-Jul-2007	SCRWA 29-Nov-2001	SCRWA 3-Dec-2001
Pharmaceutically Active Compounds										
Caffeine	µg/L	ND	NT	NT	ND	NT	ND	ND	NT	NT
Carbamazepine	µg/L	NT	NT	NT	0.050	NT	NT	ND	NT	NT
Carisoprodol	µg/L	NT	NT	NT	ND	NT	NT	NT	NT	NT
Gemfibrozil	µg/L	NT	NT	NT	ND	NT	NT	ND	NT	NT
Ibuprofen	µg/L	NT	NT	NT	ND	NT	NT	0.15	NT	NT
Naproxen	µg/L	NT	NT	NT	ND	NT	NT	ND	NT	NT
Radioactives										
Alpha Gross	pCi/L	4.0	NT	NT	NT	NT	0.0	NT	NT	NT
Beta Gross	pCi/L	10	NT	NT	NT	NT	9.4	NT	NT	NT
Radium 228	pCi/L	NT	NT	NT	NT	NT	1.1	NT	NT	NT
Surfactants										
AP/APEO, Halogenated	µg/L	NT	NT	NT	ND	NT	NT	ND	NT	NT
AP1EO	µg/L	NT	NT	ND	NT	NT	NT	ND	NT	NT
AP2EO	µg/L	NT	NT	NT	NT	NT	NT	ND	NT	NT
AP3EO	µg/L	NT	NT	NT	NT	NT	NT	ND	NT	NT
APEC m/z 235	µg/L	NT	NT	NT	NT	NT	NT	1.1	NT	NT
APEC m/z 249	µg/L	NT	NT	NT	NT	NT	NT	ND	NT	NT
APEC m/z 279	µg/L	NT	NT	NT	NT	NT	NT	1.5	NT	NT
APEC Total	µg/L	NT	NT	NT	0.70	NT	NT	2.6	NT	NT
APEC, Halogenated	µg/L	NT	NT	0.040	NT	NT	NT	2.7	NT	NT
APEO Total	µg/L	NT	NT	NT	NT	NT	NT	ND	NT	NT
NP/OP	µg/L	NT	NT	NT	0.050	NT	NT	ND	NT	NT
Surfactants	µg/L	130	NT	NT	NT	NT	120	NT	NT	NT
Trihalomethanes										
Bromodichloromethane	µg/L	64	NT	NT	14	46	40	NT	NT	NT
Bromoform	µg/L	51	NT	NT	41	61	19	NT	NT	NT

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Table I-2-2
RECLAIMED WATER CHEMISTRY

Parameter	Location Date Units	PARWQCP 30-Jul-2002	PARWQCP 14-Nov-2002	PARWQCP 25-Jan-2005	PARWQCP 26-Jan-2005	PARWQCP 5-Apr-2005	PARWQCP 26-Jun-2007	PARWQCP 2-Jul-2007	SCRWA 29-Nov-2001	SCRWA 3-Dec-2001
Trihalomethanes										
Chloroform	µg/L	22	NT	NT	2.7	16	14	NT	NT	NT
Dibromochloromethane	µg/L	100	NT	NT	39	86	63	NT	NT	NT
Trihalomethanes, Total	µg/L	NT	NT	NT	NT	NT	NT	NT	NT	NT

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Table I-2-2
RECLAIMED WATER CHEMISTRY

Parameter	Location Date Units	SCRWA 30-Oct-2001	SCRWA 1-Nov-2001	SCRWA 26-Mar-2002	SCRWA 21-May-2002	SCRWA 30-May-2002	SCRWA 30-Jul-2002	SCRWA 13-Aug-2002	SCRWA 25-Jan-2005	SCRWA 6-Apr-2005
Cations and Anions										
Boron	µg/L	447	NT	443	NT	NT	358	NT	363	NT
Calcium as CaCO3	mg/L	90	NT	123	NT	NT	124	NT	134	NT
Calcium	mg/L	48	NT	49	NT	NT	50	NT	54	NT
Chloride	mg/L	166	NT	150	NT	NT	168	NT	119	NT
Chlorine Total by DPD	mg/L	NT	NT	NT	NT	NT	NT	NT	NT	3.0
Cyanide	µg/L	5	NT	ND	NT	NT	ND	NT	NT	NT
Fluoride	mg/L	0.15	NT	0.21	NT	NT	0.21	NT	0.41	NT
Sodium	mg/L	128	NT	138	NT	NT	141	NT	118	NT
Sulfate	mg/L	62	NT	66	NT	NT	60	NT	76	NT
Disinfection Byproducts										
Bromate	µg/L	3.0	NT	ND	NT	NT	3.0	NT	ND	NT
N-Nitroso dimethylamine (NDMA)	µg/L	0.0055	NT	ND	NT	NT	0.004	NT	NT	NT
General Water Quality										
Alkalinity, Total	mg/L	245	NT	250	NT	NT	247	NT	263	NT
Bicarbonate Alkalinity	mg/L	299	NT	299	NT	NT	301	NT	263	NT
Dissolved Organic Carbon	mg/L	NT	NT	NT	NT	NT	NT	NT	NT	NT
Hardness as CaCO3	mg/L	224	NT	180	NT	NT	232	NT	230	NT
pH	pH units	7.6	NT	7.5	NT	NT	7.6	NT	7.3	7.5
Silica	mg/L	32	NT	31	NT	NT	16	NT	35	NT
Total Filterable Residue at 180C	mg/L	670	NT	630	NT	NT	660	NT	640	NT
Total Organic Carbon	mg/L	5.0	NT	5.5	NT	NT	5.3	NT	4.0	NT
Total Suspended Solids	mg/L	10	NT	0.0	NT	NT	0.0	NT	0.0	NT
Turbidity	NTU	0.19	NT	0.25	NT	NT	0.41	NT	0.23	NT
UV-254	ABS	0.074	NT	0.070	NT	NT	0.083	NT	0.067	NT

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Table I-2-2
RECLAIMED WATER CHEMISTRY

	Location	SCRWA	SCRWA	SCRWA	SCRWA	SCRWA	SCRWA	SCRWA	SCRWA	SCRWA
	Date	30-Oct-2001	1-Nov-2001	26-Mar-2002	21-May-2002	30-May-2002	30-Jul-2002	13-Aug-2002	25-Jan-2005	6-Apr-2005
Parameter	Units									
Haloacetic Acids										
Bromochloroacetic Acid	µg/L	NT	NT	NT	NT	NT	15	NT	20	NT
Dibromoacetic Acid	µg/L	NT	NT	NT	NT	NT	1.6	NT	4.1	NT
Dichloroacetic Acid	µg/L	NT	NT	NT	NT	NT	79	NT	75	NT
Haloacetic Acids (5)	µg/L	NT	NT	NT	NT	NT	197	NT	176	NT
Monobromoacetic Acid	µg/L	NT	NT	NT	NT	NT	2.0	NT	2.0	NT
Monochloroacetic Acid	µg/L	NT	NT	NT	NT	NT	13	NT	7.7	NT
Trichloroacetic Acid	µg/L	NT	NT	NT	NT	NT	101	NT	87	NT
Hormones										
Estrone	µg/L	NT	0.011	NT	NT	NT	NT	NT	NT	NT
Estrone	µg/L	NT	NT	NT	NT	NT	NT	NT	ND	NT
Industrial Chemicals										
Carbon Tetrachloride	µg/L	ND	NT	NT	ND	NT	ND	NT	NT	NT
Di (2-Ethylhexyl) phthalate	µg/L	ND	NT	ND	NT	NT	ND	NT	NT	NT
EDTA	µg/L	NT	11	274	NT	NT	NT	NT	NT	NT
Hexachlorocyclopentadiene	µg/L	ND	NT	ND	NT	NT	ND	NT	NT	NT
NBBS	µg/L	NT	NT	ND	NT	NT	NT	NT	0.0050	NT
Perchlorate	µg/L	ND	NT	ND	NT	NT	ND	NT	ND	NT
Xylenes, Total	µg/L	ND	NT	NT	ND	NT	ND	NT	NT	NT
Metals										
Aluminum	µg/L	100	NT	100	NT	NT	174	NT	ND	NT
Cadmium	µg/L	ND	NT	ND	NT	NT	ND	NT	ND	NT
Copper	µg/L	ND	NT	ND	NT	NT	ND	NT	ND	NT
Iron	µg/L	ND	NT	ND	NT	NT	ND	NT	ND	NT
Lead	µg/L	ND	NT	ND	NT	NT	ND	NT	ND	NT
Magnesium	mg/L	28	NT	32	NT	NT	30	NT	35	NT
Manganese	µg/L	ND	NT	ND	NT	NT	ND	NT	ND	NT

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Table I-2-2
RECLAIMED WATER CHEMISTRY

Parameter	Location Date Units	SCRWA 30-Oct-2001	SCRWA 1-Nov-2001	SCRWA 26-Mar-2002	SCRWA 21-May-2002	SCRWA 30-May-2002	SCRWA 30-Jul-2002	SCRWA 13-Aug-2002	SCRWA 25-Jan-2005	SCRWA 6-Apr-2005
Metals										
Nickel	µg/L	ND	NT	ND	NT	NT	ND	NT	ND	NT
Zinc	µg/L	130	NT	63	NT	NT	61	NT	73	NT
Nutrients										
Nitrate as NO3	mg/L	9.0	NT	7.5	NT	NT	8.0	NT	9.6	NT
Nitrite as N	mg/L	ND	NT	ND	NT	NT	0.0	NT	ND	NT
Phosphate	mg/L	9.7	NT	8.7	NT	NT	4.9	NT	12	NT
Organophosphates										
Tris(2,3-dichloropropyl)phosphate	µg/L	NT	NT	0.010	NT	NT	NT	NT	0.020	NT
Tris(3-chloropropyl)phosphate	µg/L	NT	NT	0.0070	NT	NT	NT	NT	0.030	NT
Pathogens										
Coliforms, Total	MPN/100ml	0.0	NT	0.0	NT	NT	0.0	NT	0.0	NT
Cryptosporidium Oocysts	oocysts/L	0.0	NT	0.0	NT	NT	0.0	NT	0.0	NT
E. Coli	MPN/100ml	0.0	NT	0.0	NT	NT	0.0	NT	0.0	NT
Fecal Coliforms	MPN/100ml	0.0	NT	0.0	NT	NT	0.0	NT	0.0	NT
Giardia	cysts/L	0.0	NT	0.0	NT	NT	0.0	NT	0.0	NT
Heterotrophic Plate Count by R2A	CFU/mL	210	NT	3.0	NT	NT	1.0	NT	0.0	NT
Legionella	NA	NT	ND	NT	ND	NT	NT	ND	NT	NT
Total Culturable Virus Assay	MPN/100 L	NT	ND	ND	NT	NT	NT	ND	NT	NT
Pesticides										
Aldicarb Sulfoxide	µg/L	ND	NT	0.90	NT	ND	ND	NT	NT	NT
Heptachlor Epoxide	µg/L	ND	NT	ND	NT	NT	ND	NT	NT	NT
Lindane (gamma-BHC)	µg/L	0.010	NT	ND	NT	NT	ND	NT	NT	NT
Terbuthylazine	µg/L	NT	NT	NT	NT	NT	NT	NT	NT	NT

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Table I-2-2
RECLAIMED WATER CHEMISTRY

Parameter	Location Date Units	SCRWA 30-Oct-2001	SCRWA 1-Nov-2001	SCRWA 26-Mar-2002	SCRWA 21-May-2002	SCRWA 30-May-2002	SCRWA 30-Jul-2002	SCRWA 13-Aug-2002	SCRWA 25-Jan-2005	SCRWA 6-Apr-2005
Pharmaceutically Active Compounds										
Caffeine	µg/L	ND	NT	ND	NT	NT	ND	NT	ND	NT
Carbamazepine	µg/L	NT	0.0	ND	NT	NT	NT	NT	0.20	NT
Carisoprodol	µg/L	NT	NT	ND	NT	NT	NT	NT	0.0010	NT
Gemfibrozil	µg/L	NT	ND	ND	NT	NT	NT	NT	ND	NT
Ibuprofen	µg/L	NT	ND	ND	NT	NT	NT	NT	ND	NT
Naproxen	µg/L	NT	ND	ND	NT	NT	NT	NT	ND	NT
Radioactives										
Alpha Gross	pCi/L	1.5	NT	6.7	NT	NT	2.2	NT	NT	NT
Beta Gross	pCi/L	15	NT	14	NT	NT	17	NT	NT	NT
Radium 228	pCi/L	NT	NT	NT	NT	NT	NT	NT	NT	NT
Surfactants										
AP/APEO, Halogenated	µg/L	NT	NT	0.0060	NT	NT	NT	NT	ND	NT
AP1EO	µg/L	NT	ND	ND	NT	NT	NT	NT	ND	NT
AP2EO	µg/L	NT	ND	ND	NT	NT	NT	NT	NT	NT
AP3EO	µg/L	NT	ND	ND	NT	NT	NT	NT	NT	NT
APEC m/z 235	µg/L	NT	0.54	ND	NT	NT	NT	NT	NT	NT
APEC m/z 249	µg/L	NT	0.15	ND	NT	NT	NT	NT	NT	NT
APEC m/z 279	µg/L	NT	7.6	ND	NT	NT	NT	NT	NT	NT
APEC Total	µg/L	NT	8.3	ND	NT	NT	NT	NT	2.0	NT
APEC, Halogenated	µg/L	NT	NT	2.1	NT	NT	NT	NT	0.10	NT
APEO Total	µg/L	NT	ND	ND	NT	NT	NT	NT	NT	NT
NP/OP	µg/L	NT	0.16	ND	NT	NT	NT	NT	ND	NT
Surfactants	µg/L	220	NT	NT	100	NT	160	NT	NT	NT
Trihalomethanes										
Bromodichloromethane	µg/L	38	45	56	64	NT	23	NT	NT	NT
Bromoform	µg/L	0.50	ND	ND	1.8	NT	3.3	NT	NT	NT

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Table I-2-2
RECLAIMED WATER CHEMISTRY

Parameter	Location Date Units	SCRWA 30-Oct-2001	SCRWA 1-Nov-2001	SCRWA 26-Mar-2002	SCRWA 21-May-2002	SCRWA 30-May-2002	SCRWA 30-Jul-2002	SCRWA 13-Aug-2002	SCRWA 25-Jan-2005	SCRWA 6-Apr-2005
Trihalomethanes										
Chloroform	µg/L	64	88	95	84	NT	82	NT	NT	NT
Dibromochloromethane	µg/L	13	18	18	32	NT	5.7	NT	NT	NT
Trihalomethanes, Total	µg/L	NT	150	169	NT	NT	NT	NT	NT	NT

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Table I-2-2

RECLAIMED WATER CHEMISTRY

Parameter	Location Date Units	SCRWA 4-Apr-2007	SCRWA 19-Jun-2007	SCRWA 29-Jun-2007	SCRWA 2-Jul-2007	SCRWA 3-Jul-2007	SCRWA 2-Aug-2007	SCRWA 2-Jul-2007	SCRWA 2-May-2007	SJ/SC WPCP 30-Oct-2001
Cations and Anions										
Boron	µg/L	NT	421	NT	NT	NT	NT	NT	NT	482
Calcium as CaCO3	mg/L	NT	131	NT	NT	NT	NT	NT	NT	105
Calcium	mg/L	NT	52	NT	NT	NT	NT	NT	NT	48
Chloride	mg/L	NT	170	NT	NT	NT	NT	NT	NT	216
Chlorine Total by DPD	mg/L	NT	NT	NT	NT	NT	NT	NT	NT	NT
Cyanide	µg/L	NT	ND	NT	NT	NT	NT	NT	NT	ND
Fluoride	mg/L	NT	0.23	NT	NT	NT	NT	NT	NT	0.60
Sodium	mg/L	NT	147	NT	NT	NT	NT	NT	NT	143
Sulfate	mg/L	NT	74	NT	NT	NT	NT	NT	NT	97
Disinfection Byproducts										
Bromate	µg/L	NT	ND	NT	NT	NT	NT	NT	NT	ND
N-Nitroso dimethylamine (NDMA)	µg/L	NT	0.0033	NT	NT	NT	NT	NT	NT	0.036
General Water Quality										
Alkalinity, Total	mg/L	NT	263	NT	NT	NT	NT	NT	NT	134
Bicarbonate Alkalinity	mg/L	NT	320	NT	NT	NT	NT	NT	NT	163
Dissolved Organic Carbon	mg/L	NT	7.1	NT	NT	NT	NT	NT	NT	NT
Hardness as CaCO3	mg/L	NT	246	NT	NT	NT	NT	NT	NT	220
pH	pH units	NT	7.6	NT	NT	NT	NT	NT	NT	6.9
Silica	mg/L	NT	32	NT	NT	NT	NT	NT	NT	24
Total Filterable Residue at 180C	mg/L	NT	690	NT	NT	NT	NT	NT	NT	770
Total Organic Carbon	mg/L	NT	6.5	NT	NT	NT	NT	NT	NT	7.3
Total Suspended Solids	mg/L	NT	0.0	NT	NT	NT	NT	NT	NT	0.0
Turbidity	NTU	NT	0.39	NT	NT	NT	NT	NT	NT	0.73
UV-254	ABS	NT	0.078	NT	NT	NT	NT	NT	NT	0.11

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Table I-2-2
RECLAIMED WATER CHEMISTRY

Parameter	Location Date Units	SCRWA 4-Apr-2007	SCRWA 19-Jun-2007	SCRWA 29-Jun-2007	SCRWA 2-Jul-2007	SCRWA 3-Jul-2007	SCRWA 2-Aug-2007	SCRWA 2-Jul-2007	SCRWA 2-May-2007	SJ/SC WPCP 30-Oct-2001
Haloacetic Acids										
Bromochloroacetic Acid	µg/L	NT	NT	NT	NT	NT	NT	NT	NT	NT
Dibromoacetic Acid	µg/L	NT	ND	NT	NT	NT	NT	NT	NT	NT
Dichloroacetic Acid	µg/L	NT	26	NT	NT	NT	NT	NT	NT	NT
Haloacetic Acids (5)	µg/L	NT	NT	79	NT	NT	NT	NT	NT	NT
Monobromoacetic Acid	µg/L	NT	ND	ND	NT	NT	NT	NT	NT	NT
Monochloroacetic Acid	µg/L	NT	2.4	NT	NT	NT	NT	NT	NT	NT
Trichloroacetic Acid	µg/L	NT	51	NT	NT	NT	NT	NT	NT	NT
Hormones										
Estrone	µg/L	NT	NT	NT	NT	NT	ND	NT	ND	NT
Estrone	µg/L	NT	NT	NT	NT	NT	NT	ND	NT	NT
Industrial Chemicals										
Carbon Tetrachloride	µg/L	NT	ND	NT	NT	NT	NT	NT	NT	0.69
Di (2-Ethylhexyl) phthalate	µg/L	NT	ND	NT	NT	NT	NT	NT	NT	0.70
EDTA	µg/L	NT	NT	NT	NT	NT	NT	NT	NT	NT
Hexachlorocyclopentadiene	µg/L	NT	0.10	NT	NT	NT	NT	NT	NT	ND
NBBS	µg/L	NT	NT	NT	NT	NT	NT	0.050	NT	NT
Perchlorate	µg/L	NT	ND	NT	NT	NT	NT	NT	NT	ND
Xylenes, Total	µg/L	NT	ND	NT	NT	NT	NT	NT	NT	ND
Metals										
Aluminum	µg/L	NT	170	NT	NT	NT	NT	NT	NT	ND
Cadmium	µg/L	NT	ND	NT	ND	NT	NT	NT	NT	ND
Copper	µg/L	NT	ND	NT	ND	NT	NT	NT	NT	ND
Iron	µg/L	NT	ND	NT	NT	NT	NT	NT	NT	ND
Lead	µg/L	NT	ND	NT	ND	NT	NT	NT	NT	ND
Magnesium	mg/L	NT	31	NT	NT	NT	NT	NT	NT	27
Manganese	µg/L	NT	ND	NT	ND	NT	NT	NT	NT	35

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Table I-2-2
RECLAIMED WATER CHEMISTRY

	Location	SCRWA	SCRWA	SCRWA	SCRWA	SCRWA	SCRWA	SCRWA	SCRWA	SJ/SC WPCP
	Date	4-Apr-2007	19-Jun-2007	29-Jun-2007	2-Jul-2007	3-Jul-2007	2-Aug-2007	2-Jul-2007	2-May-2007	30-Oct-2001
Parameter	Units									
Metals										
Nickel	µg/L	NT	ND	NT	ND	NT	NT	NT	NT	ND
Zinc	µg/L	NT	71	NT	71	NT	NT	NT	NT	77
Nutrients										
Nitrate as NO3	mg/L	NT	16	NT	NT	NT	NT	NT	NT	55
Nitrite as N	mg/L	NT	ND	NT	NT	NT	NT	NT	NT	ND
Phosphate	mg/L	NT	11	NT	NT	NT	NT	NT	NT	1.2
Organophosphates										
Tris(2,3-dichloropropyl)phosphate	µg/L	NT	NT	NT	NT	NT	NT	0.46	NT	NT
Tris(3-chloropropyl)phosphate	µg/L	NT	NT	NT	NT	NT	NT	0.23	NT	NT
Pathogens										
Coliforms, Total	MPN/100ml	NT	4.0	NT	NT	NT	NT	NT	NT	0.0
Cryptosporidium Oocysts	oocysts/L	NT	ND	NT	NT	NT	NT	NT	NT	0.0
E. Coli	MPN/100ml	NT	ND	NT	NT	NT	NT	NT	NT	0.0
Fecal Coliforms	MPN/100ml	NT	ND	NT	NT	NT	NT	NT	NT	0.0
Giardia	cysts/L	NT	0.30	NT	NT	NT	NT	NT	NT	0.0
Heterotrophic Plate Count by R2A	CFU/mL	NT	1200	NT	NT	NT	NT	NT	NT	2.0
Legionella	NA	NT	NT	NT	NT	NT	NT	NT	NT	NT
Total Culturable Virus Assay	MPN/100 L	NT	NT	NT	NT	NT	NT	NT	NT	NT
Pesticides										
Aldicarb Sulfoxide	µg/L	NT	ND	NT	NT	ND	NT	NT	NT	ND
Heptachlor Epoxide	µg/L	NT	ND	NT	NT	NT	NT	NT	NT	ND
Lindane (gamma-BHC)	µg/L	NT	ND	NT	NT	ND	NT	NT	NT	ND
Terbuthylazine	µg/L	NT	ND	NT	NT	NT	NT	NT	NT	NT

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Table I-2-2
RECLAIMED WATER CHEMISTRY

	Location	SCRWA	SCRWA	SCRWA	SCRWA	SCRWA	SCRWA	SCRWA	SCRWA	SJ/SC WPCP
	Date	4-Apr-2007	19-Jun-2007	29-Jun-2007	2-Jul-2007	3-Jul-2007	2-Aug-2007	2-Jul-2007	2-May-2007	30-Oct-2001
Parameter	Units									
Pharmaceutically Active Compounds										
Caffeine	µg/L	NT	ND	NT	NT	NT	NT	ND	NT	ND
Carbamazepine	µg/L	NT	NT	NT	NT	NT	NT	ND	NT	NT
Carisoprodol	µg/L	NT	NT	NT	NT	NT	NT	ND	NT	NT
Gemfibrozil	µg/L	NT	NT	NT	NT	NT	NT	ND	NT	NT
Ibuprofen	µg/L	NT	NT	NT	NT	NT	NT	ND	NT	NT
Naproxen	µg/L	NT	NT	NT	NT	NT	NT	ND	NT	NT
Radioactives										
Alpha Gross	pCi/L	6.7	0.0	NT	NT	NT	NT	NT	NT	3.9
Beta Gross	pCi/L	14	19	NT	NT	NT	NT	NT	NT	12
Radium 228	pCi/L	NT	0.0	NT	NT	NT	NT	NT	NT	NT
Surfactants										
AP/APEO, Halogenated	µg/L	NT	NT	NT	NT	NT	NT	ND	NT	NT
AP1EO	µg/L	NT	ND	NT	NT	NT	NT	ND	NT	NT
AP2EO	µg/L	NT	NT	NT	NT	NT	NT	ND	NT	NT
AP3EO	µg/L	NT	NT	NT	NT	NT	NT	ND	NT	NT
APEC m/z 235	µg/L	NT	NT	NT	NT	NT	NT	ND	NT	NT
APEC m/z 249	µg/L	NT	NT	NT	NT	NT	NT	ND	NT	NT
APEC m/z 279	µg/L	NT	NT	NT	NT	NT	NT	ND	NT	NT
APEC Total	µg/L	NT	NT	NT	NT	NT	NT	ND	NT	NT
APEC, Halogenated	µg/L	NT	NT	NT	NT	NT	NT	1.7	NT	NT
APEO Total	µg/L	NT	NT	NT	NT	NT	NT	ND	NT	NT
NP/OP	µg/L	NT	ND	NT	NT	NT	NT	0.094	NT	NT
Surfactants	µg/L	NT	99	NT	NT	NT	NT	NT	NT	360
Trihalomethanes										
Bromodichloromethane	µg/L	NT	25	NT	NT	NT	NT	NT	NT	54
Bromoform	µg/L	NT	ND	NT	NT	NT	NT	NT	NT	2.1

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SWPCP - Sunnyvale Water Pollution Control Plant

Table I-2-2
RECLAIMED WATER CHEMISTRY

Parameter	Location Date Units	SCRWA 4-Apr-2007	SCRWA 19-Jun-2007	SCRWA 29-Jun-2007	SCRWA 2-Jul-2007	SCRWA 3-Jul-2007	SCRWA 2-Aug-2007	SCRWA 2-Jul-2007	SCRWA 2-May-2007	SJ/SC WPCP 30-Oct-2001
Trihalomethanes										
Chloroform	µg/L	NT	77	NT	NT	NT	NT	NT	NT	54
Dibromochloromethane	µg/L	NT	4.5	NT	NT	NT	NT	NT	NT	28
Trihalomethanes, Total	µg/L	NT	NT	NT	NT	NT	NT	NT	NT	NT

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SWPCP - Sunnyvale Water Pollution Control Plant

Table I-2-2
RECLAIMED WATER CHEMISTRY

Parameter	Location Date Units	SJ/SC WPCP 1-Nov-2001	SJ/SC WPCP 3-Dec-2001	SJ/SC WPCP 4-Dec-2001	SJ/SC WPCP 5-Dec-2001	SJ/SC WPCP 26-Mar-2002	SJ/SC WPCP 21-May-2002	SJ/SC WPCP 30-Jul-2002	SJ/SC WPCP 14-Aug-2002	SJ/SC WPCP 25-Jan-2005
Cations and Anions										
Boron	µg/L	NT	NT	NT	NT	505	NT	405	NT	445
Calcium as CaCO3	mg/L	NT	NT	NT	NT	138	NT	122	NT	173
Calcium	mg/L	NT	NT	NT	NT	55	NT	49	NT	69
Chloride	mg/L	NT	NT	NT	NT	180	NT	196	NT	194
Chlorine Total by DPD	mg/L	NT	NT	NT	NT	NT	NT	NT	NT	NT
Cyanide	µg/L	NT	NT	NT	NT	ND	NT	ND	NT	NT
Fluoride	mg/L	NT	NT	NT	NT	0.59	NT	0.74	NT	0.82
Sodium	mg/L	NT	NT	NT	NT	149	NT	156	NT	152
Sulfate	mg/L	NT	NT	NT	NT	101	NT	94	NT	107
Disinfection Byproducts										
Bromate	µg/L	NT	NT	NT	NT	ND	NT	ND	NT	ND
N-Nitroso dimethylamine (NDMA)	µg/L	NT	NT	NT	NT	0.026	NT	0.026	NT	NT
General Water Quality										
Alkalinity, Total	mg/L	NT	NT	NT	NT	174	NT	157	NT	217
Bicarbonate Alkalinity	mg/L	NT	NT	NT	NT	212	NT	192	NT	217
Dissolved Organic Carbon	mg/L	NT	NT	NT	NT	NT	NT	NT	NT	NT
Hardness as CaCO3	mg/L	NT	NT	NT	NT	190	NT	218	NT	276
pH	pH units	NT	NT	NT	NT	7.0	NT	7.0	NT	7.6
Silica	mg/L	NT	NT	NT	NT	25	NT	11	NT	23
Total Filterable Residue at 180C	mg/L	NT	NT	NT	NT	710	NT	700	NT	720
Total Organic Carbon	mg/L	NT	NT	NT	NT	8.6	NT	7.8	NT	4.7
Total Suspended Solids	mg/L	NT	NT	NT	NT	0.0	NT	10	NT	1.0
Turbidity	NTU	NT	NT	NT	NT	0.33	NT	0.63	NT	0.90
UV-254	ABS	NT	NT	NT	NT	0.12	NT	0.11	NT	0.073

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SWPCP - Sunnyvale Water Pollution Control Plant

Table I-2-2
RECLAIMED WATER CHEMISTRY

Parameter	Location Date Units	SJ/SC WPCP 1-Nov-2001	SJ/SC WPCP 3-Dec-2001	SJ/SC WPCP 4-Dec-2001	SJ/SC WPCP 5-Dec-2001	SJ/SC WPCP 26-Mar-2002	SJ/SC WPCP 21-May-2002	SJ/SC WPCP 30-Jul-2002	SJ/SC WPCP 14-Aug-2002	SJ/SC WPCP 25-Jan-2005
Haloacetic Acids										
Bromochloroacetic Acid	µg/L	NT	37	NT	NT	30	NT	21	NT	ND
Dibromoacetic Acid	µg/L	NT	8.4	NT	NT	5.4	NT	6.8	NT	ND
Dichloroacetic Acid	µg/L	NT	79	NT	NT	80	NT	60	NT	1.3
Haloacetic Acids (5)	µg/L	NT	NT	184	NT	232	NT	155	NT	1.7
Monobromoacetic Acid	µg/L	NT	5.0	NT	NT	4.4	NT	4.6	NT	ND
Monochloroacetic Acid	µg/L	NT	21	NT	NT	18	NT	11	NT	ND
Trichloroacetic Acid	µg/L	NT	70	NT	NT	124	NT	73	NT	ND
Hormones										
Estrone	µg/L	ND	NT	NT	NT	NT	NT	NT	NT	NT
Estrone	µg/L	NT	NT	NT	NT	NT	NT	NT	NT	ND
Industrial Chemicals										
Carbon Tetrachloride	µg/L	NT	NT	NT	NT	NT	ND	ND	NT	NT
Di (2-Ethylhexyl) phthalate	µg/L	NT	NT	NT	NT	ND	0.70	ND	NT	NT
EDTA	µg/L	NT	NT	NT	6.0	305	NT	NT	NT	NT
Hexachlorocyclopentadiene	µg/L	NT	NT	NT	NT	ND	ND	NT	NT	NT
NBBS	µg/L	NT	NT	NT	NT	0.015	NT	NT	NT	0.0040
Perchlorate	µg/L	NT	NT	NT	NT	ND	NT	ND	NT	ND
Xylenes, Total	µg/L	NT	NT	NT	NT	NT	ND	ND	NT	NT
Metals										
Aluminum	µg/L	NT	NT	NT	NT	ND	NT	86	NT	ND
Cadmium	µg/L	NT	NT	NT	NT	ND	NT	ND	NT	ND
Copper	µg/L	NT	NT	NT	NT	ND	NT	ND	NT	ND
Iron	µg/L	NT	NT	NT	NT	ND	NT	ND	NT	ND
Lead	µg/L	NT	NT	NT	NT	ND	NT	ND	NT	ND
Magnesium	mg/L	NT	NT	NT	NT	33	NT	27	NT	30
Manganese	µg/L	NT	NT	NT	NT	22	NT	33	NT	ND

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Table I-2-2
RECLAIMED WATER CHEMISTRY

Parameter	Location Date Units	SJ/SC WPCP 1-Nov-2001	SJ/SC WPCP 3-Dec-2001	SJ/SC WPCP 4-Dec-2001	SJ/SC WPCP 5-Dec-2001	SJ/SC WPCP 26-Mar-2002	SJ/SC WPCP 21-May-2002	SJ/SC WPCP 30-Jul-2002	SJ/SC WPCP 14-Aug-2002	SJ/SC WPCP 25-Jan-2005
Metals										
Nickel	µg/L	NT	NT	NT	NT	ND	NT	ND	NT	12
Zinc	µg/L	NT	NT	NT	NT	ND	NT	ND	NT	ND
Nutrients										
Nitrate as NO3	mg/L	NT	NT	NT	NT	47	NT	33	NT	43
Nitrite as N	mg/L	NT	NT	NT	NT	ND	NT	0.0	NT	ND
Phosphate	mg/L	NT	NT	NT	NT	2.1	NT	0.71	NT	2.0
Organophosphates										
Tris(2,3-dichloropropyl)phosphate	µg/L	NT	NT	NT	NT	0.010	NT	NT	NT	0.0070
Tris(3-chloropropyl)phosphate	µg/L	NT	NT	NT	NT	0.011	NT	NT	NT	0.010
Pathogens										
Coliforms, Total	MPN/100ml	NT	NT	NT	NT	2.0	NT	0.0	NT	110
Cryptosporidium Oocysts	oocysts/L	NT	NT	NT	NT	0.0	NT	0.0	NT	0.0
E. Coli	MPN/100ml	NT	NT	NT	NT	0.0	NT	0.0	NT	0.0
Fecal Coliforms	MPN/100ml	NT	NT	NT	NT	0.0	NT	0.0	NT	0.0
Giardia	cysts/L	NT	NT	NT	NT	0.0	NT	0.20	NT	0.0
Heterotrophic Plate Count by R2A	CFU/mL	NT	NT	NT	NT	0.0	NT	0.0	NT	64000
Legionella	NA	NT	ND	NT	NT	ND	NT	NT	ND	NT
Total Culturable Virus Assay	MPN/100 L	NT	ND	NT	NT	ND	NT	NT	ND	NT
Pesticides										
Aldicarb Sulfoxide	µg/L	NT	NT	NT	NT	1.3	NT	ND	NT	NT
Heptachlor Epoxide	µg/L	NT	NT	NT	NT	ND	ND	ND	NT	NT
Lindane (gamma-BHC)	µg/L	NT	NT	NT	NT	ND	ND	ND	NT	NT
Terbuthylazine	µg/L	NT	NT	NT	NT	NT	NT	NT	NT	NT

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Table I-2-2
RECLAIMED WATER CHEMISTRY

	Location	SJ/SC WPCP	SJ/SC WPCP	SJ/SC WPCP	SJ/SC WPCP	SJ/SC WPCP	SJ/SC WPCP	SJ/SC WPCP	SJ/SC WPCP	SJ/SC WPCP
	Date	1-Nov-2001	3-Dec-2001	4-Dec-2001	5-Dec-2001	26-Mar-2002	21-May-2002	30-Jul-2002	14-Aug-2002	25-Jan-2005
Parameter	Units									
Pharmaceutically Active Compounds										
Caffeine	µg/L	NT	NT	NT	NT	ND	ND	ND	NT	ND
Carbamazepine	µg/L	NT	NT	NT	ND	ND	NT	NT	NT	ND
Carisoprodol	µg/L	NT	NT	NT	NT	ND	NT	NT	NT	ND
Gemfibrozil	µg/L	NT	NT	NT	ND	ND	NT	NT	NT	ND
Ibuprofen	µg/L	NT	NT	NT	ND	ND	NT	NT	NT	ND
Naproxen	µg/L	NT	NT	NT	ND	ND	NT	NT	NT	ND
Radioactives										
Alpha Gross	pCi/L	NT	NT	NT	NT	4.1	NT	0.0	NT	NT
Beta Gross	pCi/L	NT	NT	NT	NT	11	NT	11	NT	NT
Radium 228	pCi/L	NT	NT	NT	NT	NT	NT	NT	NT	NT
Surfactants										
AP/APEO, Halogenated	µg/L	NT	NT	NT	NT	0.026	NT	NT	NT	ND
AP1EO	µg/L	NT	NT	NT	NT	ND	NT	NT	NT	ND
AP2EO	µg/L	NT	NT	NT	NT	ND	NT	NT	NT	NT
AP3EO	µg/L	NT	NT	NT	NT	ND	NT	NT	NT	NT
APEC m/z 235	µg/L	NT	NT	NT	NT	ND	NT	NT	NT	NT
APEC m/z 249	µg/L	NT	NT	NT	NT	ND	NT	NT	NT	NT
APEC m/z 279	µg/L	NT	NT	NT	NT	ND	NT	NT	NT	NT
APEC Total	µg/L	NT	NT	NT	NT	ND	NT	NT	NT	0.060
APEC, Halogenated	µg/L	NT	NT	NT	NT	13	NT	NT	NT	0.20
APEO Total	µg/L	NT	NT	NT	NT	ND	NT	NT	NT	NT
NP/OP	µg/L	NT	NT	NT	NT	ND	NT	NT	NT	0.0020
Surfactants	µg/L	NT	NT	NT	NT	NT	120	190	NT	NT
Trihalomethanes										
Bromodichloromethane	µg/L	NT	NT	NT	NT	NT	72	36	NT	NT
Bromoform	µg/L	NT	NT	NT	NT	NT	2.2	2.5	NT	NT

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Table I-2-2
RECLAIMED WATER CHEMISTRY

Parameter	Location Date Units	SJ/SC WPCP 1-Nov-2001	SJ/SC WPCP 3-Dec-2001	SJ/SC WPCP 4-Dec-2001	SJ/SC WPCP 5-Dec-2001	SJ/SC WPCP 26-Mar-2002	SJ/SC WPCP 21-May-2002	SJ/SC WPCP 30-Jul-2002	SJ/SC WPCP 14-Aug-2002	SJ/SC WPCP 25-Jan-2005
Trihalomethanes										
Chloroform	µg/L	NT	NT	NT	NT	NT	94	37	NT	NT
Dibromochloromethane	µg/L	NT	NT	NT	NT	NT	34	18	NT	NT
Trihalomethanes, Total	µg/L	NT	NT	NT	NT	NT	NT	NT	NT	NT

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Table I-2-2
RECLAIMED WATER CHEMISTRY

Parameter	Location Date Units	SJ/SC WPCP 2-Mar-2005	SJ/SC WPCP 6-Apr-2005	SJ/SC WPCP 4-Apr-2007	SJ/SC WPCP 18-Jun-2007	SJ/SC WPCP 19-Jun-2007	SJ/SC WPCP 20-Jun-2007	SJ/SC WPCP 22-Jun-2007	SJ/SC WPCP 26-Jun-2007	SJ/SC WPCP 4-Jul-2007
Cations and Anions										
Boron	µg/L	NT	NT	NT	449	NT	NT	NT	NT	NT
Calcium as CaCO3	mg/L	NT	NT	NT	141	NT	NT	NT	NT	NT
Calcium	mg/L	NT	NT	NT	56	NT	NT	NT	55	NT
Chloride	mg/L	196	NT	NT	172	NT	NT	NT	NT	NT
Chlorine Total by DPD	mg/L	NT	0.20	NT	NT	NT	NT	NT	NT	NT
Cyanide	µg/L	NT	NT	NT	NT	NT	NT	NT	58	NT
Fluoride	mg/L	NT	NT	NT	0.85	NT	NT	NT	NT	NT
Sodium	mg/L	137	NT	NT	149	NT	NT	NT	NT	NT
Sulfate	mg/L	NT	NT	NT	NT	113	NT	NT	NT	NT
Disinfection Byproducts										
Bromate	µg/L	NT	NT	NT	ND	NT	NT	NT	NT	NT
N-Nitroso dimethylamine (NDMA)	µg/L	NT	NT	NT	NT	NT	NT	NT	0.287	NT
General Water Quality										
Alkalinity, Total	mg/L	203	NT	NT	187	NT	NT	NT	186	NT
Bicarbonate Alkalinity	mg/L	203	NT	NT	187	NT	NT	NT	230	231
Dissolved Organic Carbon	mg/L	5.0	NT	NT	5.4	NT	NT	NT	NT	NT
Hardness as CaCO3	mg/L	285	NT	NT	NT	246	NT	NT	NT	246
pH	pH units	7.7	7.6	NT	NT	7.5	NT	NT	8.1	NT
Silica	mg/L	NT	NT	NT	NT	NT	NT	23	NT	NT
Total Filterable Residue at 180C	mg/L	729	NT	NT	668	NT	NT	NT	NT	NT
Total Organic Carbon	mg/L	NT	NT	NT	4.7	NT	NT	NT	NT	NT
Total Suspended Solids	mg/L	NT	NT	NT	1.0	NT	NT	NT	NT	NT
Turbidity	NTU	NT	NT	NT	NT	0.89	NT	NT	NT	NT
UV-254	ABS	0.080	NT	NT	NT	0.14	NT	NT	NT	NT

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Table I-2-2
RECLAIMED WATER CHEMISTRY

	Location	SJ/SC WPCP	SJ/SC WPCP	SJ/SC WPCP	SJ/SC WPCP	SJ/SC WPCP	SJ/SC WPCP	SJ/SC WPCP	SJ/SC WPCP	SJ/SC WPCP
	Date	2-Mar-2005	6-Apr-2005	4-Apr-2007	18-Jun-2007	19-Jun-2007	20-Jun-2007	22-Jun-2007	26-Jun-2007	4-Jul-2007
Parameter	Units									
Haloacetic Acids										
Bromochloroacetic Acid	µg/L	ND	NT	NT	NT	NT	NT	NT	NT	NT
Dibromoacetic Acid	µg/L	2.0	NT	NT	2.4	NT	NT	NT	NT	NT
Dichloroacetic Acid	µg/L	1.9	NT	NT	15	NT	NT	NT	NT	NT
Haloacetic Acids (5)	µg/L	3.9	NT	NT	27	NT	NT	NT	NT	NT
Monobromoacetic Acid	µg/L	ND	NT	NT	1.0	NT	NT	NT	NT	NT
Monochloroacetic Acid	µg/L	ND	NT	NT	2.7	NT	NT	NT	NT	NT
Trichloroacetic Acid	µg/L	ND	NT	NT	6.1	NT	NT	NT	NT	NT
Hormones										
Estrone	µg/L	NT	NT	NT	NT	NT	NT	NT	NT	NT
Estrone	µg/L	NT	NT	NT	NT	NT	NT	NT	NT	NT
Industrial Chemicals										
Carbon Tetrachloride	µg/L	NT	NT	NT	ND	NT	NT	NT	NT	NT
Di (2-Ethylhexyl) phthalate	µg/L	NT	NT	NT	NT	NT	NT	NT	ND	NT
EDTA	µg/L	NT	NT	NT	NT	NT	NT	NT	NT	NT
Hexachlorocyclopentadiene	µg/L	NT	NT	NT	NT	NT	NT	NT	ND	NT
NBBS	µg/L	NT	NT	NT	NT	NT	NT	NT	NT	NT
Perchlorate	µg/L	NT	NT	NT	ND	NT	NT	NT	NT	NT
Xylenes, Total	µg/L	NT	NT	NT	ND	NT	NT	NT	NT	NT
Metals										
Aluminum	µg/L	NT	NT	NT	ND	NT	NT	NT	NT	NT
Cadmium	µg/L	NT	NT	NT	12	NT	NT	NT	NT	NT
Copper	µg/L	NT	NT	NT	61	NT	NT	NT	NT	NT
Iron	µg/L	NT	NT	NT	120	NT	NT	NT	NT	NT
Lead	µg/L	NT	NT	NT	ND	NT	NT	NT	NT	NT
Magnesium	mg/L	NT	NT	NT	31	NT	NT	NT	NT	NT
Manganese	µg/L	NT	NT	NT	35	NT	NT	NT	NT	NT

Notes:

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NT - sample not tested for the given parameter
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Table I-2-2
RECLAIMED WATER CHEMISTRY

Parameter	Location Date Units	SJ/SC WPCP 2-Mar-2005	SJ/SC WPCP 6-Apr-2005	SJ/SC WPCP 4-Apr-2007	SJ/SC WPCP 18-Jun-2007	SJ/SC WPCP 19-Jun-2007	SJ/SC WPCP 20-Jun-2007	SJ/SC WPCP 22-Jun-2007	SJ/SC WPCP 26-Jun-2007	SJ/SC WPCP 4-Jul-2007
Metals										
Nickel	µg/L	NT	NT	NT	ND	NT	NT	NT	NT	NT
Zinc	µg/L	NT	NT	NT	ND	NT	NT	NT	NT	NT
Nutrients										
Nitrate as NO3	mg/L	40	NT	NT	NT	36	NT	NT	NT	NT
Nitrite as N	mg/L	NT	NT	NT	ND	NT	NT	NT	NT	NT
Phosphate	mg/L	NT	NT	NT	NT	0.45	NT	NT	NT	NT
Organophosphates										
Tris(2,3-dichloropropyl)phosphate	µg/L	NT	NT	NT	NT	NT	NT	NT	NT	NT
Tris(3-chloropropyl)phosphate	µg/L	NT	NT	NT	NT	NT	NT	NT	NT	NT
Pathogens										
Coliforms, Total	MPN/100ml	NT	NT	NT	ND	NT	NT	NT	NT	NT
Cryptosporidium Oocysts	oocysts/L	NT	NT	NT	ND	NT	NT	NT	NT	NT
E. Coli	MPN/100ml	NT	NT	NT	ND	NT	NT	NT	NT	NT
Fecal Coliforms	MPN/100ml	NT	NT	NT	ND	NT	NT	NT	NT	NT
Giardia	cysts/L	NT	NT	NT	0.40	NT	NT	NT	NT	NT
Heterotrophic Plate Count by R2A	CFU/mL	NT	NT	NT	450	NT	NT	NT	NT	NT
Legionella	NA	NT	NT	NT	NT	NT	NT	NT	NT	NT
Total Culturable Virus Assay	MPN/100 L	NT	NT	NT	NT	NT	NT	NT	NT	NT
Pesticides										
Aldicarb Sulfoxide	µg/L	NT	NT	NT	ND	NT	NT	NT	NT	NT
Heptachlor Epoxide	µg/L	NT	NT	NT	NT	NT	NT	NT	ND	NT
Lindane (gamma-BHC)	µg/L	NT	NT	NT	NT	NT	NT	NT	ND	NT
Terbuthylazine	µg/L	NT	NT	NT	NT	NT	NT	NT	0.10	NT

Notes:

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Table I-2-2
RECLAIMED WATER CHEMISTRY

Parameter	Location Date Units	SJ/SC WPCP 2-Mar-2005	SJ/SC WPCP 6-Apr-2005	SJ/SC WPCP 4-Apr-2007	SJ/SC WPCP 18-Jun-2007	SJ/SC WPCP 19-Jun-2007	SJ/SC WPCP 20-Jun-2007	SJ/SC WPCP 22-Jun-2007	SJ/SC WPCP 26-Jun-2007	SJ/SC WPCP 4-Jul-2007
Pharmaceutically Active Compounds										
Caffeine	µg/L	NT	NT	NT	NT	NT	NT	NT	ND	NT
Carbamazepine	µg/L	NT	NT	NT	NT	NT	NT	NT	NT	NT
Carisoprodol	µg/L	NT	NT	NT	NT	NT	NT	NT	NT	NT
Gemfibrozil	µg/L	NT	NT	NT	NT	NT	NT	NT	NT	NT
Ibuprofen	µg/L	NT	NT	NT	NT	NT	NT	NT	NT	NT
Naproxen	µg/L	NT	NT	NT	NT	NT	NT	NT	NT	NT
Radioactives										
Alpha Gross	pCi/L	NT	NT	4.1	NT	NT	NT	NT	0.0	NT
Beta Gross	pCi/L	NT	NT	11	NT	NT	NT	NT	5.2	NT
Radium 228	pCi/L	NT	NT	NT	NT	NT	NT	NT	0.0	NT
Surfactants										
AP/APEO, Halogenated	µg/L	NT	NT	NT	NT	NT	NT	NT	NT	NT
AP1EO	µg/L	NT	NT	NT	NT	NT	NT	NT	NT	NT
AP2EO	µg/L	NT	NT	NT	NT	NT	NT	NT	NT	NT
AP3EO	µg/L	NT	NT	NT	NT	NT	NT	NT	NT	NT
APEC m/z 235	µg/L	NT	NT	NT	NT	NT	NT	NT	NT	NT
APEC m/z 249	µg/L	NT	NT	NT	NT	NT	NT	NT	NT	NT
APEC m/z 279	µg/L	NT	NT	NT	NT	NT	NT	NT	NT	NT
APEC Total	µg/L	NT	NT	NT	NT	NT	NT	NT	NT	NT
APEC, Halogenated	µg/L	NT	NT	NT	NT	NT	NT	NT	NT	NT
APEO Total	µg/L	NT	NT	NT	NT	NT	NT	NT	NT	NT
NP/OP	µg/L	NT	NT	NT	NT	NT	NT	NT	NT	NT
Surfactants	µg/L	NT	NT	NT	NT	NT	NT	NT	130	NT
Trihalomethanes										
Bromodichloromethane	µg/L	NT	NT	NT	7.0	NT	7.0	NT	NT	NT
Bromoform	µg/L	NT	NT	NT	ND	NT	NT	NT	NT	NT

Notes:

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PARWQCP - Palo Alto Regional Water Quality Control Plant
SCRWA - South County Regional Wastewater Authority
SJ/SC WPCP - San Jose/Santa Clara Water Pollution Control Plant
SWPCP - Sunnyvale Water Pollution Control Plant

Table I-2-2
RECLAIMED WATER CHEMISTRY

Parameter	Location Date Units	SJ/SC WPCP 2-Mar-2005	SJ/SC WPCP 6-Apr-2005	SJ/SC WPCP 4-Apr-2007	SJ/SC WPCP 18-Jun-2007	SJ/SC WPCP 19-Jun-2007	SJ/SC WPCP 20-Jun-2007	SJ/SC WPCP 22-Jun-2007	SJ/SC WPCP 26-Jun-2007	SJ/SC WPCP 4-Jul-2007
Trihalomethanes										
Chloroform	µg/L	NT	NT	NT	NT	NT	13	NT	NT	NT
Dibromochloromethane	µg/L	NT	NT	NT	NT	NT	2.4	NT	NT	NT
Trihalomethanes, Total	µg/L	NT	NT	NT	NT	NT	NT	NT	NT	NT

Notes:

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NT - sample not tested for the given parameter
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SWPCP - Sunnyvale Water Pollution Control Plant

Table I-2-2
RECLAIMED WATER CHEMISTRY

Parameter	Location Date Units	SJ/SC WPCP 2-Aug-2007	SJ/SC WPCP 2-Jul-2007	SJ/SC WPCP 2-Jun-2007	SJ/SC WPCP 2-May-2007	SWPCP 30-Oct-2001	SWPCP 1-Nov-2001	SWPCP 3-Dec-2001	SWPCP 5-Dec-2001	SWPCP 26-Mar-2002
Cations and Anions										
Boron	µg/L	NT	NT	NT	NT	469	NT	NT	NT	432
Calcium as CaCO3	mg/L	NT	NT	NT	NT	109	NT	NT	NT	133
Calcium	mg/L	NT	NT	NT	NT	51	NT	NT	NT	53
Chloride	mg/L	NT	NT	NT	NT	254	NT	NT	NT	215
Chlorine Total by DPD	mg/L	NT	NT	NT	NT	NT	NT	NT	NT	NT
Cyanide	µg/L	NT	NT	NT	NT	ND	NT	NT	NT	ND
Fluoride	mg/L	NT	NT	NT	NT	0.71	NT	NT	NT	0.74
Sodium	mg/L	NT	NT	NT	NT	201	NT	NT	NT	165
Sulfate	mg/L	NT	NT	NT	NT	247	NT	NT	NT	126
Disinfection Byproducts										
Bromate	µg/L	NT	NT	NT	NT	ND	NT	NT	NT	ND
N-Nitroso dimethylamine (NDMA)	µg/L	NT	NT	NT	NT	0.080	NT	NT	NT	0.11
General Water Quality										
Alkalinity, Total	mg/L	NT	NT	NT	NT	95	NT	NT	NT	115
Bicarbonate Alkalinity	mg/L	NT	NT	NT	NT	95	NT	NT	NT	131
Dissolved Organic Carbon	mg/L	NT	NT	NT	NT	NT	NT	NT	NT	NT
Hardness as CaCO3	mg/L	NT	NT	NT	NT	273	NT	NT	NT	200
pH	pH units	NT	NT	NT	NT	6.5	NT	NT	NT	6.9
Silica	mg/L	NT	NT	NT	NT	14	NT	NT	NT	16
Total Filterable Residue at 180C	mg/L	NT	NT	NT	NT	1000	NT	NT	NT	770
Total Organic Carbon	mg/L	NT	NT	NT	NT	9.0	NT	NT	NT	8.0
Total Suspended Solids	mg/L	NT	NT	NT	NT	0.0	NT	NT	NT	0.0
Turbidity	NTU	NT	NT	NT	NT	1.5	NT	NT	NT	0.73
UV-254	ABS	NT	NT	NT	NT	0.17	NT	NT	NT	0.14

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SWPCP - Sunnyvale Water Pollution Control Plant

Table I-2-2
RECLAIMED WATER CHEMISTRY

Parameter	Location Date Units	SJ/SC WPCP 2-Aug-2007	SJ/SC WPCP 2-Jul-2007	SJ/SC WPCP 2-Jun-2007	SJ/SC WPCP 2-May-2007	SWPCP 30-Oct-2001	SWPCP 1-Nov-2001	SWPCP 3-Dec-2001	SWPCP 5-Dec-2001	SWPCP 26-Mar-2002
Haloacetic Acids										
Bromochloroacetic Acid	µg/L	NT	NT	NT	NT	NT	NT	ND	NT	3.8
Dibromoacetic Acid	µg/L	NT	NT	NT	NT	NT	NT	ND	NT	1.4
Dichloroacetic Acid	µg/L	NT	NT	NT	NT	NT	NT	ND	NT	6.7
Haloacetic Acids (5)	µg/L	NT	NT	NT	NT	NT	NT	5.2	NT	15
Monobromoacetic Acid	µg/L	NT	NT	NT	NT	NT	NT	ND	NT	ND
Monochloroacetic Acid	µg/L	NT	NT	NT	NT	NT	NT	ND	NT	1.2
Trichloroacetic Acid	µg/L	NT	NT	NT	NT	NT	NT	5.2	NT	5.5
Hormones										
Estrone	µg/L	ND	NT	NT	ND	NT	ND	NT	NT	NT
Estrone	µg/L	NT	ND	ND	NT	NT	NT	NT	NT	NT
Industrial Chemicals										
Carbon Tetrachloride	µg/L	NT	NT	NT	NT	ND	NT	NT	NT	NT
Di (2-Ethylhexyl) phthalate	µg/L	NT	NT	NT	NT	ND	NT	NT	NT	ND
EDTA	µg/L	NT	NT	NT	NT	NT	NT	NT	8.3	28
Hexachlorocyclopentadiene	µg/L	NT	NT	NT	NT	ND	NT	NT	NT	ND
NBBS	µg/L	NT	0.27	0.017	NT	NT	NT	NT	NT	ND
Perchlorate	µg/L	NT	NT	NT	NT	ND	NT	NT	NT	ND
Xylenes, Total	µg/L	NT	NT	NT	NT	3.8	NT	NT	NT	NT
Metals										
Aluminum	µg/L	NT	NT	NT	NT	ND	NT	NT	NT	ND
Cadmium	µg/L	NT	NT	NT	NT	ND	NT	NT	NT	ND
Copper	µg/L	NT	NT	NT	NT	ND	NT	NT	NT	ND
Iron	µg/L	NT	NT	NT	NT	ND	NT	NT	NT	ND
Lead	µg/L	NT	NT	NT	NT	ND	NT	NT	NT	ND
Magnesium	mg/L	NT	NT	NT	NT	37	NT	NT	NT	37
Manganese	µg/L	NT	NT	NT	NT	ND	NT	NT	NT	34

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Table I-2-2
RECLAIMED WATER CHEMISTRY

Parameter	Location Date Units	SJ/SC WPCP 2-Aug-2007	SJ/SC WPCP 2-Jul-2007	SJ/SC WPCP 2-Jun-2007	SJ/SC WPCP 2-May-2007	SWPCP 30-Oct-2001	SWPCP 1-Nov-2001	SWPCP 3-Dec-2001	SWPCP 5-Dec-2001	SWPCP 26-Mar-2002
Metals										
Nickel	µg/L	NT	NT	NT	NT	ND	NT	NT	NT	ND
Zinc	µg/L	NT	NT	NT	NT	67	NT	NT	NT	ND
Nutrients										
Nitrate as NO3	mg/L	NT	NT	NT	NT	70	NT	NT	NT	61
Nitrite as N	mg/L	NT	NT	NT	NT	0.40	NT	NT	NT	ND
Phosphate	mg/L	NT	NT	NT	NT	6.6	NT	NT	NT	5.6
Organophosphates										
Tris(2,3-dichloropropyl)phosphate	µg/L	NT	0.32	0.010	NT	NT	NT	NT	NT	0.0020
Tris(3-chloropropyl)phosphate	µg/L	NT	0.022	0.0030	NT	NT	NT	NT	NT	0.0080
Pathogens										
Coliforms, Total	MPN/100ml	NT	NT	NT	NT	0.0	NT	NT	NT	0.0
Cryptosporidium Oocysts	oocysts/L	NT	NT	NT	NT	NT	NT	NT	NT	NT
E. Coli	MPN/100ml	NT	NT	NT	NT	0.0	NT	NT	NT	0.0
Fecal Coliforms	MPN/100ml	NT	NT	NT	NT	0.0	NT	NT	NT	0.0
Giardia	cysts/L	NT	NT	NT	NT	NT	NT	NT	NT	NT
Heterotrophic Plate Count by R2A	CFU/mL	NT	NT	NT	NT	1800	NT	NT	NT	19
Legionella	NA	NT	NT	NT	NT	NT	NT	detected	NT	ND
Total Culturable Virus Assay	MPN/100 L	NT	NT	NT	NT	NT	NT	ND	NT	ND
Pesticides										
Aldicarb Sulfoxide	µg/L	NT	NT	NT	NT	ND	NT	NT	NT	1.5
Heptachlor Epoxide	µg/L	NT	NT	NT	NT	0.010	NT	NT	NT	ND
Lindane (gamma-BHC)	µg/L	NT	NT	NT	NT	ND	NT	NT	NT	ND
Terbuthylazine	µg/L	NT	NT	NT	NT	NT	NT	NT	NT	NT

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Table I-2-2
RECLAIMED WATER CHEMISTRY

Parameter	Location Date Units	SJ/SC WPCP 2-Aug-2007	SJ/SC WPCP 2-Jul-2007	SJ/SC WPCP 2-Jun-2007	SJ/SC WPCP 2-May-2007	SWPCP 30-Oct-2001	SWPCP 1-Nov-2001	SWPCP 3-Dec-2001	SWPCP 5-Dec-2001	SWPCP 26-Mar-2002
Pharmaceutically Active Compounds										
Caffeine	µg/L	NT	ND	ND	NT	1.0	NT	NT	NT	ND
Carbamazepine	µg/L	NT	ND	ND	NT	NT	NT	NT	ND	ND
Carisoprodol	µg/L	NT	ND	ND	NT	NT	NT	NT	NT	ND
Gemfibrozil	µg/L	NT	ND	ND	NT	NT	NT	NT	ND	0.22
Ibuprofen	µg/L	NT	ND	ND	NT	NT	NT	NT	0.046	0.020
Naproxen	µg/L	NT	ND	ND	NT	NT	NT	NT	ND	ND
Radioactives										
Alpha Gross	pCi/L	NT	NT	NT	NT	3.2	NT	NT	NT	3.8
Beta Gross	pCi/L	NT	NT	NT	NT	9.4	NT	NT	NT	11
Radium 228	pCi/L	NT	NT	NT	NT	NT	NT	NT	NT	NT
Surfactants										
AP/APEO, Halogenated	µg/L	NT	ND	ND	NT	NT	NT	NT	NT	ND
AP1EO	µg/L	NT	ND	ND	NT	NT	NT	NT	0.14	0.14
AP2EO	µg/L	NT	ND	ND	NT	NT	NT	NT	0.48	ND
AP3EO	µg/L	NT	ND	ND	NT	NT	NT	NT	0.14	ND
APEC m/z 235	µg/L	NT	ND	ND	NT	NT	NT	NT	9.2	6.0
APEC m/z 249	µg/L	NT	ND	ND	NT	NT	NT	NT	2.8	1.6
APEC m/z 279	µg/L	NT	ND	ND	NT	NT	NT	NT	6.3	2.4
APEC Total	µg/L	NT	ND	ND	NT	NT	NT	NT	18	10
APEC, Halogenated	µg/L	NT	15	1.7	NT	NT	NT	NT	NT	ND
APEO Total	µg/L	NT	ND	ND	NT	NT	NT	NT	0.76	0.14
NP/OP	µg/L	NT	ND	ND	NT	NT	NT	NT	0.064	0.035
Surfactants	µg/L	NT	NT	NT	NT	280	NT	NT	NT	NT
Trihalomethanes										
Bromodichloromethane	µg/L	NT	NT	NT	NT	6.1	NT	NT	NT	NT
Bromoform	µg/L	NT	NT	NT	NT	3.0	NT	NT	NT	NT

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Table I-2-2
RECLAIMED WATER CHEMISTRY

Parameter	Location Date Units	SJ/SC WPCP 2-Aug-2007	SJ/SC WPCP 2-Jul-2007	SJ/SC WPCP 2-Jun-2007	SJ/SC WPCP 2-May-2007	SWPCP 30-Oct-2001	SWPCP 1-Nov-2001	SWPCP 3-Dec-2001	SWPCP 5-Dec-2001	SWPCP 26-Mar-2002
Trihalomethanes										
Chloroform	µg/L	NT	NT	NT	NT	3.7	NT	NT	NT	NT
Dibromochloromethane	µg/L	NT	NT	NT	NT	5.2	NT	NT	NT	NT
Trihalomethanes, Total	µg/L	NT	NT	NT	NT	NT	NT	NT	NT	NT

Notes:

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PARWQCP - Palo Alto Regional Water Quality Control Plant
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Table I-2-2
RECLAIMED WATER CHEMISTRY

Parameter	Location Date Units	SWPCP 21-May-2002	SWPCP 30-Jul-2002	SWPCP 14-Aug-2002	SWPCP 26-Jan-2005	SWPCP 15-Mar-2005	SWPCP 5-Apr-2005	SWPCP 4-Apr-2007	SWPCP 26-Jun-2007	SWPCP 2-Aug-2007
Cations and Anions										
Boron	µg/L	NT	371	NT	355	NT	NT	NT	416	NT
Calcium as CaCO3	mg/L	NT	133	NT	135	NT	NT	NT	137	NT
Calcium	mg/L	NT	54	NT	54	NT	NT	NT	56	NT
Chloride	mg/L	NT	210	NT	225	NT	NT	NT	288	NT
Chlorine Total by DPD	mg/L	NT	NT	NT	NT	NT	2.5	NT	NT	NT
Cyanide	µg/L	NT	ND	NT	NT	NT	NT	NT	ND	NT
Fluoride	mg/L	NT	0.87	NT	0.55	NT	NT	NT	1.7	NT
Sodium	mg/L	NT	165	NT	143	NT	NT	NT	210	NT
Sulfate	mg/L	NT	99	NT	108	NT	NT	NT	103	NT
Disinfection Byproducts										
Bromate	µg/L	NT	ND	NT	ND	NT	NT	NT	ND	NT
N-Nitroso dimethylamine (NDMA)	µg/L	NT	0.0044	NT	NT	NT	NT	NT	0.0066	NT
General Water Quality										
Alkalinity, Total	mg/L	NT	157	NT	139	NT	NT	NT	170	NT
Bicarbonate Alkalinity	mg/L	NT	191	NT	139	NT	NT	NT	210	NT
Dissolved Organic Carbon	mg/L	NT	NT	NT	NT	NT	NT	NT	9.0	NT
Hardness as CaCO3	mg/L	NT	266	NT	275	NT	NT	NT	319	NT
pH	pH units	NT	7.1	NT	6.7	NT	7.1	NT	7.9	NT
Silica	mg/L	NT	0.90	NT	12	NT	NT	NT	8.8	NT
Total Filterable Residue at 180C	mg/L	NT	750	NT	777	NT	NT	NT	906	NT
Total Organic Carbon	mg/L	NT	9.6	NT	6.7	NT	NT	NT	7.9	NT
Total Suspended Solids	mg/L	NT	10	NT	4.0	NT	NT	NT	2.0	NT
Turbidity	NTU	NT	2.2	NT	2.1	NT	NT	NT	0.92	NT
UV-254	ABS	NT	0.14	NT	0.11	NT	NT	NT	0.12	NT

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SWPCP - Sunnyvale Water Pollution Control Plant

Table I-2-2
RECLAIMED WATER CHEMISTRY

Parameter	Location Date Units	SWPCP 21-May-2002	SWPCP 30-Jul-2002	SWPCP 14-Aug-2002	SWPCP 26-Jan-2005	SWPCP 15-Mar-2005	SWPCP 5-Apr-2005	SWPCP 4-Apr-2007	SWPCP 26-Jun-2007	SWPCP 2-Aug-2007
Haloacetic Acids										
Bromochloroacetic Acid	µg/L	NT	24	NT	6.6	NT	NT	NT	NT	NT
Dibromoacetic Acid	µg/L	NT	15	NT	6.4	NT	NT	NT	23	NT
Dichloroacetic Acid	µg/L	NT	28	NT	9.3	NT	NT	NT	17	NT
Haloacetic Acids (5)	µg/L	NT	97	NT	21	NT	NT	NT	64	NT
Monobromoacetic Acid	µg/L	NT	4.6	NT	ND	NT	NT	NT	1.6	NT
Monochloroacetic Acid	µg/L	NT	3.4	NT	ND	NT	NT	NT	NT	NT
Trichloroacetic Acid	µg/L	NT	46	NT	5.4	NT	NT	NT	22	NT
Hormones										
Estrone	µg/L	NT	NT	NT	NT	NT	NT	NT	NT	ND
Estrone	µg/L	NT	NT	NT	NT	ND	NT	NT	NT	NT
Industrial Chemicals										
Carbon Tetrachloride	µg/L	ND	ND	NT	NT	NT	ND	NT	ND	NT
Di (2-Ethylhexyl) phthalate	µg/L	NT	ND	NT	NT	NT	NT	NT	ND	NT
EDTA	µg/L	NT	NT	NT	NT	NT	NT	NT	NT	NT
Hexachlorocyclopentadiene	µg/L	NT	ND	NT	NT	NT	NT	NT	ND	NT
NBBS	µg/L	NT	NT	NT	NT	0.010	NT	NT	NT	NT
Perchlorate	µg/L	NT	ND	NT	12	NT	NT	NT	ND	NT
Xylenes, Total	µg/L	ND	ND	NT	NT	NT	ND	NT	ND	NT
Metals										
Aluminum	µg/L	NT	ND	NT	ND	NT	NT	NT	ND	NT
Cadmium	µg/L	NT	ND	NT	ND	NT	NT	NT	ND	NT
Copper	µg/L	NT	ND	NT	ND	NT	NT	NT	ND	NT
Iron	µg/L	NT	ND	NT	ND	NT	NT	NT	ND	NT
Lead	µg/L	NT	ND	NT	11	NT	NT	NT	ND	NT
Magnesium	mg/L	NT	37	NT	39	NT	NT	NT	42	NT
Manganese	µg/L	NT	32	NT	ND	NT	NT	NT	33	NT

Notes:

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PARWQCP - Palo Alto Regional Water Quality Control Plant
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SWPCP - Sunnyvale Water Pollution Control Plant

Table I-2-2
RECLAIMED WATER CHEMISTRY

Parameter	Location Date Units	SWPCP 21-May-2002	SWPCP 30-Jul-2002	SWPCP 14-Aug-2002	SWPCP 26-Jan-2005	SWPCP 15-Mar-2005	SWPCP 5-Apr-2005	SWPCP 4-Apr-2007	SWPCP 26-Jun-2007	SWPCP 2-Aug-2007
Metals										
Nickel	µg/L	NT	ND	NT	47	NT	NT	NT	ND	NT
Zinc	µg/L	NT	ND	NT	ND	NT	NT	NT	ND	NT
Nutrients										
Nitrate as NO3	mg/L	NT	26	NT	69	NT	NT	NT	45	NT
Nitrite as N	mg/L	NT	0.0	NT	ND	NT	NT	NT	ND	NT
Phosphate	mg/L	NT	13	NT	12	NT	NT	NT	14	NT
Organophosphates										
Tris(2,3-dichloropropyl)phosphate	µg/L	NT	NT	NT	NT	0.010	NT	NT	NT	NT
Tris(3-chloropropyl)phosphate	µg/L	NT	NT	NT	NT	0.030	NT	NT	NT	NT
Pathogens										
Coliforms, Total	MPN/100ml	NT	0.0	NT	0.0	NT	NT	NT	23	NT
Cryptosporidium Oocysts	oocysts/L	NT	0.0	NT	NT	NT	NT	NT	ND	NT
E. Coli	MPN/100ml	NT	0.0	NT	0.0	NT	NT	NT	8.0	NT
Fecal Coliforms	MPN/100ml	NT	0.0	NT	0.0	NT	NT	NT	13	NT
Giardia	cysts/L	NT	0.0	NT	NT	NT	NT	NT	ND	NT
Heterotrophic Plate Count by R2A	CFU/mL	NT	250	NT	64	NT	NT	NT	12000	NT
Legionella	NA	NT	NT	ND	NT	NT	NT	NT	NT	NT
Total Culturable Virus Assay	MPN/100 L	NT	NT	ND	NT	NT	NT	NT	NT	NT
Pesticides										
Aldicarb Sulfoxide	µg/L	NT	ND	NT	NT	NT	NT	NT	ND	NT
Heptachlor Epoxide	µg/L	NT	ND	NT	NT	NT	NT	NT	ND	NT
Lindane (gamma-BHC)	µg/L	NT	ND	NT	NT	NT	NT	NT	ND	NT
Terbuthylazine	µg/L	NT	NT	NT	NT	NT	NT	NT	ND	NT

Notes:

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Table I-2-2
RECLAIMED WATER CHEMISTRY

Parameter	Location Date Units	SWPCP 21-May-2002	SWPCP 30-Jul-2002	SWPCP 14-Aug-2002	SWPCP 26-Jan-2005	SWPCP 15-Mar-2005	SWPCP 5-Apr-2005	SWPCP 4-Apr-2007	SWPCP 26-Jun-2007	SWPCP 2-Aug-2007
Pharmaceutically Active Compounds										
Caffeine	µg/L	NT	ND	NT	NT	ND	NT	NT	ND	NT
Carbamazepine	µg/L	NT	NT	NT	NT	ND	NT	NT	NT	NT
Carisoprodol	µg/L	NT	NT	NT	NT	ND	NT	NT	NT	NT
Gemfibrozil	µg/L	NT	NT	NT	NT	ND	NT	NT	NT	NT
Ibuprofen	µg/L	NT	NT	NT	NT	ND	NT	NT	NT	NT
Naproxen	µg/L	NT	NT	NT	NT	ND	NT	NT	NT	NT
Radioactives										
Alpha Gross	pCi/L	NT	0.0	NT	NT	NT	NT	3.8	0.0	NT
Beta Gross	pCi/L	NT	12	NT	NT	NT	NT	11	9.1	NT
Radium 228	pCi/L	NT	NT	NT	NT	NT	NT	NT	0.0	NT
Surfactants										
AP/APEO, Halogenated	µg/L	NT	NT	NT	NT	ND	NT	NT	NT	NT
AP1EO	µg/L	NT	NT	NT	NT	ND	NT	NT	NT	NT
AP2EO	µg/L	NT	NT	NT	NT	NT	NT	NT	NT	NT
AP3EO	µg/L	NT	NT	NT	NT	NT	NT	NT	NT	NT
APEC m/z 235	µg/L	NT	NT	NT	NT	NT	NT	NT	NT	NT
APEC m/z 249	µg/L	NT	NT	NT	NT	NT	NT	NT	NT	NT
APEC m/z 279	µg/L	NT	NT	NT	NT	NT	NT	NT	NT	NT
APEC Total	µg/L	NT	NT	NT	NT	3.0	NT	NT	NT	NT
APEC, Halogenated	µg/L	NT	NT	NT	NT	0.30	NT	NT	NT	NT
APEO Total	µg/L	NT	NT	NT	NT	NT	NT	NT	NT	NT
NP/OP	µg/L	NT	NT	NT	NT	ND	NT	NT	NT	NT
Surfactants	µg/L	94	130	NT	NT	NT	NT	NT	140	NT
Trihalomethanes										
Bromodichloromethane	µg/L	95	85	NT	NT	NT	64	NT	86	NT
Bromoform	µg/L	18	15	NT	NT	NT	18	NT	33	NT

Notes:

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NT - sample not tested for the given parameter
PARWQCP - Palo Alto Regional Water Quality Control Plant
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Table I-2-2
RECLAIMED WATER CHEMISTRY

Parameter	Location Date Units	SWPCP 21-May-2002	SWPCP 30-Jul-2002	SWPCP 14-Aug-2002	SWPCP 26-Jan-2005	SWPCP 15-Mar-2005	SWPCP 5-Apr-2005	SWPCP 4-Apr-2007	SWPCP 26-Jun-2007	SWPCP 2-Aug-2007
Trihalomethanes										
Chloroform	µg/L	70	63	NT	NT	NT	42	NT	34	NT
Dibromochloromethane	µg/L	91	70	NT	NT	NT	64	NT	115	NT
Trihalomethanes, Total	µg/L	NT	NT	NT	NT	NT	NT	NT	NT	NT

Notes:

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NT - sample not tested for the given parameter
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Table I-2-2
RECLAIMED WATER CHEMISTRY

Parameter	Location Date Units	SWPCP 2-Jul-2007	SWPCP 2-May-2007
Cations and Anions			
Boron	µg/L	NT	NT
Calcium as CaCO3	mg/L	NT	NT
Calcium	mg/L	NT	NT
Chloride	mg/L	NT	NT
Chlorine Total by DPD	mg/L	NT	NT
Cyanide	µg/L	NT	NT
Fluoride	mg/L	NT	NT
Sodium	mg/L	NT	NT
Sulfate	mg/L	NT	NT
Disinfection Byproducts			
Bromate	µg/L	NT	NT
N-Nitroso dimethylamine (NDMA)	µg/L	NT	NT
General Water Quality			
Alkalinity, Total	mg/L	NT	NT
Bicarbonate Alkalinity	mg/L	NT	NT
Dissolved Organic Carbon	mg/L	NT	NT
Hardness as CaCO3	mg/L	NT	NT
pH	pH units	NT	NT
Silica	mg/L	NT	NT
Total Filterable Residue at 180C	mg/L	NT	NT
Total Organic Carbon	mg/L	NT	NT
Total Suspended Solids	mg/L	NT	NT
Turbidity	NTU	NT	NT
UV-254	ABS	NT	NT

Notes:

ND - denotes result was below the detection limit
NT - sample not tested for the given parameter
PARWQCP - Palo Alto Regional Water Quality Control Plant
SCRWA - South County Regional Wastewater Authority
SJ/SC WPCP - San Jose/Santa Clara Water Pollution Control Plant
SWPCP - Sunnyvale Water Pollution Control Plant

Table I-2-2
RECLAIMED WATER CHEMISTRY

Parameter	Location Date Units	SWPCP 2-Jul-2007	SWPCP 2-May-2007
Haloacetic Acids			
Bromochloroacetic Acid	µg/L	NT	NT
Dibromoacetic Acid	µg/L	NT	NT
Dichloroacetic Acid	µg/L	NT	NT
Haloacetic Acids (5)	µg/L	NT	NT
Monobromoacetic Acid	µg/L	NT	NT
Monochloroacetic Acid	µg/L	NT	NT
Trichloroacetic Acid	µg/L	NT	NT
Hormones			
Estrone	µg/L	NT	ND
Estrone	µg/L	ND	NT
Industrial Chemicals			
Carbon Tetrachloride	µg/L	NT	NT
Di (2-Ethylhexyl) phthalate	µg/L	NT	NT
EDTA	µg/L	NT	NT
Hexachlorocyclopentadiene	µg/L	NT	NT
NBBS	µg/L	ND	NT
Perchlorate	µg/L	NT	NT
Xylenes, Total	µg/L	NT	NT
Metals			
Aluminum	µg/L	NT	NT
Cadmium	µg/L	NT	NT
Copper	µg/L	NT	NT
Iron	µg/L	NT	NT
Lead	µg/L	NT	NT
Magnesium	mg/L	NT	NT
Manganese	µg/L	NT	NT

Notes:

ND - denotes result was below the detection limit
NT - sample not tested for the given parameter
PARWQCP - Palo Alto Regional Water Quality Control Plant
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Table I-2-2
RECLAIMED WATER CHEMISTRY

Parameter	Location Date Units	SWPCP 2-Jul-2007	SWPCP 2-May-2007
Metals			
Nickel	µg/L	NT	NT
Zinc	µg/L	NT	NT
Nutrients			
Nitrate as NO3	mg/L	NT	NT
Nitrite as N	mg/L	NT	NT
Phosphate	mg/L	NT	NT
Organophosphates			
Tris(2,3-dichloropropyl)phosphate	µg/L	ND	NT
Tris(3-chloropropyl)phosphate	µg/L	ND	NT
Pathogens			
Coliforms, Total	MPN/100ml	NT	NT
Cryptosporidium Oocysts	oocysts/L	NT	NT
E. Coli	MPN/100ml	NT	NT
Fecal Coliforms	MPN/100ml	NT	NT
Giardia	cysts/L	NT	NT
Heterotrophic Plate Count by R2A	CFU/mL	NT	NT
Legionella	NA	NT	NT
Total Culturable Virus Assay	MPN/100 L	NT	NT
Pesticides			
Aldicarb Sulfoxide	µg/L	NT	NT
Heptachlor Epoxide	µg/L	NT	NT
Lindane (gamma-BHC)	µg/L	NT	NT
Terbuthylazine	µg/L	NT	NT

Notes:

ND - denotes result was below the detection limit
NT - sample not tested for the given parameter
PARWQCP - Palo Alto Regional Water Quality Control Plant
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SJ/SC WPCP - San Jose/Santa Clara Water Pollution Control Plant
SWPCP - Sunnyvale Water Pollution Control Plant

Table I-2-2
RECLAIMED WATER CHEMISTRY

Parameter	Location Date Units	SWPCP 2-Jul-2007	SWPCP 2-May-2007
Pharmaceutically Active Compounds			
Caffeine	µg/L	ND	NT
Carbamazepine	µg/L	ND	NT
Carisoprodol	µg/L	ND	NT
Gemfibrozil	µg/L	0.030	NT
Ibuprofen	µg/L	0.70	NT
Naproxen	µg/L	0.040	NT
Radioactives			
Alpha Gross	pCi/L	NT	NT
Beta Gross	pCi/L	NT	NT
Radium 228	pCi/L	NT	NT
Surfactants			
AP/APEO, Halogenated	µg/L	ND	NT
AP1EO	µg/L	ND	NT
AP2EO	µg/L	ND	NT
AP3EO	µg/L	ND	NT
APEC m/z 235	µg/L	3.6	NT
APEC m/z 249	µg/L	0.39	NT
APEC m/z 279	µg/L	1.7	NT
APEC Total	µg/L	5.7	NT
APEC, Halogenated	µg/L	1.2	NT
APEO Total	µg/L	ND	NT
NP/OP	µg/L	ND	NT
Surfactants	µg/L	NT	NT
Trihalomethanes			
Bromodichloromethane	µg/L	NT	NT
Bromoform	µg/L	NT	NT

Notes:

ND - denotes result was below the detection limit
NT - sample not tested for the given parameter
PARWQCP - Palo Alto Regional Water Quality Control Plant
SCRWA - South County Regional Wastewater Authority
SJ/SC WPCP - San Jose/Santa Clara Water Pollution Control Plant
SWPCP - Sunnyvale Water Pollution Control Plant

Table I-2-2
RECLAIMED WATER CHEMISTRY

Parameter	Location Date Units	SWPCP 2-Jul-2007	SWPCP 2-May-2007
Trihalomethanes			
Chloroform	µg/L	NT	NT
Dibromochloromethane	µg/L	NT	NT
Trihalomethanes, Total	µg/L	NT	NT

Notes:

ND - denotes result was below the detection limit
NT - sample not tested for the given parameter
PARWQCP - Palo Alto Regional Water Quality Control Plant
SCRWA - South County Regional Wastewater Authority
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SWPCP - Sunnyvale Water Pollution Control Plant

Table I-2-3
SODIUM ADSORPTION RATIO

Location	Date	Calcium mg/L	Sodium mg/L	Magnesium mg/L	SAR
PARWQCP	30-Jul-2002	45	209	33	5.8
PARWQCP	26-Jun-2007	45	206	31	5.8
SCRWA	29-Nov-2001	41	147	27	4.4
SCRWA	30-Oct-2001	48	128	28	3.6
SCRWA	26-Mar-2002	49	138	32	3.8
SCRWA	30-Jul-2002	50	141	30	3.9
SCRWA	25-Jan-2005	54	118	35	3.1
SCRWA	19-Jun-2007	52	147	31	4.0
SJ/SC WPCP	30-Oct-2001	48	143	27	4.1
SJ/SC WPCP	26-Mar-2002	55	149	33	3.9
SJ/SC WPCP	30-Jul-2002	49	156	27	4.4
SJ/SC WPCP	25-Jan-2005	69	152	30	3.8
SJ/SC WPCP	18-Jun-2007	56	149	31	4.0
SWPCP	30-Oct-2001	51	201	37	5.2
SWPCP	26-Mar-2002	53	165	37	4.3
SWPCP	30-Jul-2002	54	165	37	4.2
SWPCP	26-Jan-2005	54	143	39	3.6
SWPCP	26-Jun-2007	56	210	42	5.2

Notes:

SAR - Sodium Adsorption Ratio
PARWQCP - Palo Alto Regional Water Quality Control Plant
SCRWA - South County Regional Wastewater Authority
SJ/SC WPCP - San Jose/Santa Clara Water Pollution Control Plant
SWPCP - Sunnyvale Water Pollution Control Plant

Volume II
Soil Attenuation Model and Bench Test

Recycled Water Irrigation and Groundwater Study
Santa Clara and Llagas Groundwater Subbasins
Santa Clara County, California

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LIST OF ACRONYMS AND ABBREVIATIONS

ACRONYM	**DESCRIPTION**
1D	One dimensional
ARWT	Advanced Recycled Water Treatment
AWWA	American Water Works Association
BCAA	bromochloroacetic acid
Bgs	below ground surface
cm/sec	centimeter per second
DO	dissolved oxygen
DOC	dissolved organic carbon
DBAA	dibromoacetic acid
DCAA	dichloroacetic acid
EDTA	Ethylenediaminetetraacetic acid
HAA5	Group of five haloacetic acids (monochloroacetic acid, dichloroacetic acid, trichloroacetic acid, monobromoacetic acid, dibromoacetic acid)
HAA6	Group of six haloacetic acids (HAA5 and bromochloracetic acid)
HIM	Hydroxy-Interlayered 2:1 Mineral
HPC	heterotrophic plate count
K_d	Adsorption isotherm coefficient
LACSD	Los Angeles County Sanitation District
Locus	Locus Technologies
MBAA	monobromoacetic acid
MCAA	monochloroacetic acid
mg/L	milligrams per liter
MTBE	methyl tert butyl ether
NDMA	N-nitrosodimethylamine
NTA	nitrilotriacetic acid
ORP	oxidation reduction potential
PARWQCP	Palo Alto Regional Water Quality Control Plant

LIST OF ACRONYMS AND ABBREVIATIONS

PFBA	perfluoro butanoic acid
PFCs	perfluorochemicals
PFOA	perfluoro octanoic acid
PFOS	perfluoro octanesulfonate
SAR	Sodium Adsorption Ratio
SCRWA	South County Regional Wastewater Authority
SCVWD	Santa Clara Valley Water District
SJ/SC WPCP	San Jose/Santa Clara Water Pollution Control Plant
SWPCP	Sunnyvale Water Pollution Control Plant
TCAA	trichloroacetic acid
TDS	total dissolved solids
THMs	trihalomethanes
TOC	total organic carbon
TDS	total dissolved solids
VOCs	volatile organic compounds
µg/L	micrograms per liter

EXECUTIVE SUMMARY

Volume II of this report is on the second phase of the Recycled Water Irrigation and Groundwater Study.The overall goal of the study is to evaluate the potential impact to groundwater from expanded use of recycled water for irrigation in the Santa Clara and Llagas Subbasins. The two main components that are focused in Volume II include soil attenuation modeling and bench test.

Soil Attenuation Modeling

This component of the study used a one-dimensional numerical model to estimate the transport of recycled water and its constituents from the surface to the groundwater. HYDRUS-1D was selected as the numerical model. Four recycled water constituents were modeled in HYDRUS-1D including bromodichloromethane, chloroform, m-xylene, and N-nitrosodimethylamine (NDMA). Each constituent was modeled in three different soil types (sand, silt, and clay) and over three time frames (2 months, 2 years, 50 years). The results of the soil attenuation model of the four constituents are presented in Figures II-1-1 to II-2-4.

The behavior of concentration curves of the modeled constituents was exponential in shape. Concentrations decreased with respect to depth and most of the initial attenuation occurred in the first several feet of soil. As time progressed, the constituents saturate along the depth similar to a wave front. Generally, clay had the highest attenuation capacity followed by silt and sand with the exception of NDMA. NDMA migration in the model was more prominent in the clays than silt or sand. This is because the increased percent saturation of the clay in the model allows less opportunity for volatilization of NDMA.

The main process in the model that contributes to attenuation is the high sorption onto soil particles. Adsorption capacity is fixed and over extended contact with recycled water constituents, that capacity may be spent. Degradation and transformation into daughter products were mechanisms that were not included in the model that may also contribute to attenuation.

A sensitivity analysis was performed to evaluate the sensitivity of the model's input parameters. The analysis determines the most important parameters that affect the model's outcome. Constituent characteristics including Henry's constant, adsorption isotherm, and the molecular diffusion in air are factors that most significantly determine the solute's potential for migration to groundwater. In addition, soil type plays an important role in determining which solutes present greater threats to groundwater. The factors that did not significantly change the model results were molecular diffusion in water, bulk density, and choice of transport model.

Soil Core Bench Test

The bench test was used to simulate the subsurface fate and transport of the recycled water under conditions similar to those expected on sites where recycled water would be used for irrigation. Eleven soil cores (1 foot in length for fine grained and 2.3 to 3.8 feet in length for semi-fine and coarse grained) were selected for the bench test from borings collected from the Santa Clara and Llagas Subbasins. The irrigation sources included in the test were recycled water from the San Jose/Santa Clara Water Pollution Control Plant (SJSC WPCP), and the South County Regional Water Authority (SCRWA) Gilroy Plant. Distilled water plus a calcium chloride additive was used as a control irrigation source. Gypsum was also included as a test parameter for fine grained soils to simulate common field practice to increase permeability. A depiction of the process flow is shown in Figure II-3-3.

Influents (the two recycled water sources and distilled water) and effluents were monitored twice. The first sampling event was at first breakthrough and the second sampling event was after ten pore volumes and was intended to be more representative of long term conditions. A list of the constituents that were monitored is listed in Table II-3-1.

Irrigation of cores for the bench test began on June 9, 2008, and continued through October 8, 2008. Of the eleven soil core sections, six had adequate effluent to complete the analysis of all constituents of concern shown in Table II-3-1. Due to extremely low permeability, the remaining soil core sections were unable to yield sufficient sample volume to analyze for all constituents.

Part of the evaluation included a characterization of the soil samples by conducting several tests as part of the bench test. Sieve analysis and hydrometer tests were completed to provide grain distribution information; hydraulic conductivity tests were completed to provide information about the soil permeability; and x-ray diffraction tests were performed to evaluate the clay mineralogy. Results for sieve analysis and hydrometer test, hydraulic conductivity, and x-ray diffraction for the soil samples are shown in Table II-3-2. Samples with low initial hydraulic conductivity (by ASTM D-5084, Method C) include SJSC-A SJSC-B, SCRWA-A, SCRWA-B, and SCRWA-D having a range of 10^{-8} to 10^{-5} centimeters per second (cm/sec). These soils cores all contain a high percentage of fine grains. Samples with high initial hydraulic conductivity (by ASTM D-5084, Method C) include SJSC-D, SCRWA-C, DI-A, DI-B, and DI-C having a range of 10^{-5} to 10^{-2} cm/sec. These soil samples tend to have higher coarse grain content, although DI-A and SJSC-D are outliers which have relatively high silt content and high initial hydraulic conductivity. Due to high rock content, there was not sufficient material to evaluate the SJSC-C soil sample for hydraulic conductivity.

The x-ray diffraction indicated that major clay minerals present in the soil samples include smectite, kaolinite, vermiculite, chlorite, and mica. Quartz, hydroxyl-interlayered 2:1, feldspar were found in lesser amounts. Due to the higher abundance of smectite in the samples collected from the Llagas Subbasin, more clay expansion is expected there, compared to the Santa Clara Subbasin. Given that gypsum use in conjunction with irrigation is a common best management practice, clay expansion is not expected to contribute to soil aquifer plugging. However, in cases where gypsum is not applied, significant clay expansion can occur, which could reduce infiltration rates and cause surface ponding.

The addition of gypsum had a significant effect in increasing the hydraulic conductivity of recycled water through fine grained soil. This is evident as the fine grained soil cores without gypsum (SJSC-A and SCRWA-A) produced very little effluent water. The respective fine grained soil cores with gypsum applied (SJSC-D and SCRWA-D) produced enough effluent water enough to complete the sampling objectives. Comparison of initial to final hydraulic conductivity values in soil cores SJSC-D and SCRWA-D shows that the increase in hydraulic conductivity when gypsum is applied can range from two to five orders of magnitude.

Bacterial growth was present in almost all the effluent samples as shown in the HPC results. Bacterial growth may have contributed to a lower hydraulic conductivity. However, since the majority of the effluents contained a high concentration of HPC, it is unknown what contribution bacterial growth had on soil aquifer plugging.

Chemical results are shown in Tables II-3-3 to II-3-11. Those results are also presented in Figures II-3-4 to II-3-48. The monitored constituents for the bench test can be grouped into categories based on their observed potential to migrate through the soil cores with minimal changes in concentration.

For purposes of this study, a significant change is regarded as a 20% change or more in concentration. Constituents that exhibited significant (20% or more) attenuation across the soil column for a majority of the soil cores include potassium, phosphate, nitrate, THMs, and some haloacetic acids (BCAA, DBAA, and DCAA). Constituents that exhibited consistent significant increases after percolation through soil include nitrite and PFCs.

Constituents that have exhibited initial large increases in the first round of sampling followed by no significant changes in the second round of sampling include DOC, TOC, calcium, and magnesium. The behavior of these constituents is suspected to be a result of an initial leaching from the soil cores, followed by equilibration with the infiltrating water.

Alkalinity, pH, TDS, DO, boron, chloride, sulfate and sodium exhibited no significant changes after percolation through soil. NDMA also does not appear to be affected by the transport through soil, although concentrations were variable from the influent to the effluent concentrations. One of the haloacetic acids (TCAA) and EDTA did not show strong removal.

Constituents that have been inconclusive due to significant variation in the influent concentration or high potential for bacterial growth include surfactants, HPC, and coliforms. Surfactant concentrations observed minor decreases in the SJSC soil cores, and minor increases in the SCRWA soil cores. Bromide, cyanide, terbuthylazine, NTA, E. Coli, and perchlorate were not detected in the influent or effluent samples.

Conclusions

The potential threat of each constituent to groundwater was categorized into low, medium and high threat categories based on the results of the bench test and modeling. A summary of those conclusions is provided in the table below.

Constituents	High Risk		Medium Risk	Low Risk		
	1) have shown an increase rather than a removal from soil percolation in the bench test	2) have not shown short-term significant removal and are not typically present in groundwater	1) have not attenuated from percolation in the bench test or model, and 2) are typically higher in recycled water than in groundwater	1) have exhibited significant attenuation in the bench test or model	2) have not exhibited significant attenuation but are similar in concentration in reclaimed water and groundwater	3) have not been detected in any of the samples in the bench test
Nitrite/Nitrate	X					
PFCs	X					
EDTA		X				
HAA6		X				
NDMA		X				
Surfactants		X				
TDS			X			
Boron			X			
Chloride			X			
Sulfate			X			
Sodium			X			
TOC			X			
DOC			X			
THMs			X			
Phosphate				X		
Calcium					X	
Magnesium					X	
Potassium				X		
Bromide						X
Cyanide						X
Terbuthylazine						X
NTA						X

Constituents	**High Risk**		**Medium Risk**	**Low Risk**		
	1) have shown an increase rather than a removal from soil percolation in the bench test	2) have not shown short-term significant removal and are not typically present in groundwater	1) have not attenuated from percolation in the bench test or model, and 2) are typically higher in recycled water than in groundwater	1) have exhibited significant attenuation in the bench test or model	2) have not exhibited significant attenuation but are similar in concentration in reclaimed water and groundwater	3) have not been detected in any of the samples in the bench test
E. Coli						X
Perchlorate						X
other VOCs						X

Recommendations for the next phase of the study, the full-scale pilot study, include scaling back monitoring of low threat constituents. Monitored vadose zone wells should have shallow screens to monitor the depth range where a majority of the attenuation is expected to occur. The curvature of the concentrations along depth in the model indicates that the most drastic change in concentrations occurs in the first several feet of soil.

VOLUME II
SOIL ATTENUATION MODEL AND BENCH TEST
RECYCLED WATER STUDY

1. INTRODUCTION

1.1. Introduction

This report was prepared by Locus Technologies (Locus) on behalf of the Santa Clara Valley Water District (SCVWD) for the Recycled Water Irrigation and Groundwater Study. Volume II is the second phase of a study to evaluate the impacts from expanded use of recycled water for irrigation on groundwater resources in the Santa Clara and Llagas Groundwater Subbasins in Santa Clara County. This study uses a combination of approaches, including literature review, data analysis, a soil attenuation model, bench test, and a full pilot study at a site in the Santa Clara Groundwater Subbasin. This volume of the report will address the soil attenuation modeling and bench test. The next phase of the project is the full pilot study, the results of which are evaluated in conjunction with the conclusions gathered from the soil attenuation modeling and bench test.

1.2. Purpose

Volume II reports the results from two major evaluations: soil attenuation modeling and a soil core bench test. The purpose of the soil attenuation modeling is to use a numerical model (HYDRUS-1D) to estimate the transport of recycled water and the attenuation of its constituents from the surface to the groundwater. For this report, attenuation is defined as the reduction in concentration of a constituent through the soil, through any process such as sorption, volatilization, or degradation. Constituent migration is defined as the travel and rate of travel downward. Use of the model helps to evaluate potential impacts to groundwater from irrigation with recycled water under a wider range of variables than can be represented by the bench test or pilot study. The modeling results are also used to design the soil bench test and the following phase of this study, a full-scale pilot study using recycled water for irrigation. The goals for the soil attenuation model were identified as the following:

- Identify the range of attenuation from recycled water constituents with the greatest potential impacts to groundwater per the literature review;
- Investigate the effects of attenuation from different soil types (sand, silt, and clay);
- Determine the level of constituent attenuation with respect to depth and time; and
- Determine the sensitivity of the input parameters used in the modeling.

A soil core bench test is the second major component of the fate and transport evaluation. The bench test functions as a controlled environment for observing recycled water migration through soil samples. The purpose of the bench test is to characterize the attenuation of recycled water constituents through the soil, and also the effect of recycled water on the hydraulic conductivity of soil. To adequately represent the range of conditions observed within the project study area, the bench test used recycled water obtained from SJ/SC WPCP and SCRWA, and soil cores collected from multiple locations within the Santa Clara and Llagas Subbasins. The following goals were identified for the bench test:

- Determine the rate at which recycled water permeates through the varying soil samples relative to a control water source;
- Quantify the effects on soil hydraulic conductivity due to use of recycled water on a range of soils found within the project study area;
- Quantify the amount of attenuation through soil for a list of constituents present in recycled water that may negatively impact groundwater as determined Volume I of this report.

2. SOIL ATTENUATION MODEL

Recycled water commonly contains a number of constituents introduced through the original use of the water, or through the treatment processes that the water undergoes after use. The main focus of the study is chemical constituents, including those of anthropogenic and nonanthropogenic origins. A few constituents of concern are biological. The major goal of this study is to determine whether any of these constituents have the potential to negatively impact groundwater if recycled water is used for irrigation. In this section, the soil attenuation modeling and its application to this project are discussed.

2.1. Introduction

The goal of the attenuation model is to be able to characterize the fate and transport of the recycled water constituents through soil from the surface to groundwater. Four models were reviewed for this task, as discussed in Volume I of this report. Of the four models, HYDRUS-1D was chosen as the most suitable program, for its ability as a finite element model to simulate the movement of water and multiple constituents in a media that is variably saturated. For this task, a one dimensional (1D) model was chosen over a two or three dimensional model, because the model is intended to be representative of the entire project study area. 2D or 3D models for water infiltration would require customization for specific areas within the project study area and therefore the results would be less applicable to the entire area.

HYDRUS-1D is a one-dimensional public domain program. The model was developed jointly by scientists at the University of California at Riverside and the Agricultural Research Service division of the US Department of Agriculture. In HYDRUS-1D, the Richards equation is used for saturated-unsaturated water flow and the Fickian advection/dispersion equations are used for heat and constituent transport (Šimunek et al., 2005b).

2.2. Inputs

HYDRUS-1D requires representative input information for the model to adequately represent infiltration through the vadose zone. The input parameters include the soil depth and the time frame for which the model is run, the soil and constituent properties, and the water flow and constituent boundary conditions. Below is a further discussion of the input parameters.

2.2.1. Geometry and Time Information

A depth of 50 feet (15 meters) is selected for the model. Depth to first groundwater in the Santa Clara Subbasin ranges from 0 to more than 100 feet below ground surface (bgs). In the Llagas Subbasin, the depth to shallow groundwater varies from 10 to 100 feet bgs in the northeast region of the basin to less than five feet bgs near the Pajaro River. Because the model output reports a profile of concentrations at multiple depths, the concentration at any specific depth can be obtained by looking at specific points on the profile. Therefore, the model results are applicable for any depth to groundwater up to 50 feet. Since nearly all of the attenuation occurs within the upper few feet of the vadose zone, this scale was most appropriate for displaying the concentration changes over depth.

To evaluate the changes in recycled water infiltration over time, the time frame for the model was set from 0 to 50 years after commencement of application of recycled water. Snapshots of the model are taken at 2 months, 2 years, and 50 years to represent conditions at short, intermediate, and long time frames, respectively. The intermediate time step duration is similar to that of the pilot study, the next phase of the recycled water study and 2 months is the approximate duration between sampling events for the pilot study. Although in the real world, it is not absolutely certain that equilibrium will be established in the 50-year time frame, it is meant to represent the long term condition and is a best practical estimate. Soil parameters, recycled water application rate, and recycled water constituent concentrations are all assumed to be constant over the 50-year period.

2.2.2. Soil Hydraulic Model

For the soil hydraulics, the van Genuchten–Mualem equations are used. These equations for the hydraulic properties utilize the combination of the Mualem (1976) pore-size distribution model with the Van Genuchten (1980) soil-water-retention model. The model predicts the unsaturated hydraulic conductivity based on the water retention parameters. In addition, the model was assumed to have no hysteresis (no effects from wetting/drying cycles) as continuous irrigation is assumed in the modeling time frame. This assumption is a conservative estimate because irrigation with recycled water is not applied continuously through the day or during the seasonally wet months. Including the cyclic behavior of irrigation would introduce an additional widely variable parameter, and would reduce the interpretability of the results for the study area as a whole. The effect of the selection of this water transport model is evaluated in Section 2.4.3 below.

2.2.3. Constituent Transport

The Crank-Nicholson implicit scheme is applied to the model for time weighting. The Crank-Nicholson implicit scheme is recommended by the HYDRUS 1-D model documentation in lieu of other schemes. Although the fully implicit scheme may result in excessive numerical dispersion, explicit schemes are prone to numerical instabilities.

For space weighting, the method by Galerkin finite elements is used for approximating the spatial derivatives. This is the recommended space weighting method in the model.

Tortuosity in the molecular diffusion is accounted for by the model. Due to the presence of solid particles in the soil, diffusion paths do not keep straight lines. The tortuosity factor is applied for the molecular diffusion coefficients in the water and gas phases in accordance to Millington and Quirk (1961).

2.2.4. Soil Parameters

The model can be used for several types of soils. The examined soil types were sand, silt, and clay, which are taken to represent the range of vadose zone soils. Separate model scenarios were established for each of the soil types. Multiple layers of different soil types can be created in the model, but the model was simplified so that entire soil depth was one homogeneous type of soil. This provides a more general idea of the fate and transport through different soil types. In addition, a separate scenario was developed for the sensitivity analysis to observe the impact of heterogeneity of different soils on the model results.

Default soil properties included within the HYDRUS-1D model were used for each soil type. Soil property inputs include the residual soil water content, the saturated soil water content, saturated hydraulic conductivity, and the tortuosity.

Soil specific parameters include the bulk density and the longitudinal dispersivity. HYDRUS-1D recommends values for these parameters which are 94 pounds per cubic foot (pcf) (1,500,000 g/m^3) and 0.33 ft (0.1 meters), respectively. These values are typical for most soils and are not expected to vary significantly within the project study area. It is assumed that all sorption sites in the soil are in contact with the mobile water. It is also assumed that water transport is in physical equilibrium meaning that there is not any stagnant water in the soil column.

The model assumes the temperature of the environment to be 20 degrees Celsius throughout the depth of soil column. The temperature remains constant over time.

2.2.5. Constituent Parameters

Constituent specific parameters include the molecular weight, adsorption isotherm coefficient (K_d), Henry’s constant, and diffusion coefficients for free water and gas phase. Values for these parameters are available for some, but not all constituents of concern for this recycled water study. Therefore a subset of constituents with available data on their properties was selected for modeling. Sensitivity analysis on constituent parameters was performed (Section 2.4) to evaluate constituents for which these values are not available. The sensitivity analysis broadens the applicability of this model for other constituents.

Values of the adsorption isotherm coefficient (K_d), Henry’s constant, and diffusion coefficients were obtained through published values (Schwarzenbach et al, 2003; Alabama Dept of Env. Mgmt, 2008). Values of these parameters are shown in Table II-1-1.

To provide some range in chemical properties, four constituents were used for this model: bromodichloromethane, chloroform, m-xylene, and N-nitrosodimethylamine (NDMA). Bromodichloromethane and chloroform are disinfection by-products produced when water that contains organic matter is disinfected with chlorine or bromine. M-xylene is a one of three xylene isomers (m-xylene, p-xylene, and o-xylene). Xylenes are predominantly used as a solvent. NDMA is another disinfection by-product formed from the presence of monochloramine and simples amines. NDMA is frequently detected in municipal sewage and may be formed during wastewater disinfection when chlorine is applied in the presence of ammonia. The selection of these constituents for modeling was based on their presence in recycled water and the availability of information on their chemical properties. NDMA is frequently detected in recycled water. Bromodichloromethane, chloroform, and xylenes are less frequently detected in recycled water as explained in Volume I; however, the availability of the constituents' specific chemical characteristics made them appropriate selections for this evaluation. Further background discussion of these constituents may be found in Volume I of this report. HYDRUS-1D does not have the capability to model precipitation and dissolution reactions or constituent degradation in a manner that cannot be represented by first-order or second-order kinetics. Therefore, constituents with these characteristics (e.g. groundwater ions) cannot be modeled adequately using HYDRUS-1D.

While there is the potential for degradation of the constituents and/or transformation into daughter products, the model assumes that these processes are not occurring. The assumption is conservative for the constituents in recycled water.

2.2.6. Boundary Conditions

The upper boundary condition for water flow is set at a prescribed constant pressure head. The initial pressure head is -328 ft (-100 meters) to represent a soil that is unsaturated (pressure head below the bottom of the soil column). The lower boundary condition of the water flow is modeled as free drainage. Using this condition, any infiltrating water that migrates to the bottom of the modeled soil section flows into the groundwater. This condition is appropriate for a water table below the area of interest. For simplicity, the boundary conditions set for water flow are constant for the duration of the model. Considering the climate of the San Francisco Bay area, the seasonal weather patterns would expose the surface to higher volumes of water during short winter storm events in addition to routine irrigation water during the winter months. However, over the time periods used for this model, this fluctuation would be secondary to the water flow from irrigation.

Upper and lower boundary conditions of the constituent concentration are set at 100 mg/L as the concentration of the constituent in recycled water at irrigation and zero gradient (free drainage) at the end of the soil column. The concentration of the upper boundary condition is arbitrary as the model has been set to assume no degradation. In HYDRUS-1D, the transport factors are not dependent on concentration, except for degradation which is not included in this analysis. Hence, the model behavior is not affected by the actual concentration amount. For ease of interpretation, the concentration in the irrigation water was set at 100 mg/L, and therefore any concentrations modeled along the depth of the soil profile are effectively a percentage of the initial concentration in the irrigation water.

2.2.7. Root Water Uptake

The root water uptake was modeled using the Feddes (1977) water uptake reduction model. Under root water uptake the constituent is assumed to be left behind in the soil and only constituent-free solution is taken up to the roots. This assumption is valid because the modeled constituents are not known to be taken up by the plant root pathway. Root water uptake is modeled using Feddes' parameters for grass.

2.3. Results

Graphs showing the four constituent concentration profiles with respect to depth are presented in Figures II-1-1 to II-2-4. Each figure presents three concentration curves for the three time frames: 2 months, 2 years, and 50 years. For each of the four constituents modeled, three separate figures are presented that correspond to concentration curves in the three soil types modeled (sand, silt, and clay).

The concentration curves of the constituents may underestimate the actual attenuation, because constituent degradation and transformation were not included in the model. However, these factors are expected to be minimal for the selected constituents. The main process controlling the attenuation in the model is sorption to the soil particles. Because soil sorption is a process that becomes less effective over time as the soil becomes saturated with the constituent, it is expected that the constituent concentrations in the subsurface would eventually become consistent with the irrigated concentration over the long-term time frame. Clay appears to have the highest attenuation capacity except in the case of NDMA. Additional explanation for the modeled NDMA behavior is discussed in Section 2.3.4.

The curvature of the concentration profiles does not differ significantly between constituents. Each constituent has similar behavior with respect to the concentration profile and the progression of the concentration over time. NDMA appears to show the most attenuation of the evaluated constituents in sand and silt. In clay soils, m-xylene showed the most attenuation. These observations are reflective of the constituents' adsorption isotherm coefficients which govern the equilibrium of the constituent in soil and water. Of the four constituents, m-xylene has the highest adsorption isotherm coefficient. Transport behavior of the individual constituents is discussed below.

2.3.1. Bromodichloromethane

Bromodichloromethane concentration to depth curves are shown in Figures II-2-1A to II-2-1C. Bromodichloromethane demonstrates a significant level of attenuation in all soil types. The clay exhibited the most attenuation followed by silt and then sand. After a period of 50 years, the constituent is at near-zero concentration below a depth of 23 ft (7 meters) in the sand model. The behavior is expected because bromodichloromethane is a constituent with a relatively high adsorption coefficient. Its attenuation is dominated by the sorption by the soil particles.

2.3.2. Chloroform

Chloroform concentration to depth curves are shown in Figures II-2-2A to II-2-2C. Chloroform demonstrates significant attenuation in clay but limited attenuation in silt and sand. After 50 years in the sand and silt models, chloroform is transported beyond the modeled 50 feet (15 meters) of soil with 10 to 30 percent of the original concentration continuing to migrate downwards. In the clay model, the constituent shows a higher attenuation capacity than the other soil types. After 50 years, the constituent is at near-zero concentration at depth of 13 ft (4 meters) of clay and below. Compared to the other constituents, chloroform has a relatively low adsorption coefficient, high Henry's constant, and high diffusion of coefficient in air. The lower adsorption means there is less capacity for chloroform to be sorbed onto soil particles. In addition, the high Henry's constant and high diffusion of coefficient in air allows more volatilization of chloroform into the gas phase where it can migrate more effectively downwards through the vadose zone.

2.3.3. m-Xylene

Concentration to depth curves for m-xylene are shown in Figures II-2-3A to II-2-3C. Significant attenuation of m-xylene is demonstrated in all soil types, with the most attenuation in clay. In the silt and sand models, the concentrations are at near-zero concentrations at a depth of 10 ft (3 meters) after 50 years. In the clay model, concentrations of xylene do not significantly migrate beyond 3 ft (1 meter) after 50 years. Of the four constituents, m-Xylene has the highest adsorption coefficient. The high sorption contributes significantly to the attenuation of m-Xylene.

2.3.4. NDMA

NDMA concentration to depth curves are shown in Figures II-2-4A to II-2-4C. NDMA demonstrates significant attenuation in the soil types modeled. The highest attenuation was observed in the sand followed by silt and clay. The transport behavior of NDMA appears less influenced by sorption in the model compared to the other constituents, which corresponds to its lower adsorption isotherm coefficient. In clays, there is less opportunity for volatilization of NDMA due to higher percent saturation and less air-filled pores as opposed to silt or sand types of soils. Migration in clays is controlled by the downward migration of water. After 50 years, the constituent is at near-zero concentration below a depth of 13 ft (4 meters) in the soil types evaluated in the model.

2.4. Sensitivity Analysis

A sensitivity analysis was performed to evaluate the sensitivity of the model's input parameters. The analysis determines the most important parameters that affect the model's outcome. Input parameters were adjusted to observe the change in effect it would have on the constituent's attenuation. Parameters were adjusted to a range of potential values of the parameter. Many of these parameters are chemical properties.

In this case, the range in each chemical property was derived from a listing of properties for various constituents, which includes most of the known parameters for constituents in recycled water (Alabama Dept of Env. Mgmt, 2008). Table II-2-2 includes the minimum and maximum values for each of the chemical properties evaluated in the sensitivity analysis. The model for bromodichloromethane in a homogeneous sand layer was used as the baseline of this analysis. The baseline's constituent and soil type were arbitrarily chosen. However, any recycled water constituent and soil type would have been appropriate as a baseline for the purposes of this analysis, since the relative change in output is the same regardless of the starting conditions.

2.4.1. Henry's constant

Henry's law constant is an equilibrium constant for a constituent in its aqueous and gas phase. At constant temperature, Henry's law asserts that the concentration of a constituent in the gas phase is proportional to the concentration in the aqueous phase. A constituent with a higher Henry's constant has a higher affinity to the gas phase.

Henry's constant was adjusted to a minimum value of 1.27×10^{-7} (unit-less) and a maximum value of 4.00×10^{0}. The concentration curves of these results are shown in Figure II-2-5. Increasing Henry's constant decreased the attenuation of the constituent. This suggests that more volatile constituents are less likely to be attenuated. In the same respect, decreasing Henry's constant increases the constituent's attenuation in the soil. The explanation for this behavior is that the modeled soil is only partly saturated. Constituents with higher Henry's law constants can effectively migrate through air or water in the subsurface, whereas constituents with lower Henry's law constants are limited to migration through the aqueous phase. In addition, the lower concentration of the constituent in water allows for less adsorption onto soil particles.

2.4.2. Adsorption Isotherm

The adsorption isotherm, K_d, is used to express the equilibrium of the concentration of the constituent in the aqueous phase and the concentration of the constituent sorbed onto organic matter in the soil particles. A constituent with a high adsorption isotherm is has a higher affinity to adsorb to organic matter.

The adsorption isotherm was adjusted to a minimum value of 2.40×10^{-14} m^3/g and a maximum value of 8.80×10^{-3} m^3/g. The concentration curves of these results are shown in Figure II-2-6. As expected, increasing the adsorption isotherm significantly limits the migration of the constituent. In the same respect, decreasing adsorption isotherm significantly decreased the constituent's attenuation in the soil. In this model, adsorption to organic matter contributes significantly to the attenuation of constituents.

2.4.3. Water Transport Models

To evaluate the sensitivity of the selection of water transport model, three alternative models for water transport were applied, including modified van Gunechten, Brooks Corey (1964), and Kosugi (1996). The concentration curves of these results are shown in Figure II-2-7A through II-2-7C. These figures can be compared to Figure II-2-1A, which used the identical inputs for the originally selected water transport model (van Genuchten–Mualem). Of the four water transport models, only the Brooks Corey model shows any significant difference. The other three models have nearly identical results. The Brooks Corey model shows slightly greater attenuation than the other models. Since the results of the originally selected van Genuchten–Mualem model are matched by two other models, and are more conservative than the results from the Brooks Corey model, the original water transport model selection appears to be appropriate.

2.4.4. Molecular Diffusion

The molecular diffusion is the transport of molecules from a region of higher concentration to one of lower concentration. In the vadose zone, the rate of diffusion is proportional to the gradient of concentration. Diffusion of constituents occurs most rapidly in gases and less so in liquids. Diffusion through water may be limited by the saturation in the subsurface, because diffusion requires connected pore spaces filled with water. Conversely, diffusion through air is more effective in unsaturated soils.

The molecular diffusion in air was adjusted to a minimum value of 1.49×10^{-11} m^2/d and a maximum value of 1.30×10^{-1} m^2/d. The concentration curves of these results are shown in Figure II-2-8. Increasing the molecular diffusion in air significantly decreased the attenuation of the constituent. In the same respect, decreasing molecular diffusion in air significantly increased the constituent's attenuation in the soil. This behavior is expected because in the unsaturated zone, diffusion through air can be a significant transport mechanism particularly to highly volatile constituents. In this model, the molecular diffusion in air is a significant factor in the attenuation of constituents.

The molecular diffusion in water was adjusted to a minimum value of 1.04×10^{-5} m^2/d and a maximum value of 1.47×10^{-4} m^2/d. In general, values of the diffusion coefficient for water do not vary as significantly as the diffusion coefficient for air. The concentration curves of these results are shown in Figure II-2-9. Increasing and decreasing the molecular diffusion in water within this range did not significantly change the attenuation of the constituent.

2.4.5. Bulk Density

The bulk density of soil is the mass of the soil particles divided by the total volume occupied by the soil. Bulk density of soil is typically between 62 and 124 pcf. The bulk density was adjusted to this minimum and maximum value in the model to observe the effect on the results. The concentration curves of these results are shown in Figure II-2-10. Increasing the bulk density slightly increased the attenuation of the constituent. In the same respect, decreasing bulk density slightly decreased the constituent’s attenuation in the soil. Based on these observations, bulk density does not appear to significantly affect attenuation of constituent concentrations.

2.4.6. Heterogeneity in Soil Profile

The previous model scenarios were constructed as homogeneous sand, silt, or clay soil profiles. However, at most locations within the project study area, soil is heterogeneous with respect to depth and soil profiles are composed of layers of different soil types. To evaluate the potential effect of heterogeneity on the model results, a scenario was developed that included a distribution of soils in the subsurface.

The heterogeneous soil profile used in this scenario consisted of alternating 10-ft layers of sand and clay. The 0 to 10 ft, 20 to 30 ft, and 40 to 50 ft depths were layers of sand. The 10 to 20 ft and 30 to 40 ft depths were layers of clay. The concentration curve of this model is shown in Figure II-2-11. The bromodichloromethane exhibited a sharper decline in concentration at the 10 foot depth where a clay layer was introduced. This is expected as the clay exhibited a higher level of attenuation than the sand. Attenuation in this case is more prominent than in the case of sandy soil (Figure II-2-1A) and less prominent in the case of clayey soil (Figure II-2-1C).

2.5. Conclusions

The modeling shows that concentrations of some constituents are attenuated under certain simulated conditions of irrigation with recycled water with a modeled 50-foot vadose zone. The model verifies that constituents generally attenuate better in clayey soils than sandy or silty soils. Attenuation is most greatly achieved by constituents that have transport processes dominated by low volatilization and high sorption. Because the model is a closed system (i.e. constituents cannot be lost through escape to the atmosphere), volatilization may enhance the migration of a constituent downward. Constituents such as NDMA, which are relatively less prone to volatilization, may actually be transported more quickly through clayey soils. Beyond the 50-year time mark, the constituent concentrations will continue to progress towards the irrigated concentrations along the entire depth profile. This is because adsorption to organic matter has a fixed capacity, and given enough exposure to the constituent, the soil will eventually become saturated and sorption will essentially be nullified. However, on this time frame, the processes of degradation which were not considered in this model may be significant enough to prevent further migration. Degradation is an important element to the attenuation of recycled water. The level of degradation or transformation is different for each constituent. Evaluations on the contribution from degradation or transformation could not be made due to lack of available data for recycled water constituents.

The sensitivity analysis has shown that the model results are sensitive to certain input parameters. Constituent characteristics including Henry’s constant, adsorption isotherm, and the molecular diffusion in air are factors that most significantly determine the constituent’s rate of migration to groundwater. In addition, soil type plays an important role in determining which constituents present greater threats to groundwater. The molecular diffusion in water, bulk density, and choice of transport model did not significantly change the model results.

The model is useful as a tool for a preliminary evaluation of constituent transport through the vadose zone, but not appropriate for a detailed site specific evaluation because chemical characteristics are not known for many of the recycled water constituents. Reference values for chemical characteristics such as first-order degradation rate, diffusion coefficients, and so forth are generally limited.

Recommendations for the pilot study based on findings from the model are discussed in Section 4.3.

3. SOIL CORE BENCH TEST

Recycled water commonly contains a number of constituents introduced through the original use of the water, or through the treatment processes that the water undergoes after use. The main focus of the study is chemical constituents, including those of anthropogenic and nonanthropogenic origins. A few constituents of concern are biological. One major goal of this study is to determine whether any of these constituents have the potential to negatively impact groundwater if recycled water is used for irrigation. As one method to evaluate this potential, a bench-scale test was conducted using actual soil samples and recycled water in controlled laboratory conditions. In this section, the soil core bench test and its application to this project are discussed.

3.1. Introduction

The goal of the soil core bench test is to simulate the subsurface fate and transport of recycled water under conditions similar to those expected on sites where recycled water would be used for irrigation. The bench test serves as a controlled environment where the materials and parameters in the test are known. In this environment, recycled water from two different treatment plants and eleven soil cores are selected. By introducing recycled water at the top of the soil core, and measuring the quantity and concentrations of the effluent water at the bottom of the soil core, the estimated loading of each constituent to groundwater was estimated. The effects of the recycled water on the hydraulic conductivity of the soil were also calculated by comparing a final hydraulic conductivity where recycled water is applied to the soil cores and the initial hydraulic conductivity without exposure to recycled water by using ASTM method D-5084.

3.2. Methodology

3.2.1. Soil Cores

Soil cores were collected in eight locations throughout the Santa Clara and Llagas Subbasins. Four locations were selected in each subbasin, representing a geographic distribution over the areas where recycled water is currently being used and may be expanded in the future, and a range of surface soil types. The locations where the drilling occurred are shown in Figures II-3-1 and II-3-2. The IDT site, which is the location of the pilot study to be conducted in the next phase of this project, was one of the four locations in the Santa Clara Subbasin (location 3 on Figure II-3-1). The locations for the soil core collection were chosen within SCVWD easement and right-of-way areas throughout the Santa Clara and Llagas Subbasins.

At each location, two adjacent cores were collected. The first core was opened and logged onsite. The other was capped and saved for potential use as core sections for the bench test. Soil cores were taken from May 12 to 14, 2008. Cores were approximately 1.8 inches in diameter. Due to physical refusal at the drilling site, cores could not be extracted to the planned depth of 30 feet from locations SCV-2 and Llagas-1. Location SCV-2 was completed to a depth of 18 feet, and location Llagas-1 was collected to a depth of 12 feet. At two other locations, Llagas-2 and Llagas-3, a single 30-foot soil core was collected, but a second soil boring could not be collected due to damages to the drill tips. The soil at these locations was logged from the first boring by inspection through the transparent sleeve and at the open ends of each section. Boring logs for all locations are included in Appendix II-A.

3.2.2. Soil Core Section Selection

Of the eight soil cores collected, eleven sections from the undisturbed collected cores were selected for the bench test: three four-foot sections representative of coarse-grained soils, three four-foot sections representative of semi-fine-grained soils, and five one-foot sections representative of fine-grained soils. Four foot sections were the longest continuous sections that could be extracted by the drill rig. In some of these sections, particularly for loose soils, a full four feet of soil was not collected. Some amounts of loose soil were lost at the ends of the sections during lab setup.

Shorter sections of fine-grained soil were chosen for this test to allow more sample water to permeate through within the time frame of the study. Shortening the soil sections is expected to result in less constituent attenuation, however since the attenuation was expected to be higher for fine-grained soils, it could still be measured and evaluated over one foot lengths. The core sections were selected based on the adjacent logged core sections. The core sections representing each soil type were selected to be similar in grain size distribution.

For each selected core section, an additional six-inch segment was collected either directly above or below the section. The segment was analyzed for hydraulic conductivity (by ASTM D-5084) and grain size distribution using sieve and hydrometer analysis. Each segment was similar in composition to its respective soil core by visual inspection. Hydraulic conductivity values obtained from these sections were used to represent initial conditions of the soil prior to exposure to recycled water.

3.2.3. Remolding

In the process of collecting the soil cores through direct-push drilling, small channels were formed between the soil and the sleeve. The channels resulted from the use of a soil-trapping device at the end of the sleeve which is designed to minimize loss of soil as the core is extracted from the borehole. The cores could not be used for the bench test in this condition because the applied recycled water would flow through the channels along the side of the core instead of infiltrating slowly through the soil as would occur in the environment. To eliminate the open channels, each soil core was remolded prior to initiation of the bench test. The moisture content and density of each soil core were measured, and the soil was extracted and fitted into a new sleeve with no channels, maintaining the moisture and density of the original cores. This prevented side percolation as a preferential pathway for water between the soil core and sleeve and ensured that the migration time through the soil cores would be similar to conditions in the field. In the process of remolding, rocks larger than 3/8 inches were removed from the cores to prevent artificial void spaces within the soil cores and ensure a better fit within the sleeves. The remolding process is not expected to create additional preferential pathways or irregular grain distributions. The soil core lengths are expected to decrease slightly due to the removal of the larger sized rocks. However, the effective length of the soil core at which attenuation occurs remains the same because the rocks do not contribute significantly to attenuation. Because the moisture content and density were identical to the original cores, remolding is not expected to change the final hydraulic conductivity of the soil matrix.

3.2.4. Use of Gypsum

The application of gypsum (hydrated calcium sulfate) is commonly used to promote soil hydraulic conductivity which may affect constituent transport to groundwater, especially where recycled water is used for irrigation. Most often, gypsum is distributed on the soil surface in areas of fine-grained soil to improve soil hydraulic conductivity. Because the use of recycled water for irrigation is often accompanied by the use of gypsum to prevent adverse effects to the soil hydraulic conductivity, gypsum is included as an important variable to analyze for the bench test. To measure the effects of gypsum use, an additional one-foot fine-grained soil core section was used to test each recycled water source used in the bench test with gypsum added. Adding gypsum affects soil by lowering the soil's Sodium Adsorption Ratio (SAR). A lower SAR prevents clay swelling. SAR and clay swelling are further discussed in Section 3.3.2.2. Because gypsum specifically affects the clays in soil, the most significant hydraulic conductivity impact due to gypsum application is expected in the fine-grained soil cores. Therefore, only the fine-grained soil cores were used to evaluate the effect of gypsum application. Approximately 0.4 grams of gypsum was applied evenly to the top of each of these sections. This value corresponds to the prescribed product application rate of 50 lb per 1000 square feet.

3.2.5. Water Sources

Two sources of recycled water were used for the bench test: the San Jose/Santa Clara Water Pollution Control Plant (SJ/SC WPCP), and the South County Regional Water Authority (SCRWA) Gilroy plant. SJ/SC WPCP services wastewater treatment to cities in the Santa Clara Subbasin including San Jose, Santa Clara, Milpitas, Campbell, Cupertino, Los Gatos, Saratoga, and Monte Sereno. The SCRWA plant services wastewater treatment to cities in the Llagas Subbasin including Morgan Hill and Gilroy. These two plants cover the areas where recycled water expansion is most likely in the Santa Clara and Llagas Subbasins.

SJ/SC WPCP wastewater is treated in a three step process. Primary treatment takes place in large settling tanks removing 50 percent of the wastewater contaminants in a 24 hour process. Secondary treatment includes aeration and secondary clarifiers. The final step is tertiary treatment involving filtration through filter beds and then gaseous chlorine for disinfection. Pollutants and solid wastes removed from the three treatment steps are directed to anaerobic digesters. The SCRWA plant also treats wastewater in three steps. Primary treatment consists of bar screens and grit chambers which are aerated basins that remove heavy particles. Secondary treatment includes oxidation ditches and secondary clarifiers. The oxidation ditches have aerated and non-aerated zones. Tertiary treatment includes filtration using anthracite media filters and disinfection by sodium hypochlorite. Solids collected from the SCRWA treatment steps are dewatered by belt filter presses. Recycled water from both sources meets Title 22 regulations.

Distilled water was used as a third source, to represent a control for comparison. The control water in the influent monitoring is analogous to a field blank; the water is expected to be clean (no detections of contaminants). Effluent monitoring of the control water is expected to observe detections of some constituents as a result of leaching from the soil. Using the control, the contribution of potential leaching of constituents may be observed and measured. Distilled water was treated with calcium chloride ($CaCl_2$) in order to maintain an ionic strength similar to that of groundwater. The proposed dosage of the additive was 11.1 grams per 10 liters of distilled water. The additive was mixed with the distilled water prior to application on the soil column. Each water source was used on three soil core sections with different soil types: coarse-grained, semifine-grained and fine-grained.

Ideally, the influent water for the bench test would be directly obtained from the recycled water distribution system. However, it was not possible to maintain the bench test at a location where both recycled water sources could be plumbed directly to the bench test. Therefore, recycled water was collected in batches from each of the two source plants, and preserved as well as possible during the execution of the bench test. Recycled water was collected twice from each plant in order to refresh the source water midway through the test. The first sample of each source was collected on May 14, 2008. The second sample of each source was collected on June 12, 2008 to refresh the sources. During the bench test, the recycled water sources were maintained in closed opaque containers above the soil cores in an enclosed cabinet space with minimal exposure to air, to minimize volatilization and photodegradation. The influent sources were connected to the soil cores by plastic tubing, and the application of the influent sources was gravity-driven. Influent water sampling occurred simultaneously to effluent water sampling of the respective coarse grained core. The coarse grain core was selected as it was expected to produce effluent water before the semi-fine and fine grained core. Samples of the influent recycled water collected from the closed opaque containers throughout the bench test indicate that the influent water remained representative of the recycled water sources, and were consistent with previously measured values (see Volume I).

3.2.6. Bench Test Procedures

Figure II-3-3 presents a flow diagram for the bench test apparatus. Recycled water from the SJ/SC WPCP is paired with soil core sections derived from the Santa Clara Subbasin and recycled water from the SCRWA plant is paired with soil core sections derived from the Llagas Subbasin. Thus, each soil core is exposed to the corresponding recycled water source for that area.

Effluent water from each core was monitored twice during the bench test. The first sampling event occurred at first breakthrough for each core section. The second sampling event for each core started immediately after completion of the first sampling event. The separation between the first and second sampling for a given constituent was 8.2 liters; this volume is the combined sample volume requirement for all of the constituents to be tested (Table II-3-1). Based on the measured pore volumes for each core, 8.2 liters equates to 9.3 to 40 pore volumes based on the porosity of the soil cores. A pore volume refers to the total amount of void space in the soil column. A higher pore volume between sampling of a constituent was desired so that changes in attenuation over time could be observed. As more pore volumes of recycled water are passed through the soil core, the system better represents longer term conditions. Due to the different hydraulic conductivity of each soil, sampling events for each core did not occur at the same time.

Sample bottles were filled for each analysis in a specific order prioritized by a constituent of concern list shown in Table II-3-1. The constituents to be monitored in the bench test were selected based on their potential to be present in recycled water and their potential to negatively impact groundwater. This evaluation was conducted in the previous phase of this project (see Volume I of this report). Aldicarb sulfoxide, PHaCs, NDCs, NBBS, and trisphosphates which were recommended for further monitoring from Volume I were not included in the bench test as a commercial laboratory to test for these constituents could not be identified. While these constituents were not monitored, the constituents that were part of the monitoring plan in the bench test are of a wide characteristic range that confidently represents recycled water. VOCs, which were not recommended for further monitoring in Volume I, were included in the bench test because the VOCs are a part of the analysis (EPA 8260B) that also analyzes THMs. In addition, bromide was included in the sampling list as a tracer.

During sampling, sample bottles were filled as the volume of the effluent water reached the required volume for the next analysis. Six out of the eleven soil cores sections completed the full sampling objectives. Due to extremely low final hydraulic conductivity, the remaining soil core sections were unable to yield a complete sample for all constituents. Irrigation of cores for the bench test began on June 8, 2008, and continued through October 8, 2008.

During the bench test, all portions of the apparatus were sealed to prevent exposure to air and light. Water sources were covered and effluent water was collected in amber glass jars to prevent volatilization and photodegradation. A record was maintained of the water volume that passed through each core section over time. Using Darcy’s law and this information, the final hydraulic conductivity of each soil core section was determined during the bench test.

3.2.7. Analytical Laboratories

Laboratory analysis of the water samples were conducted by a combination of four laboratories: Weck Laboratories, MWH Laboratories, EMLab P&K, and Cranmer Analytical Laboratory. The specific laboratories performing each analysis and the corresponding analytical methods are listed in Table II-3-1.

3.2.8. Hydraulic Conductivity

Hydraulic conductivity tests were conducted to determine the effects of recycled water on soil permeability. Hydraulic conductivity of the soil was determined prior to recycled water application by ASTM D-5084, Method C: Falling Head, Rising Tailwater Elevation (herein referred to as initial hydraulic conductivity). The hydraulic conductivity of each soil sample was also estimated during the bench test using Darcy's Law and the recorded times and effluent volumes during the bench test (referred to as final hydraulic conductivity in this report). The main intent of the two sets of data on hydraulic conductivity is to compare the effect of the water source (recycled water versus control water) on the hydraulic conductivity of the soil. The hydraulic conductivity data is also used to compare between different soil cores for each recycled water source.

3.2.9. X-ray Diffraction

To evaluate the potential correlation between initial hydraulic conductivity by ASTM D-5084 and the clay mineralogy of each soil core, samples of each soil core section were analyzed by x-ray diffraction. Of the 11 soil core sections, samples from 10 of those sections were analyzed. Core section SJSC-C was a sample with high coarse grain content and very little fine grains. Due to the low amount of fine grains there was not enough material from that section to perform the diffraction analysis. X-ray diffraction was performed by the UC Davis laboratory at the Land, Air and Water Resources Department. Results of the x-ray diffraction analyses are discussed in Section 3.2.10 along with descriptions of the soil columns.

3.2.10. Soil Core Descriptions

Descriptions of each of the eleven soil cores included in the bench test are provided below. Drilling locations for the Santa Clara Subbasin are shown on Figure II-3-1, and locations for the Llagas Subbasin are shown on Figure II-3-2. Full soil boring logs for each of the cores are included in Appendix II-A. Grain size and hydraulic conductivity analyses are provided in Appendix II-B. The table below provides some details of each soil core. The lengths of the cores are shorter due to some amounts of loose soil lost at the ends of the section. Note that the Santa Clara map location number 3 is the site of the pilot study.

Sample ID	Grain Category	Gypsum Applied?	Subbasin Derived	Map Location Number	Core Length (in)	Depth Extracted (ft)	Water Source Applied	Region type
SJSC-A	Fine	No	Santa Clara	3	12	20 - 24	SJSC WCPCP	Unconfined
SJSC-D	Fine	Yes	Santa Clara	3	12	20 - 24	SJSC WCPCP	Unconfined
SJSC-B	Semi-fine	No	Santa Clara	4	29	0 - 4	SJSC WCPCP	Unconfined
SJSC-C	Coarse	No	Santa Clara	2	28	4 - 8	SJSC WCPCP	Unconfined
SCRWA-A	Fine	No	Llagas	4	12	24 - 28	SCRWA	Confined

Sample ID	Grain Category	Gypsum Applied?	Subbasin Derived	Map Location Number	Core Length (in)	Depth Extracted (ft)	Water Source Applied	Region type
SCRWA-D	Fine	Yes	Llagas	4	12	24 - 28	SCRWA	Confined
SCRWA-B	Semi-fine	No	Llagas	4	33	4 - 8	SCRWA	Confined
SCRWA-C	Coarse	No	Llagas	2	29	0 - 4	SCRWA	Unconfined
DI-A	Fine	No	Santa Clara	1	12	16 - 20	Distilled Water	Confined
DI-B	Semi-fine	No	Llagas	3	46	20 - 24	Distilled Water	Unconfined
DI-C	Coarse	No	Santa Clara	4	34	12 - 16	Distilled Water	Unconfined

3.2.10.1. SJSC-A

SJSC-A is a 12-inch soil core of fine-grained material derived from an unconfined region of the Santa Clara Subbasin. The sample was extracted from between 20 and 24 feet depth at the IDT property located on Silver Creek Valley Road, San Jose (Boring SCV-3). This property was selected because it is the location for the pilot study conducted as the next phase of this project. For comparison with respect to gypsum application, SJSC-A and SJSC-D are soil cores derived from the same location and depth range. Source water used to irrigate this core was tertiary treated effluent from the SJ/SC WPCP.

X-ray diffraction of the clay minerals revealed the main composition of the clays to be, in order of decreasing percentages, kaolinite, vermiculite, smectite, and mica. Minor amounts (5 to 10%) of hydroxy-interlayered 2:1 mineral (HIM) and trace amounts (<5%) of quartz were also found. These results appear to be similar to those from the SJSC-D sample which were derived from the same section, which suggests that the results are reproducible. Of the clay minerals in major abundance, smectite is the most expansive. Vermiculite and mica can be expansive and kaolinite is generally nonexpansive (Nelson et al., 1997).

Due to the low final hydraulic conductivity with recycled water applied, very little effluent water was available from the SJSC-A soil core for chemical analysis. This resulted in incomplete analytical results as the collected volume of effluent water was sufficient only for analysis using handheld monitoring instruments (DO, ORP, pH, and chlorine). Due to the lack of water infiltration through the soil core, the soil acted as an effective physical barrier to recycled water infiltration within the time frame of the bench test (120 days). Bacterial growth may have also contributed to the reduced flow, although there was not enough effluent to test for bacterial growth.

3.2.10.2. SJSC-B

SJSC-B is a 29-inch soil core of semifine-grained material derived from an unconfined region of the Santa Clara Subbasin near the intersection of San Felipe Road and Bowery Lane, San Jose, CA (Boring SCV-4). The sample was extracted from between 0 and 4 feet depth from this soil boring. Source water used to irrigate this core was tertiary treated effluent from the SJ/SC WPCP.

X-ray diffraction of the clay minerals revealed the main composition of the clays to be, in order of decreasing percentages, kaolinite, mica, and vermiculite. Minor amounts (5 to 10%) of smectite and quartz were also found. Vermiculite and mica, which can be expansive, may have contributed to the lack of flow through SJSC-B. Kaolinite, which was the dominant clay mineral, is generally nonexpansive (Nelson et al., 1997).

Due to the low final hydraulic conductivity with recycled water applied, very little effluent water was available for chemical analysis. This resulted in incomplete analytical results as the collected volume of effluent water was sufficient only for analysis using handheld monitoring instruments (DO, ORP, pH, and chlorine). Due to the lack of water infiltration through the soil core, the soil acted as an effective physical barrier to recycled water infiltration within the time frame of the bench test (120 days). Bacterial growth may have also contributed to the reduced flow, although there was not enough effluent to test for bacterial growth.

3.2.10.3. SJSC-C

SJSC-C is a 28-inch soil core of coarse-grained material derived from an unconfined region of the Santa Clara Subbasin, near the intersection of Virginia Road and Bucknam Ave, Campbell, CA (Boring SCV-2). The sample was extracted from between 4 and 8 feet depth from this soil boring. Source water used to irrigate this core was tertiary treated effluent from the SJ/SC WPCP.

X-ray diffraction was not performed for this soil sample, because there was insufficient clay material for this analysis. Because of the relatively high final hydraulic conductivity of this core, both rounds of analytical sampling were completed within 203 hours.

3.2.10.4. SJSC-D

SJSC-D is a 12-inch soil core of fine-grained material derived from an unconfined region of the Santa Clara Subbasin, at the IDT site property, San Jose, CA (Boring SCV-3). The sample was extracted from between 20 and 24 feet depth from this soil boring. Gypsum was added to this soil core as described in Section 3.2.4. SJSC-A and SJSC-D are soil cores derived from the same location (SCV-3) and depth range (20 to 24 ft). Source water used to irrigate this core was tertiary treated effluent from the SJ/SC WPCP.

X-ray diffraction of the clay minerals revealed the main composition of the clays to be, in order of decreasing percentages, kaolinite, smectite, chlorite and mica. Minor amounts (5 to 10%) of vermiculite, hydroxy-interlayered 2:1 mineral (HIM), and quartz were also found. These results are similar to those from the SJSC-A sample which was derived from the same soil core section. Because of the relatively high final hydraulic conductivity of this core, both rounds of analytical sampling were completed within a 17.5 hour time frame. The quick percolation flow through the soil core is attributed to the addition of gypsum.

3.2.10.5. SCRWA-A

SCRWA-A is a 12-inch soil core of fine-grained material derived from a confined region of the Llagas Subbasin. The sample was extracted from between 24 and 28 feet depth from the soil boring collected near the intersection of Bolsa Road and Bloomfield Ave, Gilroy, CA (Boring Llagas-4). SCRWA-A and SCRWA -D are soil cores derived from the same location (Llagas-4) and depth range. Source water used to irrigate this core was tertiary treated effluent from the SCRWA treatment plant in Gilroy, CA.

X-ray diffraction of the clay minerals revealed the main composition of the clays to be, in order of decreasing percentages, smectite and kaolinite. Minor amounts (5 to 10%) of vermiculite and trace amounts (<5%) of quartz and mica were also found. These results are similar to those from the SCRWA-D sample which was derived from the same soil core section, which supports the reproducibility of the x-ray diffraction data. Smectite is highly expansive and likely contributed to the low flow through SCRWA-A. The kaolinite is generally nonexpansive.

Due to the low final hydraulic conductivity, effluent water did not completely migrate through the soil core within the time frame of the bench test (120 days). This resulted in no chemical analytical results for the first or second event. The soil acted as an effective physical barrier to recycled water infiltration within the time frame of the bench test (120 days). Bacterial growth may have also contributed to the reduced flow, although there was not enough effluent to test for bacterial growth.

3.2.10.6. SCRWA-B

SCRWA-B is a 33-inch soil core of semifine-grained material derived from a confined region of the Llagas Subbasin near the intersection of Bolsa Road and Bloomfield Ave, Gilroy, CA (Boring Llagas-4). The sample was extracted from between 4 and 8 feet depth from this soil boring. Source water used to irrigate this core was tertiary treated effluent from the SCRWA treatment plant in Gilroy, CA.

X-ray diffraction of the clay minerals revealed the main composition of the clays to be, in order of decreasing percentages, smectite, kaolinite, mica, and vermiculite. Hydroxy-interlayered 2:1 mineral (HIM) and quartz were also found in trace amounts (<5%). Because of the relatively high final hydraulic conductivity of this core, both rounds of analytical sampling were completed within 63 hours potentially due to an overall lower percentage (11%) of clay in the soil.

3.2.10.7. SCRWA-C

SCRWA-C is a 29-inch soil core of coarse-grained material derived from an unconfined region of the Llagas Subbasin near the intersection of Church Ave and Llagas Ave, Morgan Hill, CA (Boring Llagas-2). The sample was extracted from between 0 and 4 feet depth from this soil boring. Source water used to irrigate this core was tertiary treated effluent from the SCRWA treatment plant in Gilroy, CA.

X-ray diffraction of the clay minerals revealed the main composition of the clays to be, in order of decreasing percentages, smectite, chlorite, and kaolinite. Minor amounts (5 to 10%) of mica, hydroxy-interlayered 2:1 mineral (HIM), quartz, and feldspar were also found. Although expansive type clays such as smectite comprised the majority of clay minerals in this soil, the overall percent composition of clay in the soil was very low (the associated soil sample used for the hydrometer test actually revealed zero percent clay). However, there was sufficient clay content to complete the x-ray diffraction analysis. Therefore, clay swelling did not significantly impede the water flow. Because of the relatively high final hydraulic conductivity of this core, both rounds of analytical sampling were completed in 6.4 hours.

3.2.10.8. SCRWA-D

SCRWA-D is a 12-inch soil core of fine-grained material derived from a confined region of the Llagas Subbasin near the intersection of Bolsa Road and Bloomfield Ave, Gilroy, CA (Boring Llagas-4). The sample was extracted from between 24 and 28 feet depth in this soil boring. Gypsum was added to this soil core as described in Section 3.2.4. SCRWA-A and SCRWA -D are soil cores derived from the same location and depth range. Source water used to irrigate this core was tertiary treated effluent from the SCRWA treatment plant in Gilroy, CA.

X-ray diffraction of the clay minerals revealed the main composition of the clays to be smectite and kaolinite, in order of decreasing percentages. Minor amounts (5 to 10%) of mica and vermiculite and trace amounts (<5%) of quartz were also found. Like soil core SCRWA-A, low flow would be expected but for the addition of gypsum. Because of the relatively high final hydraulic conductivity of this core, both rounds of analytical sampling were completed within 2.4 hours.

3.2.10.9. DI-A

DI-A is a 12-inch soil core of fine-grained material derived from a confined region of the Santa Clara Subbasin near the intersection of Tasman Dr. and Cisco Way, San Jose, CA (Boring SCV-1). The sample was extracted from between 16 and 20 feet depth from this soil boring. Source water used to irrigate this core was distilled water. This soil core had the lowest percentage of coarse-grained material of all eleven soil cores. Only 1.9 percent was categorized as sand, with silt (79.1%) and clay (19.0%) comprising the remainder.

X-ray diffraction of the clay minerals revealed the main composition of the clays to be chlorite and kaolinite, in order of decreasing percentages. Minor amounts (5 to 10%) of smectite, vermiculite, hydroxy-interlayered 2:1 mineral (HIM), and trace amounts (<5%) of quartz were also found. Although present only in relatively minor amounts, the smectite and vermiculite may have contributed to clay swelling, reducing flow through the soil core. Bacterial growth may have also contributed to the reduced flow, although there was not enough effluent to test for bacterial growth.

Due to low final hydraulic conductivity, very little effluent water was available for chemical analysis. This resulted in incomplete analytical results for the first and second event. The collected volume of effluent water was sufficient only for analysis using handheld monitoring instruments (DO, ORP, pH, and chlorine) over a 120-day time frame.

3.2.10.10. DI-B

DI-B is a 46-inch soil core of semifine-grained material derived from an unconfined region of the Llagas Subbasin near the intersection of Thomas Road and Oak Brook Way, Gilroy, CA (Boring Llagas-3). The sample was extracted from between 20 and 24 feet depth from this soil boring. Source water used to irrigate this core was distilled water.

X-ray diffraction of the clay minerals revealed the main composition of the clays to be smectite and vermiculite, in order of decreasing percentages. Trace amounts (<5%) of mica were also found. The smectite and vermiculite content likely contributed to clay swelling, resulting in almost no flow through this soil core. Bacterial growth may have also contributed to the reduced flow, although there was not enough effluent to test for bacterial growth.

Due to low final hydraulic conductivity, no effluent water completely migrated through the soil core within the time frame of the bench test (120 days). This resulted in no chemical analytical results for the first or second event.

3.2.10.11. DI-C

DI-C is a 34-inch soil core of coarse-grained material derived from an unconfined region of the Llagas Subbasin near the intersection of San Felipe Road and Bowery Lane, San Jose, CA (Boring SCV-4). The sample was extracted from between 12 and 16 feet depth from this soil boring. Source water used to irrigate this core was distilled water.

X-ray diffraction of the clay minerals revealed the main composition of the clays to be mica and kaolinite, in order of decreasing percentages. Minor amounts (5 to 10%) of smectite and quartz and trace amounts (<5%) of chlorite and feldspar were also found. Mica and smectite may have contributed to clay expansion but the overall percentage of clay in this soil was very low, resulting in a higher flow volume. Because this core was highly permeable, both rounds of analytical sampling were completed in 4.1 hours.

3.3. Results

The bench test was run from June 9, 2008 to October 8, 2008. Sampling for the bench test was completed between June 9, 2008 and July 7, 2008. Very little effluent water was obtained from July 7, 2008 to October 8, 2008, when the only cores that had incomplete sampling were the low-permeability soil cores.

3.3.1. Physical Results

Before and after the bench test, each soil core was analyzed for a series of physical parameters to quantify the grain size distribution, hydraulic conductivity, and clay mineralogy. Those results are discussed below.

3.3.1.1. Sieve Analysis and Hydrometer Test

Sieve analyses and hydrometer tests were used to provide grain distribution information of the soil samples. Results from the sieve analysis and hydrometer test are shown in Table II-3-2. The laboratory report of these analyses may be found in Appendix II-B. Fine-grained core samples, including SJSC-A, SJSC-D, SCRWA-A, SCRWA-D, and DI-A contained silt and clay ranging from 71.2 to 98.1 percent. Semifine-grained core samples including SJSC-B, SCRWA-B, and DI-B contained silt and clay ranging from 29.1 to 86.9 percent. Coarse-grained core samples including SJSC-C, SCRWA-C, and DI-C contained silt and clay content ranging from 4.9 to 10.7 percent. The categories presented in Table II-3-2 (fine, semi-fine, and coarse) were determined based on initial onsite inspection of borings and boring logs using the USCS classification system. Sieve analysis and hydrometer tests later yielded a different set of soil classifications although overall, the classifications were not extremely different. Revised USCS classifications from the sieve analysis and hydrometer test are presented in Table II-3-2 and applied in this study.

The core samples that yielded little to no effluent water were primarily samples with high silt and clay content. With the exception of DI-B, the silt and clay content of these cores ranged from 82.6 to 98.1 percent. The silt and clay content of DI-B is 29.1 percent, and the clay mineralogy of the DI-B sample was not notably different from the other samples collected from the Llagas Groundwater Subbasin, other than the absence of kaolinite. The clay fraction of sample DI-B was mainly composed of smectite followed by vermiculite.

3.3.1.2. Hydraulic Conductivity

Results for initial and final hydraulic conductivity are shown in Table II-3-2. The original lab report of the tests may be found in Appendix II-B. Final hydraulic conductivity values with recycled water applied could not be obtained for all soil cores. Soil cores that yielded little or no effluent volume can only be qualitatively evaluated. For those cores (SJSC-A, SJSC-B, SCRWA-A, DI-A, DI-B), an estimated maximum final hydraulic conductivity was calculated based on a single pore volume migrating through the core within the 120-day period of the bench test.

Samples with a relatively low initial hydraulic conductivity include SJSC-A, SJSC-B, SCRWA-A, SCRWA-B, and SCRWA-D having a range of 10^{-8} to 10^{-5} centimeters per second (cm/sec). Based on the sieve analysis and hydrometer test, these soils cores tended to contain a higher percentage of fine grains. Samples with higher initial hydraulic conductivity include SJSC-D, SCRWA-C, DI-A, DI-B, and DI-C having a range of 10^{-4} to 10^{-2} cm/sec. These soil samples tend to have higher coarse grain content, although DI-A and SJSC-D are outliers which have relatively high silt content and high hydraulic conductivity.

The initial hydraulic conductivity of SJSC-A and SJSC-D soil, which were derived from the same soil section, varied significantly. The hydraulic conductivity values are two orders of magnitude different (4.70×10^{-6} cm/sec for SJSC-A and 3.10×10^{-4} cm/sec for SJSC-D) which indicates that soil collected from the same core can be variable. However, SCRWA-A and SCRWA-D are derived from the same soil core section and the respective hydraulic conductivities are within the same order of magnitude of each other which indicates a more homogenous soil column.

The addition of gypsum greatly increased the hydraulic conductivity of the samples with exposure to recycled water. Fine soil cores with the added gypsum (SJSC-D and SCRWA-D) yielded sufficient effluent volume for both rounds of sampling events whereas the respective fine soil cores without gypsum (SJSC-A and SCRWA-A) did not. The final hydraulic conductivity of the soil cores with gypsum after recycled water application behaved more similarly to that of coarse grained soil cores, with final values of 1.40×10^{-2} and 8.15×10^{-2} cm/sec for SJSC-D and SCRWA-D respectively.

For soil cores that yielded sufficient water to complete the sampling events, the final hydraulic conductivity after recycled water application is greater than the results derived from the initial hydraulic conductivity by ASTM D-5084. The value of the final hydraulic conductivity after recycled water application during the bench test ranged from 10^{-3} to 10^{-1} cm/sec while initial hydraulic conductivity by ASTM D-5084 ranged from 10^{-7} to 10^{-3} cm/sec. This includes but is not exclusive to cores with gypsum applied. The difference between the two sets of hydraulic conductivity may be partially caused by the different methods used in determining hydraulic conductivity. The final hydraulic conductivity was not determined using the ASTM method, but rather the effluent volume measurements from the bench test. The final conductivity, however, does provide a realistic indication of the observed rate of water percolation.

3.3.1.3. X-ray Diffraction of Clay Minerals

The results of the diffraction of the clay minerals are shown in Table II-3-2 and the original UC Davis analysis report is found in Appendix II-C. Minerals found in main abundance include kaolinite, vermiculite, smectite (montmorillonite), mica, and chlorite. Comparing the samples from the two subbasins, the mineralogy from Llagas Subbasin is more dominated by smectite followed by kaolinite. By comparison, the soil samples from the Santa Clara Subbasin are more dominated by kaolinite. Quartz, which is not a clay mineral, and hydroxy-Interlayered 2:1 Mineral (HIM) were found in a majority of the samples but were found only in trace or minor amounts. Feldspar, which is also not a clay mineral, was found infrequently and in low amounts.

Of the common clays, smectite has the highest capacity for clay expansion followed by illite-vermiculite clays, followed by kaolinite clays (literature review in Volume I). Due to the higher abundance of smectite in the SCRWA samples, more clay expansion is expected in the SCRWA samples than the SJSC samples. Given that gypsum use in conjunction with irrigation is a common best management practice, clay expansion is not expected to contribute to soil aquifer plugging. However, in cases where gypsum is not applied, significant clay expansion can occur, which could reduce infiltration rates and cause surface ponding.

3.3.2. Chemical Results

This section discusses the analytical data of the constituents of recycled water that were observed. Chemical results discussed in this section may be found in Tables II-3-3 to II-3-11. In addition, charts graphically displaying the chemical results are provided in Figures II-3-4 to II-3-48. Original lab reports of the constituent analyses are found in Appendix II-D. Because this evaluation relies on comparison of concentrations in samples collected at the influent and effluent points of each soil core, it became necessary to determine what constitutes a significant reduction in concentration, as opposed to minor concentration differences caused by analytical variability. As a general guideline, concentration differences less than 20% will not be considered as a significant change for the purpose of this bench test. Variability within this range is expected to stem from the analytical procedures used in the bench test. The common level of expected precision for most laboratory analyses is 20%-25%. The actual percentage change is considered when making the comparison for each constituent, so this screening does not dismiss any observed changes in constituent concentrations. The 20% criterion is used only to identify and distinguish significant changes in concentration, as opposed to changes that may be caused by analytical variability.

Of the 11 sample cores, 6 cores yielded sufficient effluent volume to complete two sampling events (SJSC-D, SJSC-C, SCRWA-D, SCRWA-B, SCRWA-C, and DI-C). Cores SJSC-A, SJSC-B, and DI-A yielded only enough volume for a single partial sampling event for constituents that could be monitored by handheld instruments (including DO, ORP, pH, and residual chlorine). Cores SCRWA-A, and DI-B did not yield any effluent volume during the entire course of the bench test.

3.3.2.1. General Water Quality

Alkalinity and pH

The pH did not change significantly between recycled water influent and core effluent samples. Data for pH is graphed in Figure II-3-4. The pH of the recycled water sources were near neutral ranging from 7.3 to 8.1. The pH of the core effluent samples of recycled water ranged from 7.7 to 8.0. For the distilled water source, the influent pH was slightly more acidic, ranging from 6.5 to 7.0 and the effluent pH ranged from 7.3 to 7.9. Because the pH of groundwater is also near neutral, groundwater would not likely be affected due to the pH of these water sources.

Overall Minimum and Maximum Data for pH (pH units) in Soil Columns

	SJSC	SCRWA	DI
Influent	7.3 - 8.0	7.5 - 8.1	6.5 - 7.0
Effluent	7.7 - 8.0	7.3 - 7.9	7.3 - 7.9

Alkalinity did not change significantly between recycled water influent and core effluent samples. Data for the total alkalinity is graphed in Figure II-3-5. Bicarbonate alkalinity was the main form of alkalinity present in the influent and effluent recycled water samples. Alkalinity as carbonate and alkalinity as hydroxide were at levels below detection in all samples. Data for the separate forms of alkalinity is graphed in Figures II-3-6 to II-3-8. In the control samples, alkalinity was not detected for influent distilled water. In the distilled water effluent samples, bicarbonate was detected as a result of percolation through soil. The total alkalinity in the distilled effluent water samples ranged from 9.5 to 32 mg/L as $CaCO_3$. The alkalinity in the distilled effluent water sample is likely to be a result of leaching from the soil.

Minimum and Maximum Data for Total Alkalinity as $CaCO_3$ (mg/l)						
	SJSC-C	SJSC-D	SCRWA-B	SCRWA-C	SCRWA-D	DI-C
Influent	160 - 190		240 - 250			ND 2.0 - ND 2.0
Effluent	180 - 180	180 - 200	220 - 340	230 - 240	240 - 240	9.5 - 32

Total Dissolved Solids

Total dissolved solids (TDS) concentrations did not change significantly between recycled water influent and core effluent samples. Data for TDS is graphed in Figure II-3-9. SJSC and SCRWA samples indicate that neither significant leaching (i.e. ion exchange) nor attenuation was occurring.

In the control cores, TDS was not detected in the influent distilled water. In the distilled water effluent samples, TDS was detected as a result of soil dissolving into the water from the influent with $CaCl_2$. TDS in the distilled effluent water samples ranged from 964 to 1360 mg/L. It is notable that these values are higher than the influent and effluent concentrations from the cores irrigated with recycled water. These TDS concentrations may have been caused by the addition of $CaCl_2$ to the distilled water source, which was done to make the ionic charge similar to that of groundwater. The influent distilled water was sampled before the addition of the $CaCl_2$. Hence the distilled influent indicates no detection in TDS and the interpretation of the results accounts for the addition of $CaCl_2$.

Flags that were encountered in the TDS results include the “C” flag. A discussion of the “C” flag is found in Section 3.4. Duplicate data indicate that the “C” flag did not significantly lower the quality of the data.

Minimum and Maximum Data for Total Dissolved Solids (mg/L)						
	SJSC-C	SJSC-D	SCRWA-B	SCRWA-C	SCRWA-D	DI-C
Influent	649 - 690		714 (C) - 725			ND 10 - ND 10
Effluent	701 - 705 (C)	700 - 723 (C)	593 – 625	691 - 699 (C)	585 - 768 (C)	964 (C) - 1360

Dissolved and Total Organic Carbon

Data for dissolved and total organic carbon is graphed in Figures II-3-10 and II-3-11 respectively. In the first sampling round for most soil cores, dissolved organic carbon (DOC) and Total Organic Carbon (TOC) exhibited a large increase in the core effluent concentration. In the second round of sampling, the change in these parameters through the soil cores was low. The data suggest that the soil samples initially leached organic carbon into the water, which was observed in the initial sampled core effluent. By the second round, leaching of organic carbon subsided and effluent concentrations equilibrated to influent concentrations.

DOC and TOC were similar in concentration for SCRWA influent ranging from 4.0 to 4.4 mg/L. The effluent concentrations for SCRWA recycled water in the first sampling round ranged from 11 to 24 mg/L for DOC and 23 to 84 mg/L for TOC. In the second sampling round, the DOC and TOC effluent concentrations for SCRWA water samples ranged from 3.5 to 4.9 mg/L, similar to the influent concentrations. This behavior was also observed in the SJSC and DI samples.

SJSC-C, a coarse-grained soil core, is an exception because the effluent concentrations observed in the first and second sampling round exhibited no significant change. This soil core contained the highest percentage of coarse-grained material, and therefore it most likely did not contain significant organic carbon content.

Minimum and Maximum Data for Total Organic Carbon (TOC) (mg/l)

	SJSC-C	SJSC-D	SCRWA-B	SCRWA-C	SCRWA-D	DI-C
Influent	6 - 6.9		4 - 4.2			ND 0.30 - ND 0.30
Effluent	5.9 - 6.7	6.4 - 50	4.3 - 23	4.3 – 84	4.9 - 35	0.68 - 44

Minimum and Maximum Data for Dissolved Organic Carbon (mg/l)

	SJSC-C	SJSC-D	SCRWA-B	SCRWA-C	SCRWA-D	DI-C
Influent	5.9 - 7		4.1 - 4.1			ND 0.30 - ND 0.30
Effluent	6 - 6.2	6.3 - 37	3.5 - 11	4.4 – 24	4.3 - 16	0.53 - 13

Redox Potential and Dissolved Oxygen

Oxidation reduction potential (ORP) showed reduction in all soil cores. Data for ORP is graphed in Figure II-3-12. The ORP of both the SJSC and SCRWA recycled water samples ranged from +217 to +417 milliVolts (mV) for the influent and from +123 to +172 mV for the core effluent. In the control samples, the behavior is similar. The ORP of the distilled water ranged from +245 to +297 mV in the influent and from +132 to +195 mV in the effluent. ORP data suggest that there were not major shifts in redox conditions. Positive ORP indicates conditions that favor oxidation reactions such as with oxygen. Negative ORP indicates conditions that favor chemicals to be reduced.

Overall Minimum and Maximum Data for Oxidation Reduction Potential (mV)			
	SJSC	SCRWA	DI
Influent	221 - 417	217 - 230	245 - 297
Effluent	149 -171	123 - 172	132 - 195

Dissolved oxygen (DO) concentrations did not change significantly between influent and effluent recycled water samples. Data for DO is graphed in Figure II-3-13. The majority of the DO data of the recycled water sources for the influent and core effluent samples and control water ranged from 8.1 to 8.7 mg/L. The two exceptions to this case are SCRWA-B and DI-C. In the second sampling round, the SCRWA-B and DI-C effluents observed DO concentrations of 5.3 and 4.2 mg/L, respectively. Overall, the data indicates that the system maintained oxic conditions.

Overall Minimum and Maximum Data for Dissolved Oxygen (mg/L)			
	SJSC	SCRWA	DI
Influent	0.040 - 8.6	8.3 - 8.7	8.3 - 8.6
Effluent	8.3 - 8.6	5.3 - 8.5	4.2 - 8.7

3.3.2.2. Anions and Cations

Chloride

Chloride exhibited no significant change in concentration through any of the soil cores. Data for chloride is graphed in Figure II-3-14.

Chloride was not detected in the distilled water source, but was detected in the effluent. The presence of chloride in the effluent is likely caused by the addition of $CaCl_2$ to make the ionic charge of the distilled water source similar to groundwater. Chloride in the distilled effluent water samples ranged from 230 to 450 mg/L. The influent distilled water was sampled before the addition of the $CaCl_2$. Hence the distilled influent indicates no detection in chloride. The interpretation of the results accounts for the addition of $CaCl_2$. Further discussion of the quality control can be found in Section 3.4.

Minimum and Maximum Data for Chloride (mg/l)						
	SJSC-C	SJSC-D	SCRWA-B	SCRWA-C	SCRWA-D	DI-C
Influent	190 - 210		220 – 230			ND 0.50 - ND 0.50
Effluent	210 - 210	180 - 200	200 - 210	210 - 210	210 - 210	230 – 450

Sulfate

Sulfate generally exhibited no significant change in concentrations between influent recycled water and core effluent samples with the exception of SJSC-D and SCRWA-D. Data for sulfate is graphed in Figure II-3-15. SJSC-D and SCRWA-D, both fine grain soil cores with added gypsum, exhibited an increase in the first round of sampling followed by concentrations similar to the influent in the second round of sampling. With the exception of SJSC-D, SJSC influent and effluent samples remained similar ranging from 94 to 100 mg/L as SO_4. With the exception of SCRWA-D, SCRWA influent and effluent samples remained similar ranging from 81 to 95 mg/L as SO_4. The initial increase in sulfate in SJSC-D and SCRWA-D is likely a result of the sulfate introduced by the gypsum (hydrated calcium sulfate) as it was broken down into calcium and sulfate ions.

In the control samples, sulfate was not detected in the influent distilled water, but was detected in the effluent of the DI-C sample, as a result of leaching from the soil into the water. Sulfate in the distilled effluent water samples ranged from 3.0 to 5.3 mg/L as SO_4.

Minimum and Maximum Data for Sulfate as SO_4 (mg/l)						
	SJSC-C	SJSC-D	SCRWA-B	SCRWA-C	SCRWA-D	DI-C
Influent	94 - 100		81 - 82			ND 0.50 - ND 0.50
Effluent	100 - 100	97 - 140	89 - 92	89 - 92	95 - 130	3 - 5.3

Bromide

Bromide was below detection in the influent and effluent samples. The laboratory reporting limit is 0.50 mg/L. Data for bromide is graphed in Figure II-3-16.

Minimum and Maximum Data for Bromide (mg/l)						
	SJSC-C	SJSC-D	SCRWA-B	SCRWA-C	SCRWA-D	DI-C
Influent	ND 0.50 - ND 0.50		ND 0.50 - ND 0.50			ND 0.50 - ND 0.50
Effluent	ND 0.50 - ND 0.50	ND 0.50 - ND 0.50	ND 0.50 - ND 0.50	ND 0.50 - ND 0.50	ND 0.50 - ND 0.50	ND 0.50 - ND 0.50

Cyanide

Cyanide was below detection in the influent and effluent samples. The laboratory reporting limit is 5 µg/L. Data for cyanide is graphed in Figure II-3-17.

Minimum and Maximum Data for Total Cyanide (µg/L)						
	SJSC-C	SJSC-D	SCRWA-B	SCRWA-C	SCRWA-D	DI-C
Influent	ND 5.0 - ND 5.0		ND 5.0 - ND 5.0			ND 5.0 - ND 5.0
Effluent	ND 5.0 - ND 5.0	ND 5.0 - ND 5.0	ND 5.0 - ND 5.0	ND 5.0 - ND 5.0	ND 5.0 - ND 5.0	ND 5.0 - ND 5.0

Boron

Boron concentrations in influent and effluent samples were not significantly different, indicating that the soil cores had minimal effect on this constituent. Data for boron is graphed in Figure II-3-18. Boron in SJSC recycled water influent ranged from 440 to 480 µg/L and boron in the associated soil core effluents ranged from 430 to 440 µg/L. Boron in SCRWA recycled water samples ranged from 360 to 430 µg/L in the influent and 350 to 400 µg/L in the core effluent. In the control sample, boron was not detected in the influent distilled water. Boron was detected in the distilled water effluent, presumably as a result of soil leaching into the water. Boron in the distilled effluent water samples ranged from 16 to 66 µg/L.

Minimum and Maximum Data for Total Boron (µg/L)						
	SJSC-C	SJSC-D	SCRWA-B	SCRWA-C	SCRWA-D	DI-C
Influent	440 - 480		360 - 430			ND 10 - ND 10
Effluent	430 - 440	430 - 440	400 - 400	350 - 360	370 - 380	16 - 66

Potassium

Potassium concentrations exhibited significant removal between recycled water influent and core effluent samples. Data for potassium is graphed in Figure II-3-19. Potassium in SJSC recycled water samples ranged from 15 to 17 mg/L in the influent and 9.3 to 12 mg/L in the soil core effluent. Potassium in SCRWA recycled water samples ranged from 27 to 32 mg/L in the influent and 1.1 to 24 mg/L in the effluent. In the SCRWA soil samples, the semifine-grained soil core exhibited the most removal of potassium and the fine-grained soil core with gypsum exhibited the lowest potassium removal.

In the control soil cores using distilled water, potassium exhibited an increase in concentration in the effluent samples likely as a result of concentrations in soil leaching into the water. Potassium in the distilled water influent ranged from below detection to 0.29 mg/L and the potassium in the associated effluent ranged from 0.98 to 1.7 mg/L. The concentrations observed in the control samples were lower than the concentrations observed in the samples with recycled water. Detections in the distilled water samples do not affect the interpretation of the results.

Minimum and Maximum Data for Potassium (mg/l)						
	SJSC-C	SJSC-D	SCRWA-B	SCRWA-C	SCRWA-D	DI-C
Influent	15 - 17		27 - 32			ND 0.10 - 0.29
Effluent	11 - 11	9.3 - 12	1.1 - 1.1	9 - 13	24 - 24	0.98 - 1.7

Calcium

In the first sampling round for the soil cores irrigated with SCRWA water, calcium increased significantly in the core effluent concentrations. By the second round, the effluent concentrations from these cores had dropped to levels similar to the influent concentrations. Data for calcium is graphed in Figure II-3-20. The data suggest that soil cores initially leached calcium into the water and later reached equilibrium. This was not the case for SJSC samples. Calcium in SJSC core effluent samples exhibited little to no change from the influent.

In the first sampling round, SCRWA soil cores had calcium concentrations ranging from 46 to 54 mg/L in the influent water samples and an effluent concentration range of 62 to 110 mg/L. Calcium in the second round SCRWA core effluent ranged from 51 to 55 mg/L, which was more similar to the influent concentrations. In the SJSC samples, the calcium concentrations ranged from 50 to 54 mg/L in the influent and from 51 to 57 mg/L in the effluent, resulting in no significant change. In the control soil core, calcium was not detected in the influent distilled water, but was detected in the effluent samples of distilled water after migration through the cores. The presence of calcium in the distilled water effluent samples is presumably the result of the $CaCl_2$ additive that was needed to make the ionic charge of the distilled water similar to groundwater. The influent distilled water was sampled before the addition of the $CaCl_2$. Hence the distilled influent indicates no detection in calcium. The interpretation of the results accounts for the additive of $CaCl_2$ and the confidence in the interpretation is not weakened. Further discussion of the quality control can be found in Section 3.4.

Minimum and Maximum Data for Calcium (mg/l)

	SJSC-C	SJSC-D	SCRWA-B	SCRWA-C	SCRWA-D	DI-C
Influent	50 - 54		46 - 54			ND 0.10 - ND 0.10
Effluent	57 - 57	51 - 57	51 - 110	52 - 75	55 - 62	64 - 150

Magnesium

Magnesium exhibited a similar behavior to calcium. Concentrations of magnesium in the first sampling round exhibited an initial large increase in the core effluent concentration followed by an insignificant change in the effluent concentration on the second sampling round. Data for magnesium is graphed in Figure II-3-21. The data suggests that soil samples initially leached magnesium into the water, but by the second round, leaching of magnesium subsided and core effluent concentrations equilibrated to influent concentrations. This effect was more pronounced in the SCRWA soil cores than in the SJSC soil cores, although the influent concentrations were similar. This effect was not observed for SJSC-C as magnesium in SJSC-C effluent samples exhibited little to no change from influent concentrations. This is likely due to very low percentage of fine-grained material in the SJSC-C soil core, which resulted in high hydraulic conductivity and less opportunity for leaching.

Magnesium in SCRWA recycled water influent ranged from 27 to 32 mg/L. Magnesium in SCRWA recycled effluent water samples ranged from 34 to 71 mg/L in the first round and from 31 to 35 mg/L in the second round. Magnesium in SJSC recycled water influent ranged from 27 to 30 mg/L. For SJSC-D, the magnesium concentration in the core effluent was 41 mg/L in the first sampling round and 32 mg/L in the second sampling round. The effluent concentration for SJSC-C was consistently 26 mg/L throughout the bench test. In the control soil cores irrigated with distilled water, magnesium was not detected in the influent distilled water, but was detected in the effluent at concentrations ranging from 34 to 40 mg/L. Magnesium in the core effluent samples is interpreted to have been derived from the soil core.

Minimum and Maximum Data for Magnesium (mg/l)						
	SJSC-C	SJSC-D	SCRWA-B	SCRWA-C	SCRWA-D	DI-C
Influent	27 - 30		27 - 32			ND 0.10 - ND 0.10
Effluent	26 - 26	32 - 41	32 - 71	35 - 52	31 - 34	34 - 40

Sodium

With the exception of SCRWA-B and SCRWA-C, sodium concentrations exhibited little to no change between the influent and effluent recycled water samples. Data for sodium is graphed in Figure II-3-22. Sodium in SCRWA-B and SCRWA-C exhibited significant removal in the first round and little change in the second round. In the first round of sampling, sodium concentrations decreased from 140 mg/L to a core effluent concentration of 24 mg/L for SCRWA-B and 91 mg/L for SCRWA-C.

Sodium influent concentration in the SCRWA recycled water samples ranged from 140 to 160 mg/L. For SCRWA-B, the effluent sodium concentration was 24 mg/L in the first round and 140 in the second round. For SCRWA-C, the effluent sodium concentration was 91 mg/L in the first round and 140 mg/L in the second round. SCRWA-D exhibited little to no change with effluent concentrations of 140 mg/L in both rounds. Sodium concentrations in the SJSC core soil samples in the influent and effluent exhibited little change, consistently ranging from 120 to 140 mg/L. In the control sample, sodium was not detected in the influent distilled water. In the distilled water effluent samples, sodium was detected as a result of soil leaching into the water. Sodium in the distilled effluent water samples ranged from 14 to 150 mg/L. Sodium in the effluent samples is interpreted to have been derived from the soil cores.

Minimum and Maximum Data for Sodium (mg/l)						
	SJSC-C	SJSC-D	SCRWA-B	SCRWA-C	SCRWA-D	DI-C
Influent	130 - 140		140 - 160			ND 0.50 - ND 0.50
Effluent	130 - 140	120 - 130	24 - 140	91 - 140	140 - 140	14 - 150

Sodium Adsorption Ratio

The sodium adsorption ratio (SAR) describes the concentration of sodium relative to calcium and magnesium. A high level of SAR in the influent has the potential to cause clay expansion and reduce hydraulic conductivity. A decrease of SAR in the effluent suggests that sodium ions are replacing calcium and magnesium ions in the inter-particle clay surfaces, which causes clay expansion. A further background discussion of SAR may be found in Section 3.1 of Volume I of this report. SAR in the recycled water influents and soil core effluents are calculated and shown in Table II-3-12. In the soil cores irrigated with SCRWA recycled water, SAR decreased in all of the effluent samples. The SJSC recycled water influent had slightly lower SAR values, and the SJSC soil cores did not significantly affect the SAR values in the infiltrating water.

Soil aquifer plugging by clay expansion is most affected by soil with high clay content. Fine-grained soil cores including SJSC-A and SCRWA-A, which both contained smectite in the clay mineralogy in high abundance, may potentially have undergone clay expansion, although since neither of these cores yielded sufficient water for SAR analysis, this cannot be quantitatively evaluated. Soil cores SJSC-D and SCRWA-D, which also have high clay content but were treated with gypsum, did not significantly change the SAR value of the water. The other recycled water soil cores, including SJSC-C, SCRWA-B, and SCRWA-C, contained a low level of clay content which made these cores less susceptible to soil aquifer plugging. Clay content was 11 percent in SCRWA-B and approximately zero percent in SCRWA-C. In SJSC-C the silt and clay content was 8.2 percent. The influent SAR could not be evaluated in the DI source, as sodium, calcium and magnesium were not detected.

3.3.2.3. Nutrients

Phosphate, Total as P.

Phosphate exhibited significant decreases between influent and effluent samples. Data for phosphate is graphed in Figure II-3-23. In the first and second round of sampling, phosphate in SJSC recycled water samples ranged from 0.44 to 0.54 mg/L as P in the influent and ranged from 0.053 to 0.28 mg/L as P in the core effluent. The first and second round of sampling for the SCRWA samples produced phosphate in the recycled water that ranged from 3.9 to 4.6 mg/L as P in the influent and from below detection to 2.9 mg/L as P in the core effluent. SCRWA-D is an exception that exhibited a concentration of 18 mg/L as P in the second round in the effluent.

In the control soil cores, phosphate was not detected in the influent distilled water, but concentrations were detected in the effluent, presumably as a result of leaching from soil into the water. Phosphate in the effluent from the control soil cores ranged from 0.42 to 0.48 mg/L as P.

Minimum and Maximum Data for Phosphate, Total as P (mg/l)						
	SJSC-C	SJSC-D	SCRWA-B	SCRWA-C	SCRWA-D	DI-C
Influent	0.44 - 0.54		3.9 - 4.6			ND 0.050 - ND 0.050
Effluent	0.26 - 0.27	0.053 - 0.28	ND 0.050 - 0.32	0.46 - 2.3	2.9 - 18	0.42 - 0.48

Nitrate and Nitrite

Data for nitrate and nitrite is graphed in Figures II-3-24 and II-3-25 respectively. Nitrate concentrations decreased across most of the soil cores irrigated with recycled water. In some soil cores, nitrite concentrations increased from the initial influent concentrations. The SCRWA-C and SCRWA-D soil cores were exceptions. SCRWA-C observed little changes in nitrate or nitrite in influent and effluent concentrations in the first round, and SCRWA-D observed no significant change in the nitrite concentrations between the influent and effluent in the first round. Decreases in nitrate can occur as a result of transformation into nitrite and/or sorption to the soil. Given the limitations of the bench test, the individual contribution of each of these mechanisms cannot be determined. Flags that were encountered in the nitrite and nitrate results in the pilot study include the “O-04” and “O-09” flags. A discussion of these flag is found in Section 3.4. Although there is some reduced confidence in the qualified data, the data is still appropriately useful for comparative purposes and is therefore used for evaluation in this study.

Nitrate concentrations for the first and second round of sampling in the SJSC recycled water samples ranged from 7.6 to 9.6 mg/L as Nitrogen (N) in the influent and from below detection to 7.5 mg/L as N in the core effluent (SJSC-C and SJSC-D). Nitrate concentrations in the first and second round of sampling in the SCRWA recycled water influent samples were consistently 3.4 mg/L as N. Nitrate concentrations in the SCRWA core effluent samples ranged from below detection to 3.1 mg/L as N. Based on the first round of sampling, the SCRWA-C soil core observed no significant changes in nitrate concentrations between the influent and effluent samples.

Minimum and Maximum Data for Nitrate as N (mg/L)						
	SJSC-C	SJSC-D	SCRWA-B	SCRWA-C	SCRWA-D	DI-C
Influent	7.5 – 9.6 (O-09)		3.4 – 3.4			ND 0.11 - ND 0.11
Effluent	7.4 (O-09)	ND 0.11 (O-09)	2.4 (O-09) – 2.7 (O-04)	3.1 (O-09)	ND 0.11 (O-09)	ND 0.11 (O-09)

Results of the nitrite concentrations are varied. Qualifiers in the data may explain some of the variations observed. Nitrite concentrations in the SJSC recycled water samples ranged from below detection to 1.7 mg/L as N in the influent and from 0.18 to 3.4 mg/L as N in the core effluent. Nitrite concentrations in the SCRWA recycled water influent samples were not detected. Nitrite concentration in the SCRWA-B core effluent sample was 0.23 mg/L as N in the first round and below detection in the second. In the first round, there were no detection for nitrite in the core effluent samples for SCRWA-C and SCRWA-D.

In the control soil cores irrigated with distilled water, nitrate and nitrite were not detected in any of the influent or effluent samples.

Minimum and Maximum Data for Nitrite as N (mg/L)						
	SJSC-C	SJSC-D	SCRWA-B	SCRWA-C	SCRWA-D	DI-C
Influent	ND 0.15 (O-09) – 1.7		ND 0.15 - ND 0.15			ND 0.15 - ND 0.15
Effluent	0.18 (O-09)	3.4 (O-09)	ND 0.15 (O-04) – 0.23 (O-09)	ND 0.15 (O-09)	ND 0.15 (O-09)	ND 0.15 (O-09)

3.3.2.4. *Anthropogenic Compounds*

Trihalomethanes (THMs)

In general, THM concentrations (bromodichloromethane, bromoform, chloroform, and dibromochloromethane) in the core effluents were significantly less than concentrations in the influent. Data for THMs is graphed in Figures II-3-26 to II-3-29. Reductions in THM concentrations were observed in the soil cores irrigated with SCRWA recycled water. Of the soil cores irrigated with SCRWA recycled water, semifine-grained soil and fine-grained soil with gypsum resulted in more reduced concentrations than the coarse grain soil core. Bromoform was consistently not detected in any of the SCRWA influent or effluent samples.

THMs in SJSC recycled water influent samples are highly varied. In general, THM influent concentrations in the first round were much higher than the influent concentrations in the second round. Effluent samples exhibited decreases in the first round of sampling and increases in the second round of sampling. However, the effluent concentrations from the SJSC soil cores remained relatively constant while the influent source sample concentrations decreased significantly in the second round of sampling. This observation suggests that the effluent water collected for the second round may have originated from the first round influent sample, delayed by the residence time in the soil core. Another possibility is that the elevated THM concentrations in the initial influent sorbed onto the soil, and later desorbed when it came into contact with the second round influent with lower concentrations.

Some THMs were found to be variable in the duplicate sample. In the SJSC second round influent sample, bromodichloromethane, chloroform, and dibromochloromethane concentrations were found to be significantly different (40 to 47 % difference) compared to the duplicate sample. The greatest numerical difference between the primary sample and the field duplicate was 1.1 µg/L for bromodichloromethane, 1.7 µg/L for chloroform, and 0.34 µg/L for dibromochloromethane. Hence, data comparisons (between influent and effluent data) cannot be confidently made for THMs where the difference is equal to or less than the given discrepancy (of primary sample and field duplicate) for that THM. Interpretations of comparisons of THMs with differences (between influent and effluent data) above the respective discrepancy can be made without reduction in the confidence.

In the control soil cores, THMs were not observed in any of the influent distilled water. THMs were not detected in the effluent samples except for chloroform. Chloroform was detected in the effluent samples ranging from 0.77 to 0.84 µg/L, possibly from cross contamination or from laboratory equipment (chloroform is a common constituent in tap water). Leaching of chloroform from the soil core was not expected. Confidence is reduced in data at or below 0.84 µg/L, however the chloroform concentrations in all other samples were above this value, therefore these low concentrations do not affect the interpretation of the data.

Minimum and Maximum Data for Bromodichloromethane (µg/L)						
	SJSC-C	SJSC-D	SCRWA-B	SCRWA-C	SCRWA-D	DI-C
Influent	1.4 - 16		5.7 - 12			ND 0.50 - ND 0.50
Effluent	4.8 - 5.2	2.3 - 3.5	2.1 - 3.1	4.9 - 5	1.6 - 3.1	ND 0.50 - ND 0.50

Minimum and Maximum Data for Bromoform (µg/L)						
	SJSC-C	SJSC-D	SCRWA-B	SCRWA-C	SCRWA-D	DI-C
Influent	ND 0.50 - 1.3		ND 0.50 - ND 0.50			ND 0.50 - ND 0.50
Effluent	0.5 - 0.61	ND 0.50 - ND 0.50	ND 0.50 - ND 0.50	ND 0.50 - ND 0.50	ND 0.50 - ND 0.50	ND 0.50 - ND 0.50

Minimum and Maximum Data for Chloroform (µg/L)						
	SJSC-C	SJSC-D	SCRWA-B	SCRWA-C	SCRWA-D	DI-C
Influent	1.9 - 13		21 - 40			ND 0.50 - ND 0.50
Effluent	6.6 - 6.7	2.8 - 4.2	9.1 - 16	18 - 20	6 - 14	0.77 - 0.84

Minimum and Maximum Data for Dibromochloromethane (µg/L)						
	SJSC-C	SJSC-D	SCRWA-B	SCRWA-C	SCRWA-D	DI-C
Influent	ND 0.50 - 7.8		1.2 - 2.6			ND 0.50 - ND 0.50
Effluent	2.5 - 2.9	1.3 - 1.9	ND 0.50 - ND 0.50	0.94 - 0.99	ND 0.50 - 0.59	ND 0.50 - ND 0.50

Haloacetic Acids (HAA6)

Effluent concentrations of HAA6, which include bromochloroacetic acid (BCAA), dibromoacetic acid (DBAA), dichloroacetic acid (DCAA), monobromoacetic acid (MBAA), monochloroacetic acid (MCAA), and trichloroacetic acid (TCAA), were mixed in results exhibiting increases and decreases for the core irrigated with SJSC recycled water samples. HAA6 were not detected in any of the influent or effluent samples for cores irrigated with SCRWA recycled water or distilled water. Data for haloacetic acids is graphed in Figures II-3-30 to II-3-36. In the tabulated analytical results, total HAA5 were reported which do not include BCAA.

In the SJSC recycled water samples, the individual influent concentrations of HAA6 varied significantly between the first round and second round of sampling. In the first round sampling, individual HAA6 were detected in the influent including BCAA, DBAA, DCAA, and TCAA. The data indicate variability in the influent concentrations with low and high concentrations found in BCAA, TCAA, and DBAA. Individual influent concentrations of HAA6 ranged up to 15 µg/L as observed for DCAA. Effluent concentrations of individual HAA6 remained constant between the first and second rounds for most cases. Of the individual HAA6, BCAA, DBAA, and DCAA demonstrated some attenuation through the soil cores, and TCAA demonstrated no attenuation at all. Overall, attenuation of HAA6 was not strongly observed in the data.

Minimum and Maximum Data for Bromochloroacetic acid (BCAA) (µg/L)						
	SJSC-C	SJSC-D	SCRWA-B	SCRWA-C	SCRWA-D	DI-C
Influent	ND 1.0 - 10		ND 1.0 - ND 1.0			ND 1.0 - ND 1.0
Effluent	4.8 - 6.3	ND 1.0 - 5.1	ND 1.0 - ND 1.0	ND 1.0 - ND 1.0	ND 1.0 - ND 1.0	ND 1.0 - ND 1.0

Minimum and Maximum Data for Dibromoacetic acid (DBAA) (µg/L)						
	SJSC-C	SJSC-D	SCRWA-B	SCRWA-C	SCRWA-D	DI-C
Influent	ND 1.0 - 3.4		ND 1.0 - ND 1.0			ND 1.0 - ND 1.0
Effluent	1.8 - 2.7	ND 1.0 - 1.9	ND 1.0 - ND 1.0	ND 1.0 - ND 1.0	ND 1.0 - ND 1.0	ND 1.0 - ND 1.0

Minimum and Maximum Data for Dichloroacetic acid (DCAA) (µg/L)

	SJSC-C	SJSC-D	SCRWA-B	SCRWA-C	SCRWA-D	DI-C
Influent	1.2 - 15		ND 1.0 - ND 1.0			ND 1.0 - ND 1.0
Effluent	6.4 - 7	2 - 9.6	ND 1.0 - ND 1.0	ND 1.0 - ND 1.0	ND 1.0 - ND 1.0	ND 1.0 - ND 1.0

Minimum and Maximum Data for Monobromoacetic acid (MBAA) (µg/L)

	SJSC-C	SJSC-D	SCRWA-B	SCRWA-C	SCRWA-D	DI-C
Influent	ND 1.0 - ND 1.0		ND 1.0 - ND 1.0			ND 1.0 - ND 1.0
Effluent	ND 1.0 - ND 1.0	ND 1.0 - ND 1.0	ND 1.0 - ND 1.0	ND 1.0 - ND 1.0	ND 1.0 - ND 1.0	ND 1.0 - ND 1.0

Minimum and Maximum Data for Monochloroacetic acid (MCAA) (µg/L)

	SJSC-C	SJSC-D	SCRWA-B	SCRWA-C	SCRWA-D	DI-C
Influent	ND 2.0 - ND 2.0		ND 2.0 - ND 2.0			ND 2.0 - ND 2.0
Effluent	ND 2.0 - ND 2.0	ND 2.0 - ND 2.0	ND 2.0 - ND 2.0	ND 2.0 - ND 2.0	ND 2.0 - ND 2.0	ND 2.0 - ND 2.0

Minimum and Maximum Data for Trichloroacetic acid (TCAA) (µg/L)

	SJSC-C	SJSC-D	SCRWA-B	SCRWA-C	SCRWA-D	DI-C
Influent	ND 1.0 - 11		ND 1.0 - ND 1.0			ND 1.0 - ND 1.0
Effluent	12 - 12	12 - 14	ND 1.0 - ND 1.0	ND 1.0 - ND 1.0	ND 1.0 - ND 1.0	ND 1.0 - ND 1.0

N-Nitrosodimethylamine (NDMA)

NDMA concentrations in recycled water samples exhibited increases and decreases in the effluent samples. Data for NDMA is graphed in Figure II-3-37. In the SJSC recycled water samples, the influent concentrations of NDMA varied significantly ranging from 112 to 375 ng/L respectively. The effluent concentration of NDMA also varied highly, ranging from below detection to 327 ng/L. The presence of NDMA in the effluent samples at concentrations similar in magnitude to the influent concentrations suggests that there is limited, if any, attenuation of NDMA within the SJSC soil cores.

In the distilled water control sample, NDMA was observed ranging from 4.0 to 8.7 ng/L in the influent and from 7.8 to 8.6 ng/L in the effluent. It is suspected that detections of NDMA originated from the distilled water source and are not a result of sampling or handling procedure. In both rounds, trace amounts of NDMA were detected in the influent which supports distilled water as the origin of the

NDMA. Commercial distilled water was used for this test, which may not be as pure as laboratory-grade blank water. Given this information, it is unlikely that the NDMA analysis is affected in the other soil core samples that use recycled water as an influent source.

In the SCRWA recycled water samples, variability in the influent concentrations in the first and second round samples was low ranging from 4.0 to 4.1 ng/L. The variability in the SCRWA core effluent samples was high, ranging from below detection to 7.3 ng/L. NDMA concentrations in the SCRWA influent are consistent with previously observed concentrations as reported in Volume I of this report.

Minimum and Maximum Data for N-Nitroso dimethylamine (NDMA) (ng/L)						
	SJSC-C	SJSC-D	SCRWA-B	SCRWA-C	SCRWA-D	DI-C
Influent	112 - 375		4 - 4.1			4 - 8.7
Effluent	ND 2 - 327	139 - 211	2.5 - 4.3	6 - 7.3	ND 2 - 5.4	7.8 - 8.6

Terbuthylazine

Terbuthylazine was below detection in the influent and effluent samples. The laboratory reporting limit is 0.1 µg/L. Data for terbuthylazine is graphed in Figure II-3-38.

Flags that were encountered in the terbuthylazine results in the bench test include the “Q5” flag. A discussion of the “Q5” flag is found in Section 3.4. Duplicate data indicate that the “Q5” flag did not significantly lower the quality of the data.

Minimum and Maximum Data for Terbuthylazine (µg/L)						
	SJSC-C	SJSC-D	SCRWA-B	SCRWA-C	SCRWA-D	DI-C
Influent	ND 0.1 - ND 0.1		ND 0.1 - ND 0.1			ND 0.1 - ND 0.1
Effluent	ND 0.1 - ND 0.1	ND 0.1 - ND 0.1	ND 0.1 - ND 0.1	ND 0.1 - ND 0.1	ND 0.1 - ND 0.1	ND 0.1 - ND 0.1

Volatile Organic Compounds (VOCs)

VOCs (excluding THMs which are discussed above) were generally not detected in the influent or effluent samples. Figures were not prepared for VOCs, however, summary tables of detected VOCs in the bench test are displayed in this section. 2-Butanone was detected in high amounts in some of the core effluent samples and in the DI influent samples. The presence of 2-Butanone in these samples did not originate from the two recycled water sources as there were no detections in the samples from these sources. It is unlikely that 2-Butanone originated from the soil cores because the chemical was found in multiple effluent samples from different soil cores collected throughout the study area. Since 2-Butanone is not a basin-wide contaminant, it does not appear that the soil is the source. The source of the 2-Butanone (also known as methyl ethyl ketone or MEK) is suspected to be one of the ingredients in the glue used to assemble the bench test apparatus, and it is not a constituent of concern for this study. No other parameters were observed in such high amounts, which suggests that this issue is localized only to 2-butanone and that results of other constituents are not impacted.

Toluene, methylene chloride, and chloromethane were also found infrequently in the core effluent samples at levels near the reporting limit. The absence of these constituents in the influent or effluent samples from the control core indicates that these detections are not related to quality control issues. Rather, the data suggest that these low concentrations originated from the soil cores, although they were not detected in all soil core effluents. Since these compounds are not considered potential constituents of recycled water, these detections do not affect the interpretation of the results.

Minimum and Maximum Data for 2-Butanone (µg/L)

	SJSC-C	SJSC-D	SCRWA-B	SCRWA-C	SCRWA-D	DI-C
Influent	ND 5.0 - ND 5.0		ND 5.0 - ND 5.0			ND 5.0 - 16
Effluent	54 - 2200	14 - 62000	ND 5.0 - 5.2	9.6 - 7300	ND 5.0 - 180000	160 - 6400

Minimum and Maximum Data for Toluene (µg/L)

	SJSC-C	SJSC-D	SCRWA-B	SCRWA-C	SCRWA-D	DI-C
Influent	ND 0.50 - ND 0.50		ND 0.50 - ND 0.50			ND 0.50 - ND 0.50
Effluent	0.51 - 0.83	ND 0.50 - 0.96	ND 0.50 - ND 0.50	ND 0.50 - 0.5	ND 0.50 - 0.82	ND 0.50 - ND 0.50

Minimum and Maximum Data for Methylene chloride (µg/L)

	SJSC-C	SJSC-D	SCRWA-B	SCRWA-C	SCRWA-D	DI-C
Influent	ND 0.50 - ND 0.50		ND 0.50 - ND 0.50			ND 0.50 - ND 0.50
Effluent	ND 0.50 - ND 0.50	ND 0.50 - 0.6	ND 0.50 - ND 0.50	ND 0.50 - ND 0.50	ND 0.50 - 0.78	ND 0.50 - ND 0.50

Minimum and Maximum Data for Chloromethane (µg/L)						
	SJSC-C	SJSC-D	SCRWA-B	SCRWA-C	SCRWA-D	DI-C
Influent	ND 0.50 - ND 0.50		ND 0.50 - ND 0.50			ND 0.50 - ND 0.50
Effluent	ND 0.50 - ND 0.50	ND 0.50 - 0.61	ND 0.50 - ND 0.50	ND 0.50 - ND 0.50	ND 0.50 - 0.67	ND 0.50 - ND 0.50

Perfluorochemicals (PFCs)

The three PFCs monitored in this bench test were perfluorobutanoic acid (PFBA), perfluorooctanesulfonate (PFOS), and perfluorooctonoic acid (PFOA). PFCs were generally found at higher concentrations in the soil core effluent samples than in the influent recycled water samples, suggesting poor attenuation. Data for PFCs is graphed in Figures II-3-39 to II-3-41. PFBA and PFOS were not detected in any of the influent samples and were detected only in effluent samples of SJSC-C. The higher concentration of PFCs in the effluent may be the result of transformation from chemical precursors, which include various fluorinated alcohols and other fluorochemicals. Overall, attenuation was not well observed.

PFOA in SJSC recycled water samples ranged from below detection to 109 ng/L in the influent and from 73 to 325 ng/L in the core effluent. PFOA in SCRWA recycled water samples ranged from below detection to 39 ng/L in the influent and from 77 to 120 ng/L in the core effluent. For SJSC-C, PFBA was detected only in the effluent ranging from below detection to 940 ng/L and PFOS was detected only in the effluent ranging from 51 to 572 ng/L.

PFOA was found to be variable in duplicate samples. In the SJSC first and second round influent sample, PFOA was found to be significantly different from the respective duplicate samples (27 to 45%). The greatest numerical difference between the primary sample and the field duplicate was 29 ng/L for PFOA in the second round. Because the maximum variation was found to be 29 ng/L, data comparisons (between influent and effluent data) cannot be confidently made for PFOA where the difference is equal to or less than 29 ng/L. Interpretation of comparisons of PFOA with differences (between influent and effluent data) above the respective variation can be made without reduction in the confidence.

In the control sample, PFOA was the only detected parameter and was reported in the influent at 88 ng/L. PFOA was not detected in the effluent samples. Similar to NDMA, the appearance of PFOA in the influent is suspected to be of minor amounts that are in the DI source. Commercial distilled water was used for this test, which may not be as pure as laboratory-grade blank water. Given this information, it is unlikely that the PFC analysis is affected in the other soil core samples that use recycled water as an influent source. Cross contamination is not a likely cause since the concentration is too high relative to the other results. Analytical variability is not a likely cause since the observed changes in PFC concentrations are greater than the determined analytical variability of 29 ng/L.

Minimum and Maximum Data for Perfluorobutanoic acid (PFBA) (ng/L)						
	SJSC-C	SJSC-D	SCRWA-B	SCRWA-C	SCRWA-D	DI-C
Influent	ND 50 - ND 50		ND 50 - ND 50			ND 50
Effluent	ND 50 - 940	ND 50 - ND 50	ND 50 - ND 50	ND 50 - ND 50	ND 50 - ND 50	ND 50 - ND 50

Minimum and Maximum Data for Perfluorooctanesulfonate (PFOS) (ng/L)						
	SJSC-C	SJSC-D	SCRWA-B	SCRWA-C	SCRWA-D	DI-C
Influent	ND 50 - ND 50		ND 50 - ND 50			ND 50
Effluent	51 - 572	ND 50 - ND 50	ND 50 - ND 50	ND 50 - ND 50	ND 50 - ND 50	ND 50 - ND 50

Minimum and Maximum Data for Perfluorooctanoic acid (PFOA) (ng/L)						
	SJSC-C	SJSC-D	SCRWA-B	SCRWA-C	SCRWA-D	DI-C
Influent	ND 20 - 109		39 - 39			88
Effluent	80 - 325	73 - 120	77 - 82	80 - 108	99 - 120	ND 20 - ND 20

Nitrilotriacetic acid (NTA) and Ethylenediaminetetraacetic Acid (EDTA)

EDTA concentrations in recycled water samples were varied in results, exhibiting increases in the SJSC recycled water samples and decreases in some of the SCRWA recycled water samples. NTA was below detection in all influent and effluent samples. The laboratory reporting limit for NTA is 100 µg/L. Data for NTA and EDTA are graphed in Figures II-3-42 and II-3-43 respectively.

EDTA concentrations in SJSC recycled water samples were below detection in the influent and ranged from 100 to 174 µg/L in the effluent, exhibiting an increase in concentrations. However, EDTA was found to be variable in the duplicate SJSC influent sample. The second round influent sample was below detection (laboratory reporting limit 100 µg/L), but the duplicate sample was 159 µg/L. Comparison of data may not be as strong for concentration differences that are 59 µg/L or less. EDTA in SCRWA recycled water samples ranged from 232 to 266 µg/L in the influent and from below detection to 242 µg/L in the effluent. Of the SCRWA soil samples, SCRWA-B exhibited the most removal of EDTA and SCRWA-D yielded no significant change in EDTA. Considering the variability in EDTA, attenuation appears to be limited.

In the distilled water control sample, EDTA was only detected in the second round influent sample at the reporting limit of 100 µg/L. This EDTA detection is within the range of potential analytical variability, but may also be attributed to the commercial distilled water source. The presence of EDTA in the distilled water source at this concentration does not significantly impact the findings for the other soil cores. NTA and EDTA were not detected in any of the control effluent samples.

Minimum and Maximum Data for EDTA (µg/L)						
	SJSC-C	SJSC-D	SCRWA-B	SCRWA-C	SCRWA-D	DI-C
Influent	ND 100 - 159		232 - 266			ND 100 - 100
Effluent	117 - 147	100 - 174	ND 100 - 121	ND 100 - 236	237 - 242	ND 100 - ND 100

Minimum and Maximum Data for NTA (µg/L)						
	SJSC-C	SJSC-D	SCRWA-B	SCRWA-C	SCRWA-D	DI-C
Influent	ND 100 - ND 100		ND 100 - ND 100			ND 100 - ND 100
Effluent	ND 100	ND 100 - ND 100	ND 100	ND 100	ND 100	ND 100

Surfactants

Surfactant concentrations in recycled water samples were varied in results exhibiting decreases in the first sampling round of the SJSC recycled water samples and increases in some of the SCRWA recycled water samples. Data for surfactants is graphed in Figure II-3-44. Surfactant SJSC influent concentrations were significantly varied between the first and second round of sampling.

Surfactants in SJSC recycled water influent sampling ranged from 0.21 mg/L in the first round to 0.11 mg/L in the second round. Surfactant SJSC effluent concentrations ranged from 0.090 to 0.12 mg/L. By comparing the influent to effluent samples, these concentrations decreased in the first round and remained relatively constant in the second round. Surfactant concentrations in the SCRWA recycled water influent ranged from below detection to 0.060 mg/L. The SCRWA-C and SCRWA-D soil cores exhibited a slight increase in surfactant concentrations, yielding concentrations ranging from 0.070 to 0.080 mg/L in the core effluents. SCRWA-B exhibited no change having effluent concentrations ranging from below detection to 0.060 mg/L. Surfactants were found to be variable in the SJSC duplicate influent sample. The second round effluent samples were below detection (laboratory reporting limit 0.05 mg/L) and 0.11 mg/L. Comparison of data may not be as strong for concentration differences that are 0.06 mg/L or less. Given the presence of surfactants in the effluent samples at concentrations similar in magnitude to the influent concentrations, attenuation of surfactants is interpreted to be limited.

In the distilled control soil cores, surfactants were not detected in the influent or effluent samples.

Minimum and Maximum Data for Surfactants (MBAS) (mg/L)						
	SJSC-C	SJSC-D	SCRWA-B	SCRWA-C	SCRWA-D	DI-C
Influent	ND 0.05 - 0.21		ND 0.05 - 0.06			ND 0.05 - ND 0.05
Effluent	0.1 - 0.12	0.09 - 0.1	ND 0.05 - 0.06	0.07 - 0.08	0.07 - 0.08	ND 0.05 - ND 0.05

Perchlorate

Perchlorate was below detection in all influent and effluent samples. The laboratory reporting limit is 4.0 µg/L. Data for perchlorate is graphed in Figure II-3-45.

Minimum and Maximum Data for Perchlorate (µg/L)						
	SJSC-C	SJSC-D	SCRWA-B	SCRWA-C	SCRWA-D	DI-C
Influent	ND 4.0 - ND 4.0		ND 4.0 - ND 4.0			ND 4.0 - ND 4.0
Effluent	ND 4.0 - ND 4.0	ND 4.0 - ND 4.0	ND 4.0 - ND 4.0	ND 4.0 - ND 4.0	ND 4.0 - ND 4.0	ND 4.0 - ND 4.0

Pathogens

Due to the potential for bacterial growth within the soil cores, there was difficulty in evaluating the effect of soil attenuation on these parameters in the bench test format. Although an additive could have been used to inhibit bacterial growth within the cores, it was not applied because of the unknown effect it may have had on the other constituents monitored in the bench test. Data for total coliforms, E. coli., and fecal coliforms are graphed in Figures II-3-46 to II-3-48. Both influent and effluent values of HPC and total coliforms appeared to be affected by bacterial growth, including the distilled water control. Growth in the distilled water control may be a result of bacterial contamination. Factors that can affect the growth of coliform and HPC bacteria include filtration, temperature, disinfectant type and residual, assimilable organic carbon level, corrosion control and pipe material selection (LeChevalier, 2003). In this case, exposure to the organic content in the soil likely contributed to bacterial growth. Results that are affected only included HPC and total coliforms. Bacterial growth may have contributed in reducing the final hydraulic conductivity in the soil cores, although the magnitude of this effect could not be measured.

Fecal coliforms and E. coli which indicate fecal matter were not observed in the influent or effluent water samples with the exception of SJSC-D, where one of the effluent samples observed a fecal coliform concentration of 4 MPN/100mL.

Flags that were encountered in these results in the pilot study include the “C” flag. A discussion of the “C” flag is found in Section 3.4. Duplicate data indicate that the “C” flag did not severely lower the quality of the data.

Minimum and Maximum Data for Heterotrophic Plate Count (HPC) (CFU/mL)						
	SJSC-C	SJSC-D	SCRWA-B	SCRWA-C	SCRWA-D	DI-C
Influent	2 - 68090		24295 - 33635			935 - 16495
Effluent	1779500 - Too High	ND 1 - Too High	56550 - Too High	1763500 - Too High	308000 - Too High	30200 - Too High

Minimum and Maximum Data for Fecal Coliform (MPN/100mL)						
	SJSC-C	SJSC-D	SCRWA-B	SCRWA-C	SCRWA-D	DI-C
Influent	ND 2 - ND 2		ND 2 - ND 2			ND 2 - ND 2
Effluent	ND 2 - ND 2	ND 2 - 4	ND 2 - ND 2	ND 2 - ND 2	ND 2 - ND 2	ND 2 - ND 2

Minimum and Maximum Data for Total Coliform (MPN/100mL)						
	SJSC-C	SJSC-D	SCRWA-B	SCRWA-C	SCRWA-D	DI-C
Influent	ND 2 - 9.0 (C)		ND 2 - ND 2			ND 2 - ND 2
Effluent	8 - 80	ND 2 - 21	ND 2 - ND 2	ND 2 - ND 2	2 - 7	ND 2 - 4

Minimum and Maximum Data for E. coli (MPN/100mL)						
	SJSC-C	SJSC-D	SCRWA-B	SCRWA-C	SCRWA-D	DI-C
Influent	ND 2 - ND 2		Absent - Absent			Absent - Absent
Effluent	Absent - Absent	Absent - Absent	Absent - Absent	Absent - Absent	Absent - Absent	Absent - Absent

3.4. Quality Control

3.4.1. Distilled Water Core Samples

Distilled water was used as the water source for the control samples. Recycled water constituents were not expected to be detected in the distilled water samples. It was determined that the commercial distilled water used for the bench test was not a laboratory-grade clean water source. The distilled source water was found to have low concentrations of NDMA, potassium, EDTA, 2-butanone, and PFOA. Of these constituents, NDMA was detected in the distilled water influent for both sample events. The distilled water source is suspected to contain NDMA and PFOA in minor amounts. HPC was also observed in the distilled water source, which is attributed to bacterial contamination. 2-butanone and EDTA were not suspected to originate from the distilled water source. The concentrations of 2-butanone are suspected to be a result of contamination from the bench test equipment. However, since 2-butanone was not observed in any of the recycled water influent samples, it is not considered a constituent of concern for this study. EDTA observed in the distilled water is suspected to be a result of analytical variability.

In the DI-C soil core, some constituents revealed increases in concentration after percolating through the soil core in both events. This can occur as a result of leaching or dissolving of constituents already present in the soil and/or from the bench test equipment. These constituents which were found in the effluent samples include magnesium, potassium, sodium, boron, sulfate, phosphate, 2-butanone, chloroform, alkalinity, DOC, and TOC. Increases in the bacterial counts such as Total Coliforms and HPC were likely due to bacterial growth in the soil core. The appearance of 2-butanone is suspected to originate from the glue used to assemble the bench test apparatus. Low concentrations of chloroform in the effluent from the DI-C soil core are suspected to be the result of contamination from the bench test equipment. Soil leaching of inorganic constituents (such as magnesium, potassium, sodium, boron, sulfate, phosphate, alkalinity) and organic carbon from the soil was expected.

Distilled water influent sampling occurred before a $CaCl_2$ additive was applied. The purpose of the $CaCl_2$ additive was to make the ionic charge of the distilled water similar to groundwater. Although it is not known what the true concentrations of calcium, chloride, and TDS were in the distilled water influent, the interpretation of the results are made given this fact, and the confidence in the interpretation is not weakened. No other constituents, other than calcium, chloride, and TDS are expected to be influenced by the additive. Hence the quality of the distilled water of other constituents is not affected.

3.4.2. Field Duplicate

Field duplicate samples were collected from the SJSC recycled water source on both sampling events. Results for both analyses are shown on Table II-3-5. Comparing the duplicate samples, EDTA, Surfactants, THMs , PFOA, HPC, and Total Coliforms were observed to be significantly variable (over 25% difference). The evaluations for these constituents are made in light of the analytical variability, as discussed in the sections above. Additional laboratory qualifiers were applied to some values, as described on Tables II-3-3 to II-3-11. None of these additional qualifiers significantly affect the interpretation of the results.

3.4.3. Ion Balance Check

Ion balances were calculated for the influent and effluent to check for electroneutrality. Cations considered were potassium, sodium, calcium, and magnesium. Anions that were considered included bicarbonate, chloride, nitrate, nitrite, and sulfate. The majority of the ion balances were acceptable, having a cation to anion ratio between 0.90 and 1.10. Three ion balances were out of this range. These were 1st event SCRWA influent, 1st event SCRWA-B effluent and 2nd event DI-C effluent. The observed unbalanced ions may be due to the staggered nature of the sampling. Due to the time required to collect enough sample volume for analysis, sampling events could not be executed for all analyses at once. The concentration of the ion may have changed during the time delay. Instantaneous sampling of all ion concentrations was not possible with the configuration of the bench test. Overall, ion balances help verify the accuracy of ion concentrations in these samples.

3.4.4. Flags

Below is a discussion of the different flags that appeared in the bench test analytical data and any implications for the qualified data. Data qualified with the following flags is still considered for evaluation in this study, but may have reduced confidence depending on the type of data qualification.

3.4.4.1. "C"

The "C" flag indicates that the sample was analyzed beyond the holding time.

This flag was applied to results for the biological constituents in the SJSC source sample and TDS at several locations. These analyses have relatively short hold times (24 hours for biological analyses and 7 days for TDS). For all biological constituents with the "C" flag, a duplicate sample was also taken. The results showed that the concentrations were still within the same order of magnitude. A duplicate TDS sample at SJSC source, which was analyzed within the hold time, showed that the results for the qualified samples were not significantly different. Overall, the "C" flag does not reduce confidence in data significantly.

3.4.4.2. "Q5"

The "Q5" flag indicates that the sample was received with inadequate chemical preservation, but was preserved by the laboratory. Although the chemical preservation was not sufficient while in transit, the laboratory was able to recover the samples by applying preservation once the samples were received.

This flag is observed only for the terbuthylazine analysis on the SJSC source in the first round and the associated duplicate. Terbuthylazine data in the second round sampling of SJSC source, which was not qualified, is consistent with the qualified data.

3.4.4.3. “O-04” and “O-09”

The “O-04” flag indicates the analysis was performed outside the EPA recommended holding time. The “O-09” flag indicates the sample was received with the EPA recommended holding time expired. In both cases, the analysis was performed outside the EPA holding time. The only difference in the flag is to indicate whether the hold time expired in transit to the laboratory or in the laboratory before the analysis was performed.

These flags were observed on the nitrate and nitrite analyses, which have a 48-hour hold time. After the hold time, nitrate can transform to nitrite and vice versa. Or they can transform into other nitrogen compounds. This effect can be more significant the longer the hold time is expired. Comparing primary sample and field duplicate data (where the primary sample was flagged O-04 and the field duplicate was not qualified), the nitrate and nitrite data were similar indicating that the O-04 flag did not significantly affect the data.

3.4.4.4. “M2”

The “M2” flag indicates the matrix spike recovery was low. The associated blank spike recovery was acceptable.

This flag is observed on endrin aldehyde, an analyte included in same analysis for terbuthylazine. Since the flag is associated only with the result for endrin aldehyde, which is not on the constituent list for evaluation, it does not present significant concern for this study.

3.4.4.5. “L3”

The “L3” flag indicates associated blank spike recovery was above method acceptance limits. A blank spike identifies the performance of the preparation method on a clean matrix that is void of interferences.

This flag is observed on pentachlorophenol, an analyte included in same analysis for terbuthylazine. Since the flag is associated only with the result for pentachlorophenol, which is not on the constituent list for evaluation, it does not present significant concern for this study.

3.5. Conclusions

3.5.1. Soil Hydraulic Conductivity

Comparing the soil hydraulic conductivity data, recycled water effluent flow and time data when exposed to recycled water, shows an increase in two of the soil cores (SCRWA-B and SCRWA-C) and a decrease in one of the soil cores (SJSC-A). This does not include soil cores with gypsum which also affect hydraulic conductivity or distilled water soil cores which were not exposed to recycled water. Generally the results suggest that soil cores with a greater distribution in fine grained material tend to exhibit a reduced hydraulic conductivity when exposed to recycled water. In SJSC-B, SJSC-C, and SCRWA-A, it could not be determined whether exposure to recycled water had reduced the hydraulic conductivity. Only a potential maximum value for final hydraulic conductivity could be measured for SJSC-B and SCRWA-A, and the potential maximum is greater than the initial hydraulic conductivity for these soil cores. The initial hydraulic conductivity could not be measured in SJSC-C, due to the insufficient percentage of fine-grained material.

The clay mineralogy indicated that expansive clays (particularly smectite) were present in a majority of the soil samples which also yielded low hydraulic conductivities. Smectite was the most prevalent component of the clays in SCRWA-D, and the second most prevalent in SJSC-D. The addition of gypsum has a significant effect in increasing the hydraulic conductivity of recycled water through fine grained soils, particularly those with clay mineralogy conducive of clay swelling. This is evident as the fine grained soils cores without gypsum (SJSC-A and SCRWA-A) produced very little effluent water. The respective fine grained soils core with gypsum (SJSC-D and SCRWA-D) produced enough effluent water to complete the sampling objectives. A comparison of the initial hydraulic conductivity by ASTM D-5084 and the final hydraulic conductivity for soil cores SJSC-D and SCRWA-D showed increases in hydraulic conductivity of two and five orders of magnitude respectively. This difference is attributed to the application of gypsum.

For the distilled core samples, it was expected that the initial and final hydraulic conductivity (exposed to distilled water with $CaCl_2$) would be similar. However, the data from the two methods yielded different results. The results indicate that DI-A and DI-B had higher initial hydraulic conductivity compared to the final hydraulic conductivity with exposure to distilled water. DI-C had a lower initial hydraulic conductivity compared to the final hydraulic conductivity with exposure to distilled water. The dissimilarity is attributed to the different methodologies in determining hydraulic conductivity. The final hydraulic conductivity was not determined using the ASTM method, but rather the effluent volume measurements from the bench test. The final conductivity, however, does provide a realistic indication of the observed rate of water percolation.

Bacterial growth was present in almost all the effluent samples as shown in the HPC results. Bacterial growth likely contributed to a lower final hydraulic conductivity with exposure to the recycled and distilled water sources, although this could not be verified.

3.5.2. Constituent Attenuation

The monitored constituents for the bench test can be grouped into categories based on their observed potential to migrate through the soil cores with minimal changes in concentration.

A number of constituents consistently exhibited significant (20% or more) attenuation across the majority of the soil columns. These constituents include potassium, phosphate, nitrate, THMs, and some haloacetic acids (BCAA, DBAA, and DCAA).

Some constituents exhibited consistent significant increases after percolation through soil. Constituents that have shown this behavior include nitrite and PFCs. Nitrite concentrations may be a result of leaching from the soil core, or transformation from the nitrate concentrations. PFC concentrations may be the result of PFC formation from precursors in the source water and the soil. PFCs may also have originated from the soil core; soil testing was not done to see if PFCs were already present in the soil.

Constituents that have exhibited initial large increases in the first round of sampling followed by no significant changes in the second round of sampling include DOC, TOC, calcium, and magnesium. The behavior of these constituents is suspected to be a result of an initial leaching from the soil cores, followed by equilibration with the infiltrating water.

Alkalinity, pH, TDS, DO, boron, chloride, sulfate and sodium exhibited no significant changes after percolation through soil. NDMA also does not appear to be affected by the transport through soil, although concentrations were variable in the influent and effluent. One of the haloacetic acids (TCAA) and EDTA did not show strong removal through the soil cores.

Constituents that have been inconclusive due to significant variation in the influent concentration or high potential for bacterial growth include surfactants, HPC, and coliforms. Minor decreases in surfactant concentrations were observed in the SJSC soil cores, and minor increases in the SCRWA soil cores.

Bromide, cyanide, terbuthylazine, NTA, E. Coli, and perchlorate were not detected in the influent or effluent samples. The reporting limit for bromide was 0.5 mg/L, for cyanide is 5 µg/L, for terbuthylazine is 0.1 µg/L, for NTA is 100 µg/L, and for perchlorate is 4 µg/L. VOCs other than THMs were generally not detected. VOCs that were detected were 2-butanone, toluene, methylene chloride, and chloromethane. Toluene, methylene chloride, and chloromethane were found infrequently in the core effluent samples and at levels near the reporting limit. 2-butanone was found in multiple core effluent samples and is regarded as an artifact from the bench test apparatus.

4. CONCLUSIONS

4.1. Summary of Constituent Risk to Groundwater

Based on the results obtained from the model and the bench test, the constituents of concern for recycled water are categorized into levels of risk: high, medium, and low, representing the relative risk to groundwater. The threat evaluated is relative to the risk of detection or increase in concentration of a constituent in the groundwater. High risk includes constituents that have 1) shown an increase rather than a removal from soil percolation or 2) have not shown short-term significant removal and are not typically present in groundwater (not naturally occurring). Medium risk is the category for constituents that 1) have been found to not be attenuated from percolation in the bench test or model (indicating potential long-term risk), and 2) have been shown in Volume I of this report to have higher concentrations in recycled water than in groundwater. The last category, low risk, is for constituents that 1) have exhibited significant attenuation in the bench test or model, or 2) have not exhibited significant attenuation but have been found in Volume I to be similar in concentration in recycled water and groundwater, or 3) have not been detected in any of the samples in the bench test. ORP, DO, alkalinity, and pH are general parameters which can influence the transport of other constituents. These constituents do not pose a threat to groundwater, and are not categorized in terms of risk. Given the close relationship between nitrate and nitrite, these constituents are linked for the purpose of this categorization.

Constituents	**High Risk**		**Medium Risk**	**Low Risk**		
	1) have shown an increase rather than removal from soil percolation in the bench test	2) have not shown short-term significant removal and are not typically present in groundwater	1) have not attenuated from percolation in the bench test or model, and 2) are typically higher concentrations in recycled water than in groundwater	1) have exhibited significant attenuation in the bench test or model	2) have not exhibited significant attenuation but are similar in concentration in reclaimed water and groundwater	3) have not been detected in any of the samples in the bench test
Nitrite/Nitrate	X					
PFCs	X					
EDTA		X				
HAA6		X				
NDMA		X				
Surfactants		X				
TDS			X			
Boron			X			
Chloride			X			
Sulfate			X			
Sodium			X			
TOC			X			
DOC			X			
THMs			X			
Phosphate				X		
Calcium					X	
Magnesium					X	
Potassium				X		
Bromide						X
Cyanide						X
Terbuthylazine						X
NTA						X
E. Coli						X
Perchlorate						X
other VOCs						X

4.2. Comparison Between Model and Bench Test

In the model, the attenuation of the four constituents evaluated was observed to be consistently present whereas the bench test monitored many more constituents and these results were more variable. In the bench test, some constituents did not show any attenuation or actually increased as they migrated through the soil cores. The bench test also had some significant variability in influent concentrations in recycled water.

The bench test was also less consistent in constituent removal over time. The second round sampling was expected to show removal as a longer term condition (the first round sampling being the initial condition). In the model, level of attenuation improved over time. In the bench test, a higher attenuation over time was not seen due to the high variation in results. However, because of the shorter soil length and shorter time frame evaluated, bench test results were expected to show less change when compared to the model short term results.

The model, which evaluated soil depths to 50 feet, showed significant attenuation of the selected constituents: (m-xylene, chloroform, NDMA, and bromodichloromethane). The bench test evaluated soil cores which varied from 1 foot in length (for fine-grained soil cores) to almost 4 feet in length (for coarse-grained core). If the bench test were over a larger soil depth, we expect the attenuation would be more apparent in the results. Generally, the overall attenuation is expected to be greater with more soil depth, however the majority of the attenuation is expected to occur in the first few feet and the incremental attenuation achieved is reduced with increased soil depth. Degradation and/or transformation of constituents, which were fate and transport processes not included in the model, may have influenced the results of the bench test.

The estimated percent removal of each constituent in the model can be compared to the results from the bench test at the same approximate time and depth. From Figure II-2-2A, chloroform is expected to be reduced to approximately 10% of the original concentration at a depth of 13 feet after 2 months. The bench test showed reductions of around 50%, as observed in Tables II-3-5 and II-3-8, indicating that the model may over-estimate attenuation of chloroform through sand. This comparison cannot be reliably made for the other model scenarios because the two-month curves are too severely sloped to obtain a reliable numeric value.

4.3. Recommendations for Pilot Study

The next phase of this study (to be discussed in Volume III of this report) includes a full-scale pilot study of recycled water application at a site in San Jose. Some of the findings from the modeling and bench test can be used to refine the design of that pilot study, so that it provides more useful data for evaluating the potential impact to groundwater.

Constituents of low risk, particularly constituents that were not detected in the bench test, may not need to be included in the full monitoring scheme. These constituents may be scaled back in the monitoring plan scope in the pilot study (e.g. monitoring only in the source recycled water until they are consistently detected).

Vadose zone wells should be installed at depths that are closer to the surface. The model has shown that attenuation behaves more in an exponential curve becoming asymptotic with respect to depth. Attenuation occurs most dramatically at the first ten feet of depth. The model also showed that significant changes in constituent transport can occur over time, and an extended monitoring program is recommended to evaluate potential long-term effects to groundwater.

REFERENCES

Alabama Department of Environmental Management, 2008, Alabama Risk-Based Corrective Action Guidance Manual, Table 3-3 Physical and Chemical Properties.

Irrigation Technical Assistance Program, 2006, Integrated Device Technology Inc Landscape Irrigation Evaluation Report, prepared by Aspeitia, M.

Karickoff, 1983, Organic Pollutant Sorption in Aquatic Systems, Journal of Hydraulic Engineering (ASCE) 110 (6), pp. 707-735

LeChevallier, M.W., 2003, Condition Favouring Coliform and HPC Bacterial Growth in Drinking-water and on Water Contact Surfaces, Heterotrophic Plate Counts and Drinking-water Safety, World Health Organization (WHO), pp. 177-197.

Millington. R.J., and J.M. Quirk, Permeability of Porous Solids, Trans. Faraday Soc., 57, 1200-1207, 1961.

Nelson, J., and Miller, D.J., 1997, Expansive Soils: Problems and Practice in Foundation and Pavement Engineering, Wiley Professional, pp. 12-13.

Santa Clara Valley Water District, 2004, Technical Documents, Technical Memoranda 1-6: Advanced Recycled Water Treatment (ARWT) Feasibility Project, prepared by Black & Veatch Corporation.

Schwarzenbach, R.P., P.M. Gschewend, and D.M Imboden, 2003, Appendix C, Physiochemical Properties of Organic Compounds, Environmental Organic Chemistry 2nd Ed., pp. 1198-1208

Šimunek, J., Van Genunchten, M.T., Šejna, M., 2005, The HYDRUS-1D Software Package for Simulating the One-Dimensional Movement of Water, Heat, and Multiple Constituents in Variably-Saturated Media version 3.0, Department of Environmental Sciences, University of California Riverside, Riverside, California.

Tan. K.H., 2000, Environmental Soil Science, Second Edition, pp 240.

FIGURES

FIGURE II-2-1A
CONCENTRATION CURVE: BROMODICHLOROMETHANE IN SAND
2 MONTH, 2 YEARS, 50 YEARS
HYDRUS 1D SOIL ATTENUATION MODEL
RECYCLED WATER STUDY

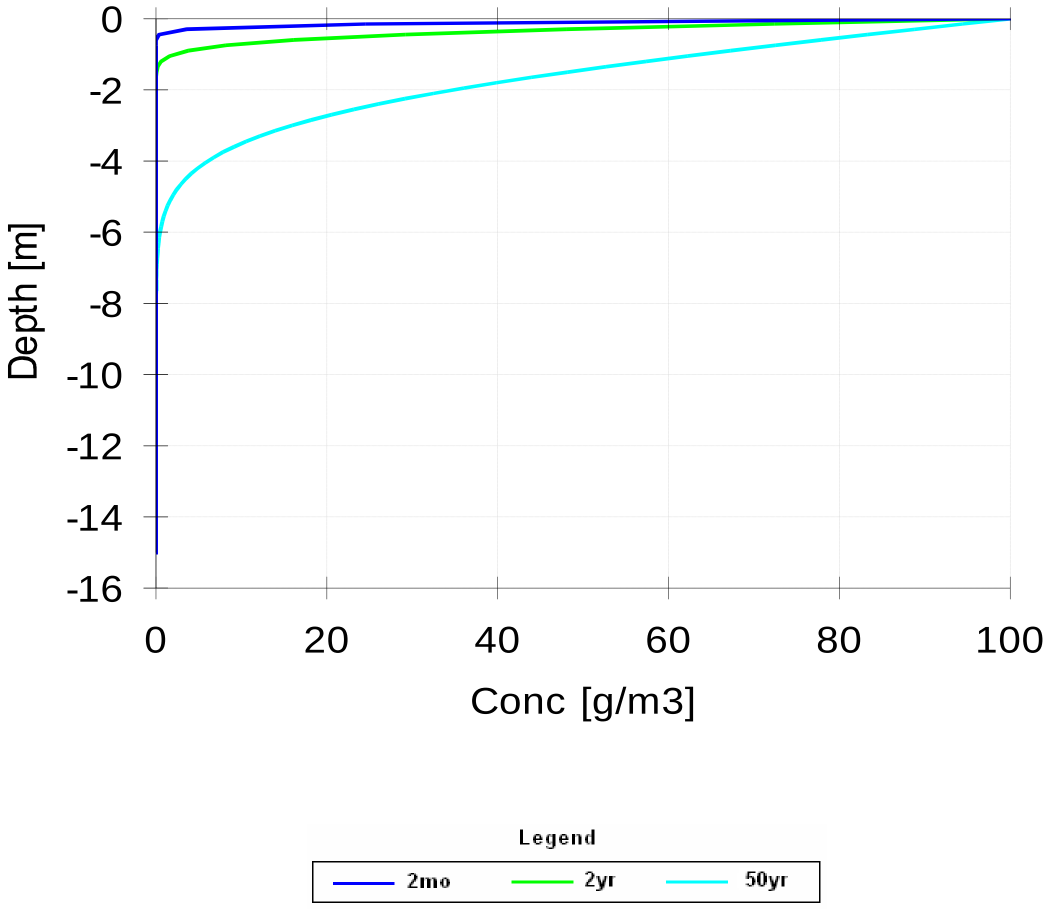

FIGURE II-2-1B
CONCENTRATION CURVE: BROMODICHLOROMETHANE IN SILT
2 MONTH, 2 YEARS, 50 YEARS
HYDRUS 1D SOIL ATTENUATION MODEL
RECYCLED WATER STUDY

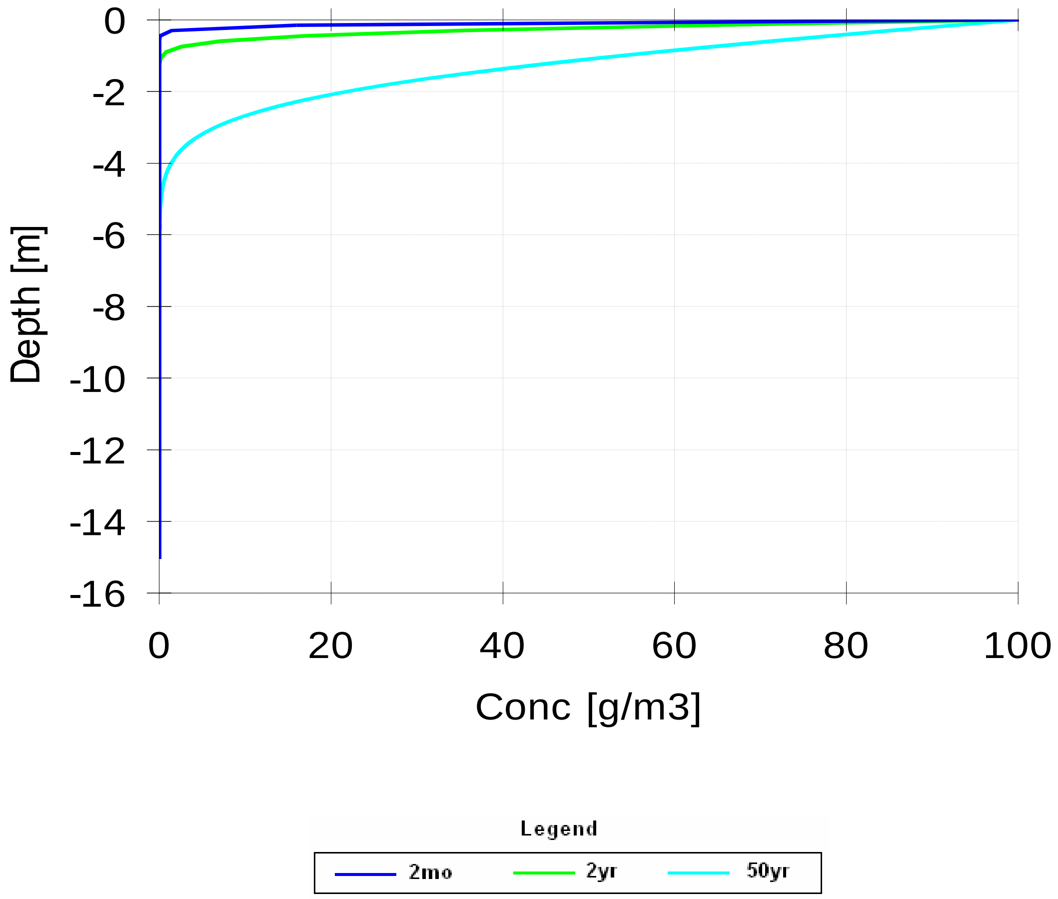

FIGURE II-2-1C
CONCENTRATION CURVE: BROMODICHLOROMETHANE IN CLAY
2 MONTH, 2 YEARS, 50 YEARS
HYDRUS 1D SOIL ATTENUATION MODEL
RECYCLED WATER STUDY

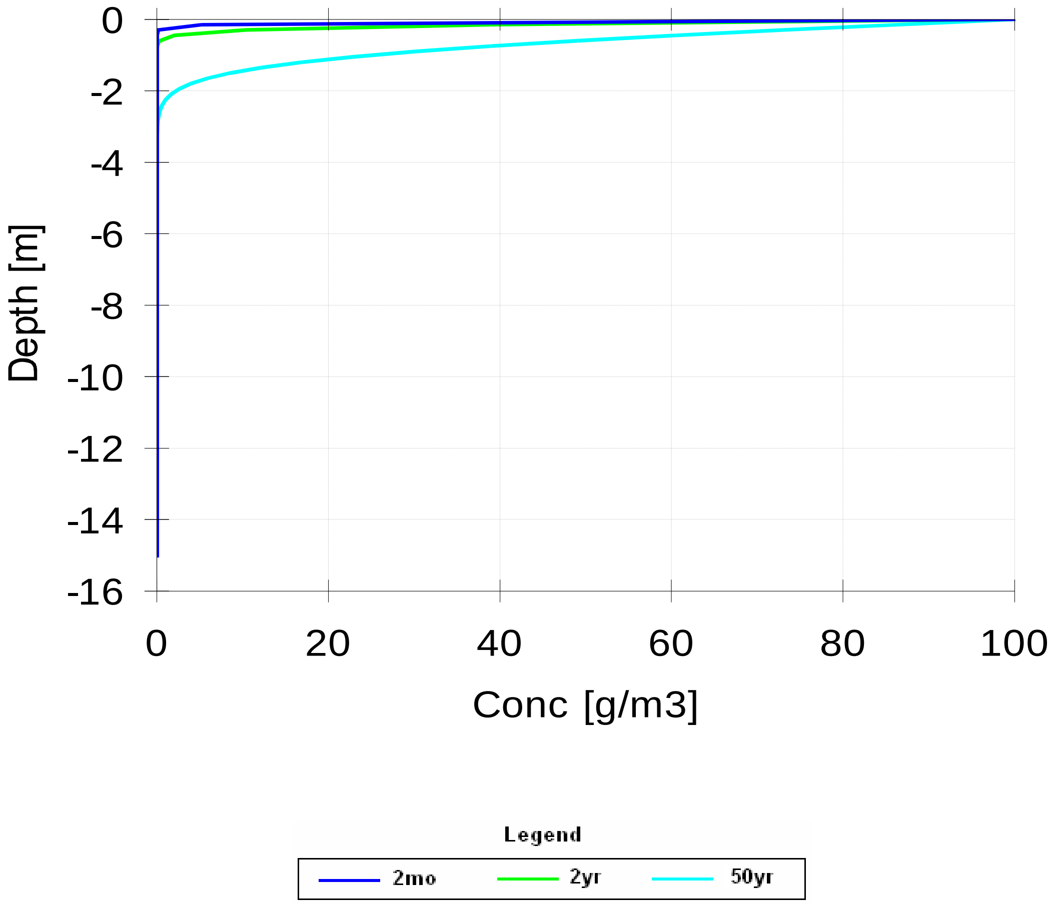

FIGURE II-2-2A
CONCENTRATION CURVE: CHLOROFORM IN SAND
2 MONTH, 2 YEARS, 50 YEARS
HYDRUS 1D SOIL ATTENUATION MODEL
RECYCLED WATER STUDY

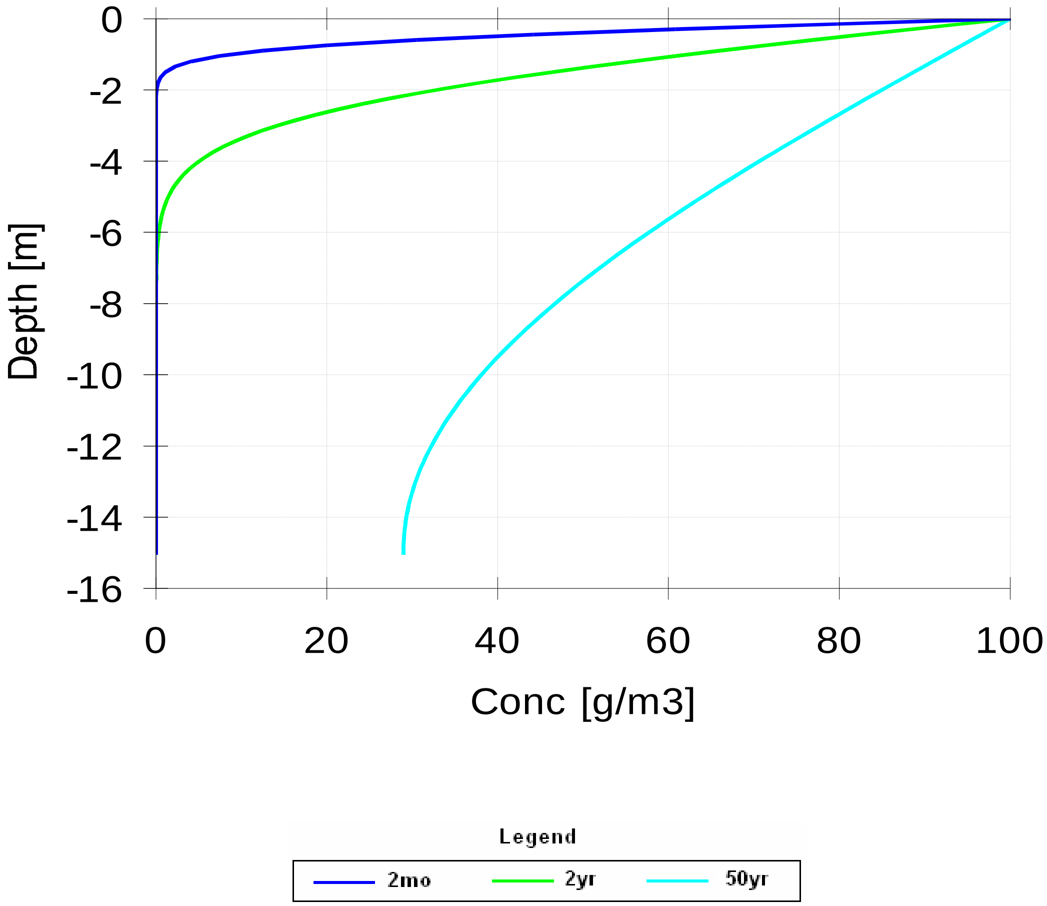

FIGURE II-2-2B
CONCENTRATION CURVE: CHLOROFORM IN SILT
2 MONTH, 2 YEARS, 50 YEARS
HYDRUS 1D SOIL ATTENUATION MODEL
RECYCLED WATER STUDY

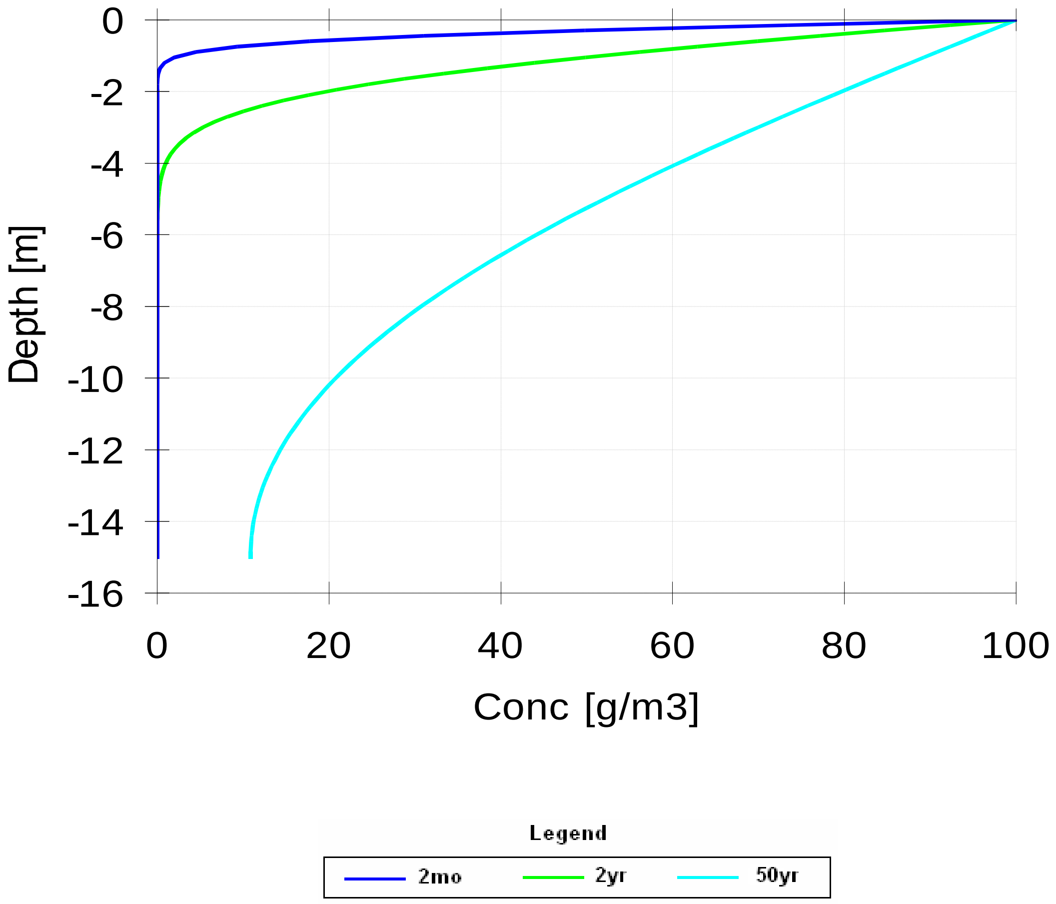

FIGURE II-2-2C
CONCENTRATION CURVE: CHLOROFORM IN CLAY
2 MONTH, 2 YEARS, 50 YEARS
HYDRUS 1D SOIL ATTENUATION MODEL
RECYCLED WATER STUDY

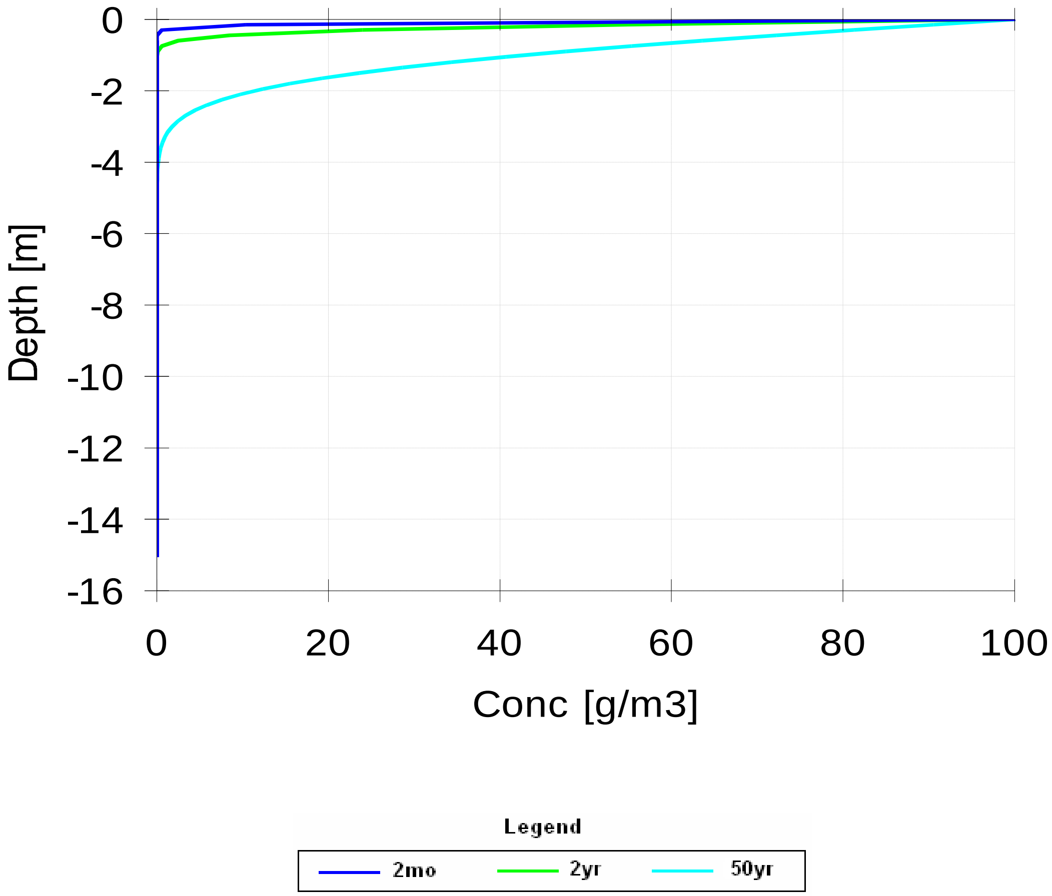

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FIGURE II-2-3A
CONCENTRATION CURVE: M-XYLENE IN SAND
2 MONTH, 2 YEARS, 50 YEARS
HYDRUS 1D SOIL ATTENUATION MODEL
RECYCLED WATER STUDY

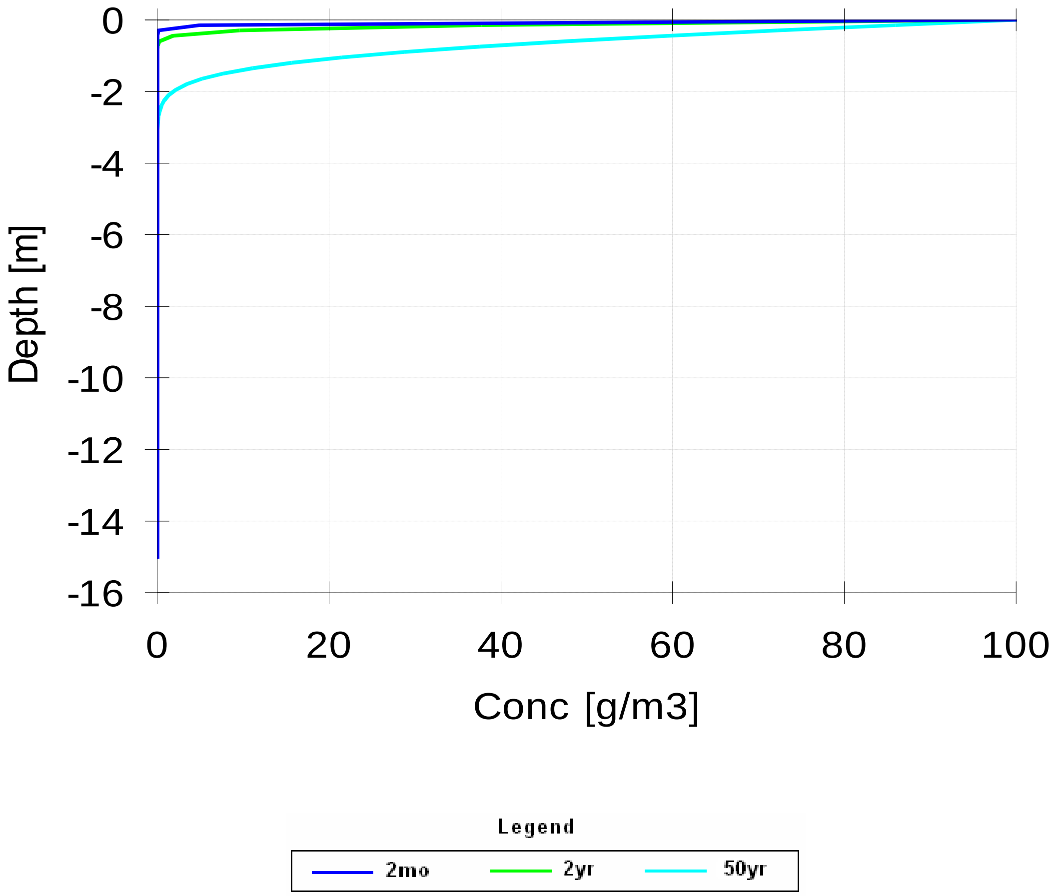


FIGURE II-2-3B
CONCENTRATION CURVE: M-XYLENE IN SILT
2 MONTH, 2 YEARS, 50 YEARS
HYDRUS 1D SOIL ATTENUATION MODEL
RECYCLED WATER STUDY

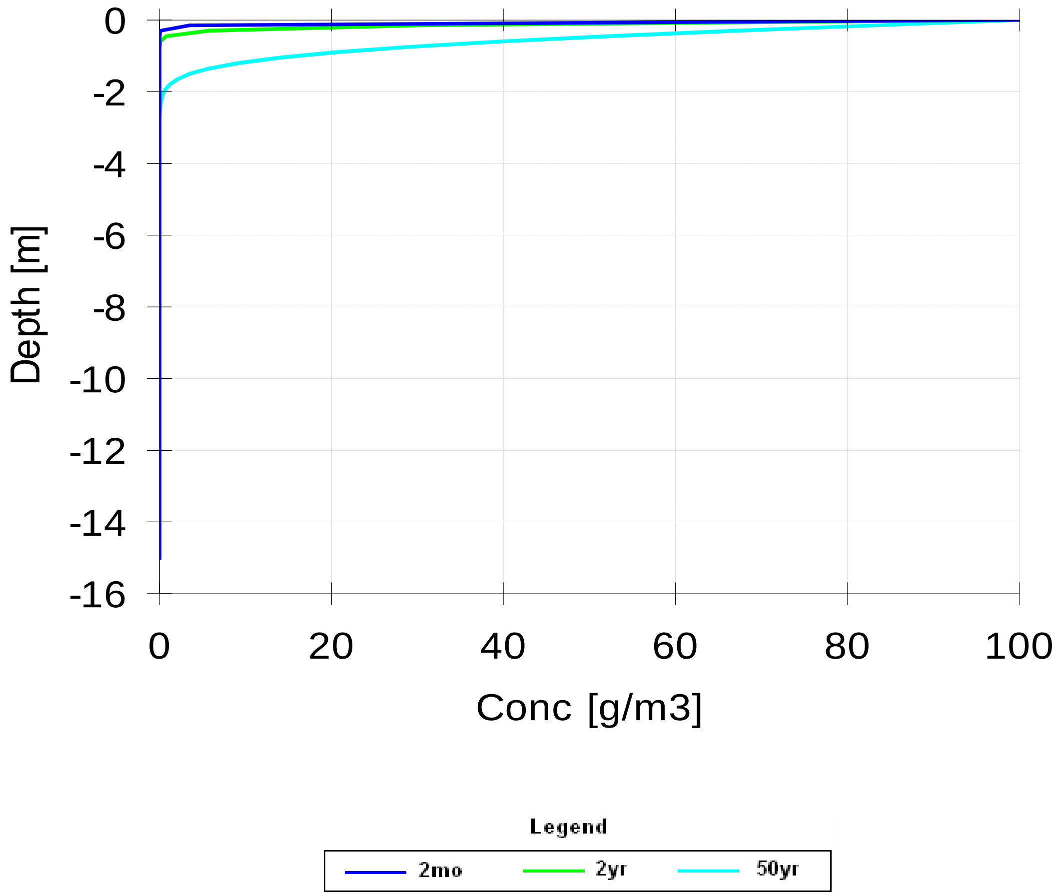


FIGURE II-2-3C
CONCENTRATION CURVE: M-XYLENE IN CLAY
2 MONTH, 2 YEARS, 50 YEARS
HYDRUS 1D SOIL ATTENUATION MODEL
RECYCLED WATER STUDY

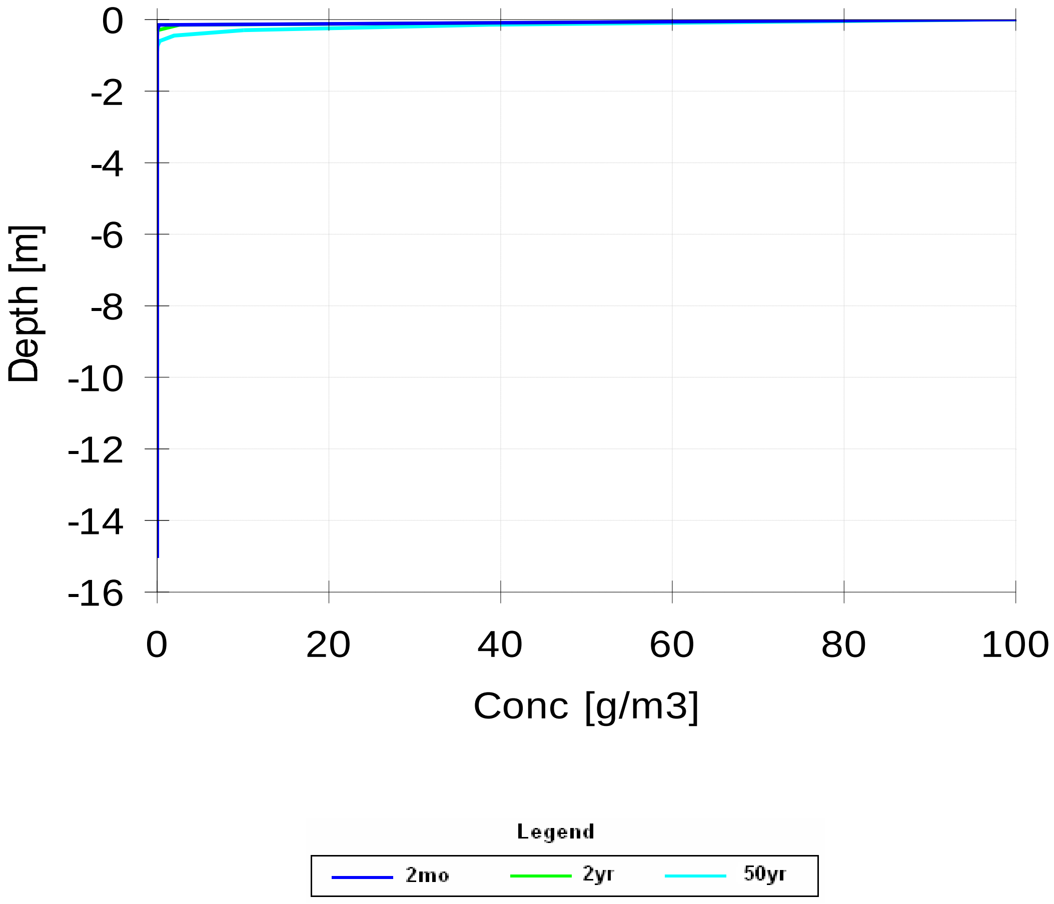


FIGURE II-2-4A
CONCENTRATION CURVE: NDMA IN SAND
2 MONTH, 2 YEARS, 50 YEARS
HYDRUS 1D SOIL ATTENUATION MODEL
RECYCLED WATER STUDY

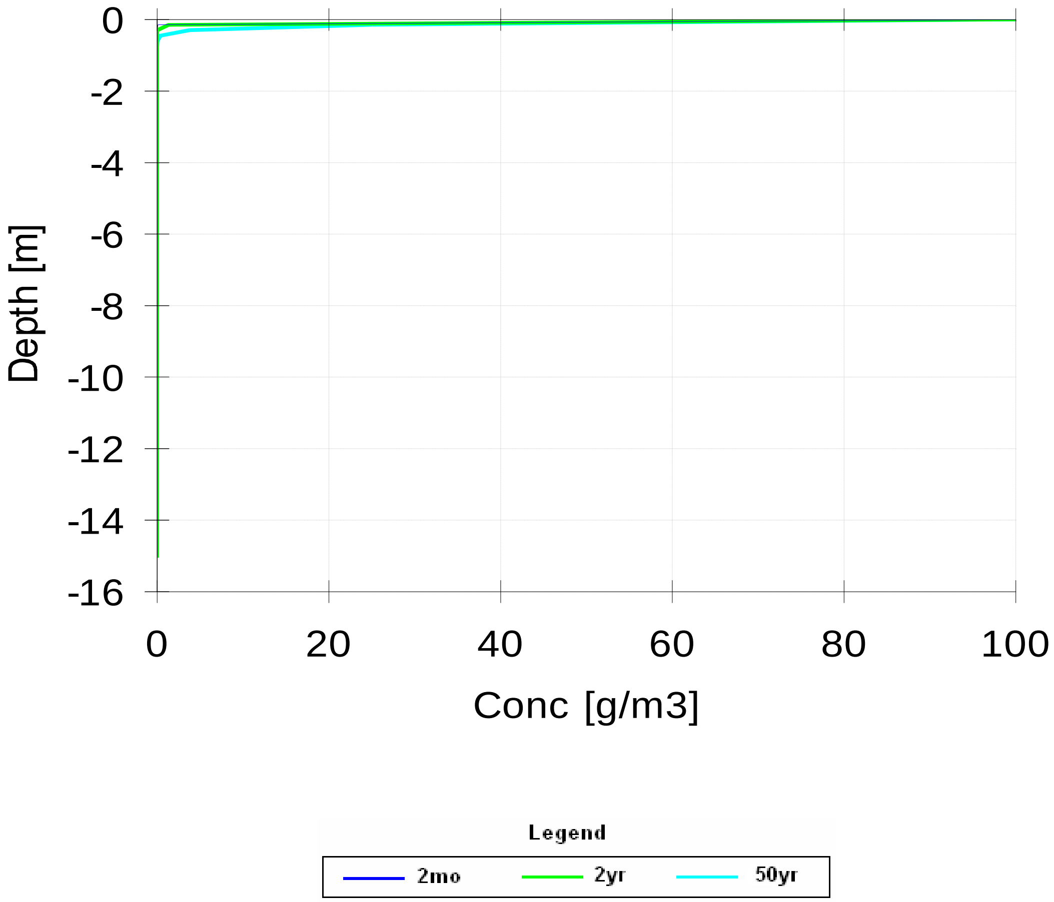


FIGURE II-2-4B
CONCENTRATION CURVE: NDMA IN SILT
2 MONTH, 2 YEARS, 50 YEARS
HYDRUS 1D SOIL ATTENUATION MODEL
RECYCLED WATER STUDY

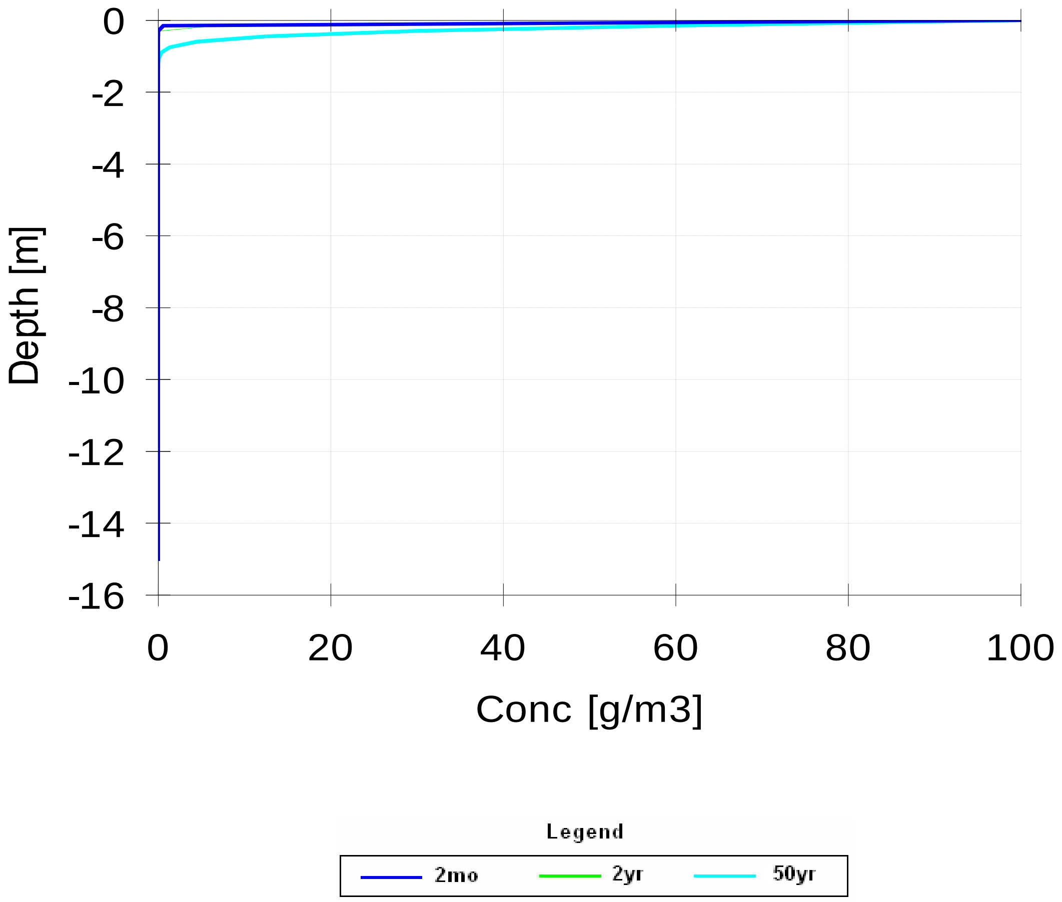


FIGURE II-2-4C
CONCENTRATION CURVE: NDMA IN CLAY
2 MONTH, 2 YEARS, 50 YEARS
HYDRUS 1D SOIL ATTENUATION MODEL
RECYCLED WATER STUDY

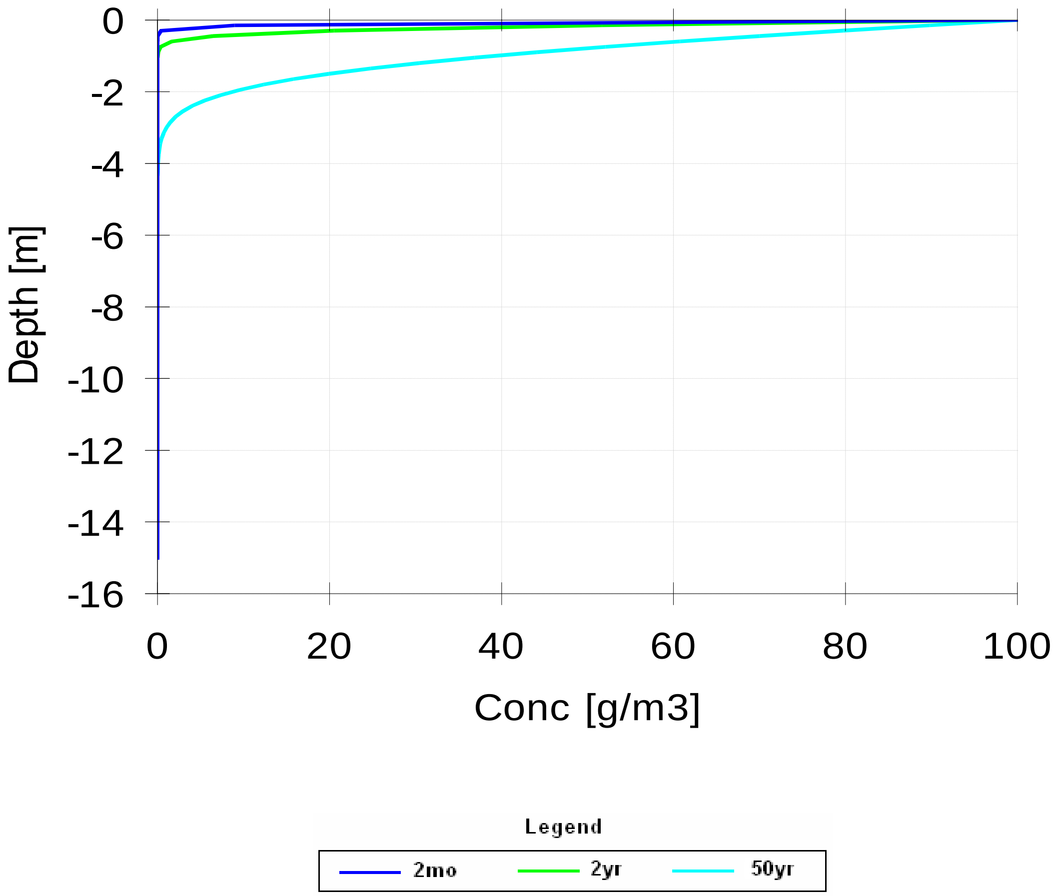
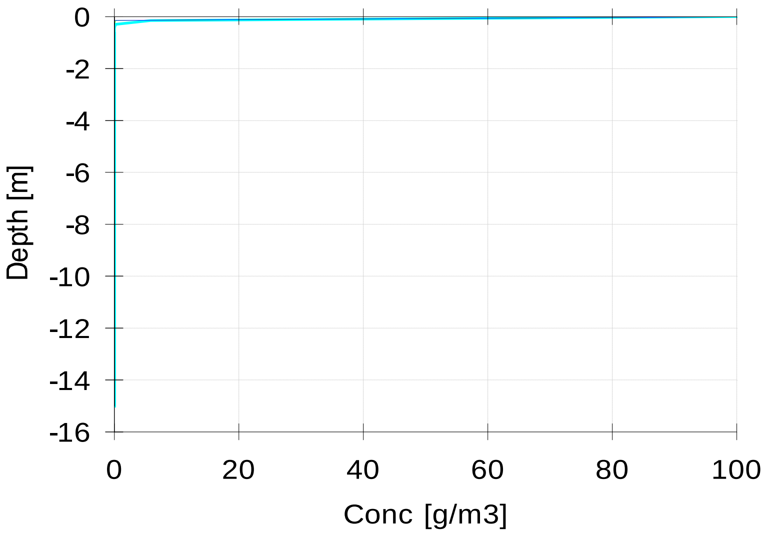


FIGURE II-2-5
CONCENTRATION CURVE: BROMODICHLOROMETHANE IN SAND
SENSITIVITY OF HENRYS CONSTANT
HYDRUS 1D SOIL ATTENUATION MODEL
RECYCLED WATER STUDY

LOW RANGE



HIGH RANGE

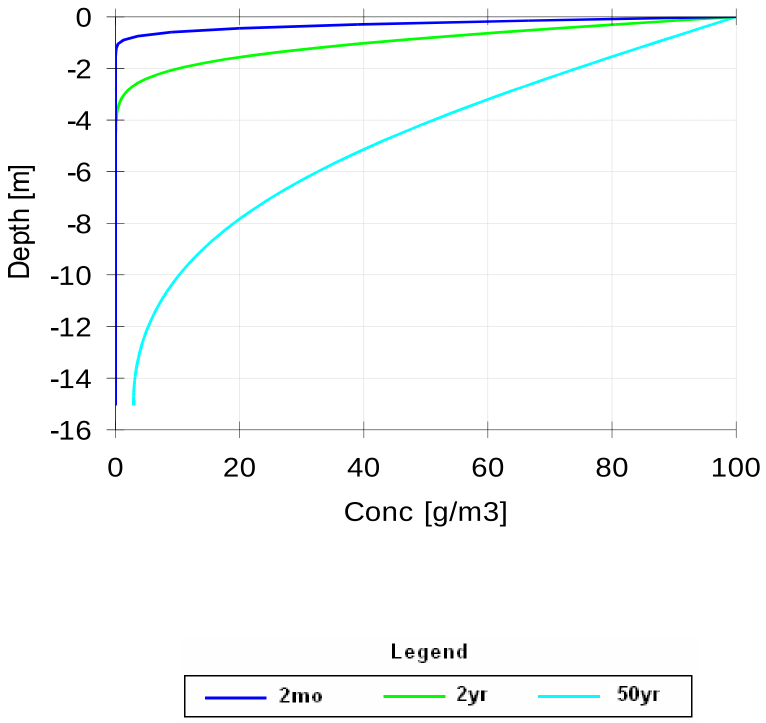
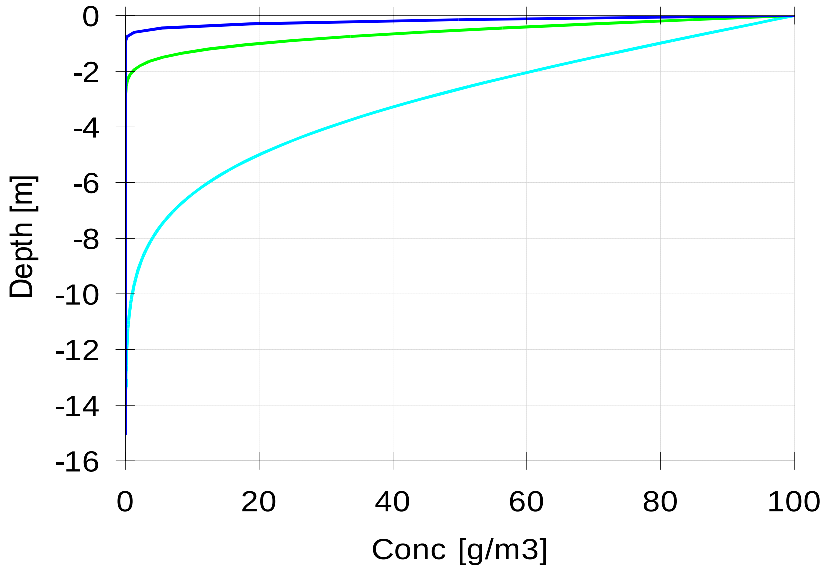


FIGURE II-2-6
CONCENTRATION CURVE: BROMODICHLOROMETHANE IN SAND
SENSITIVITY OF ADSORPTION ISOTHERM, Kd
HYDRUS 1D SOIL ATTENUATION MODEL
RECYCLED WATER STUDY

LOW RANGE



HIGH RANGE

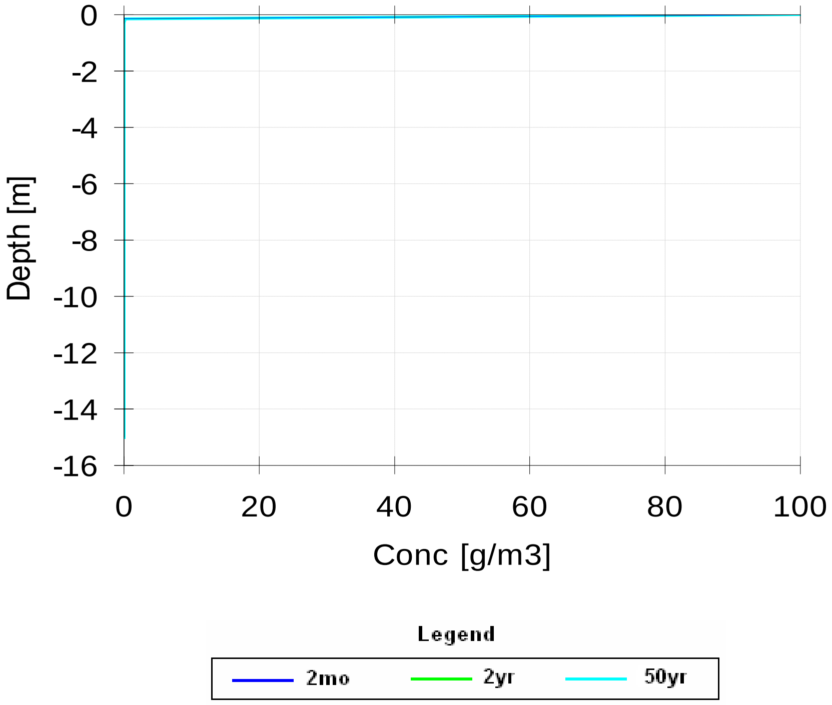


FIGURE II-2-7A
CONCENTRATION CURVE: BROMODICHLOROMETHANE IN SAND
SENSITIVITY OF MODEL: MODIFIED VAN GUNECHTEN WATER TRANSPORT MODEL
HYDRUS 1D SOIL ATTENUATION MODEL
RECYCLED WATER STUDY

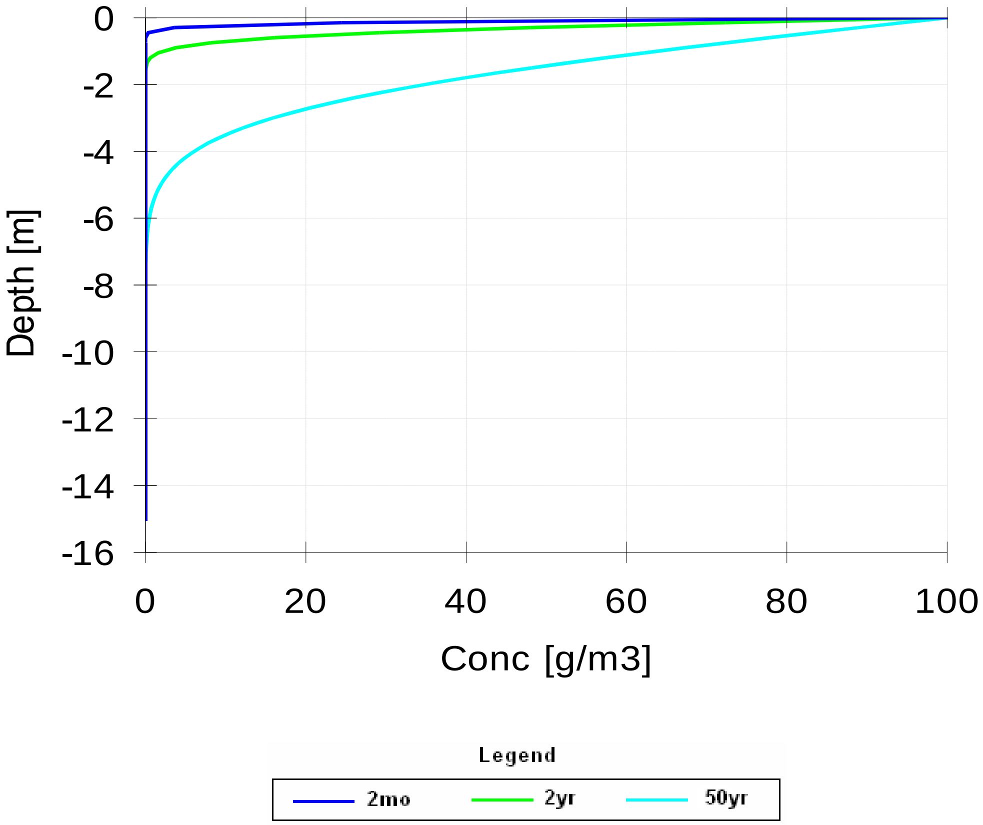


FIGURE II-2-7B
CONCENTRATION CURVE: BROMODICHLOROMETHANE IN SAND
SENSITIVITY OF MODEL: BROOKS COREY (1964) WATER TRANSPORT MODEL
HYDRUS 1D SOIL ATTENUATION MODEL
RECYCLED WATER STUDY

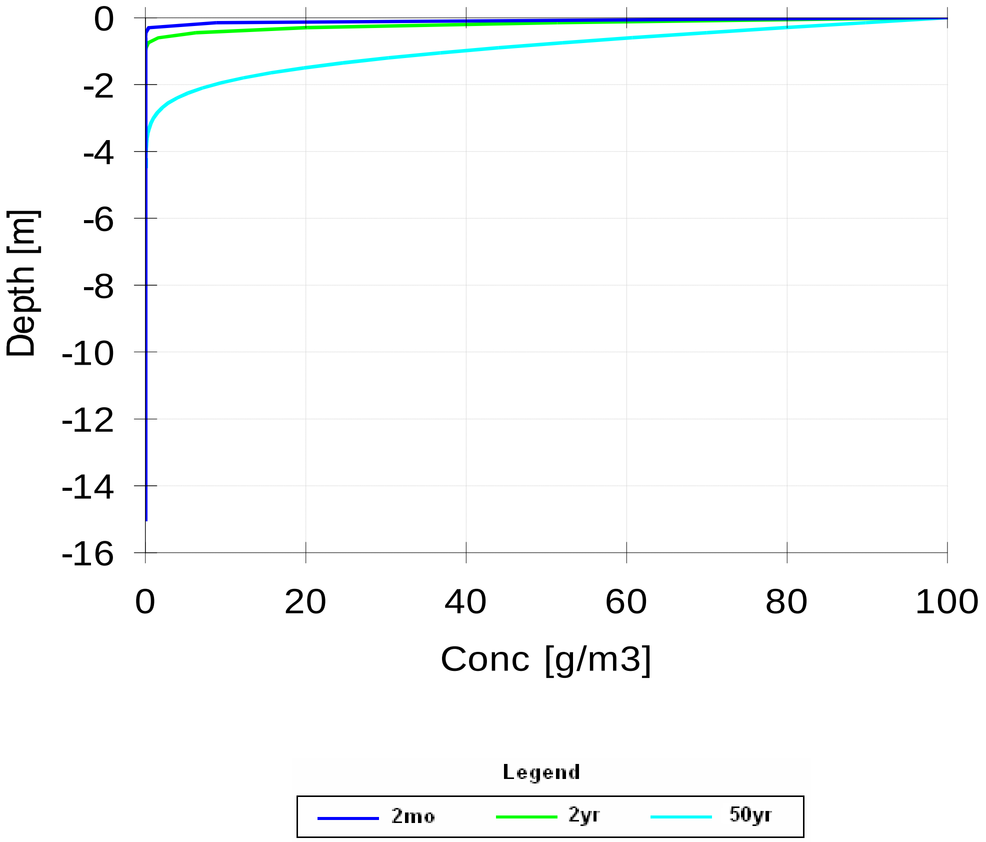


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FIGURE II-2-7C
CONCENTRATION CURVE: BROMODICHLOROMETHANE IN SAND
SENSITIVITY OF MODEL: KOSUGI (1996) WATER TRANSPORT MODEL
HYDRUS 1D SOIL ATTENUATION MODEL
RECYCLED WATER STUDY

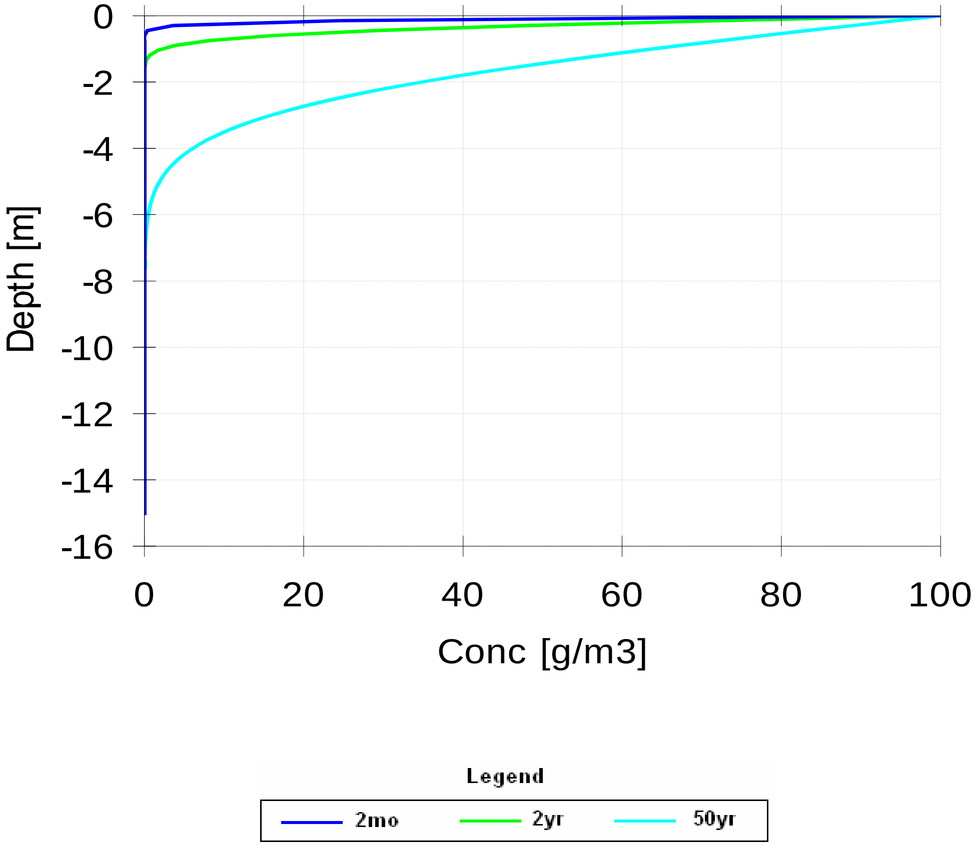
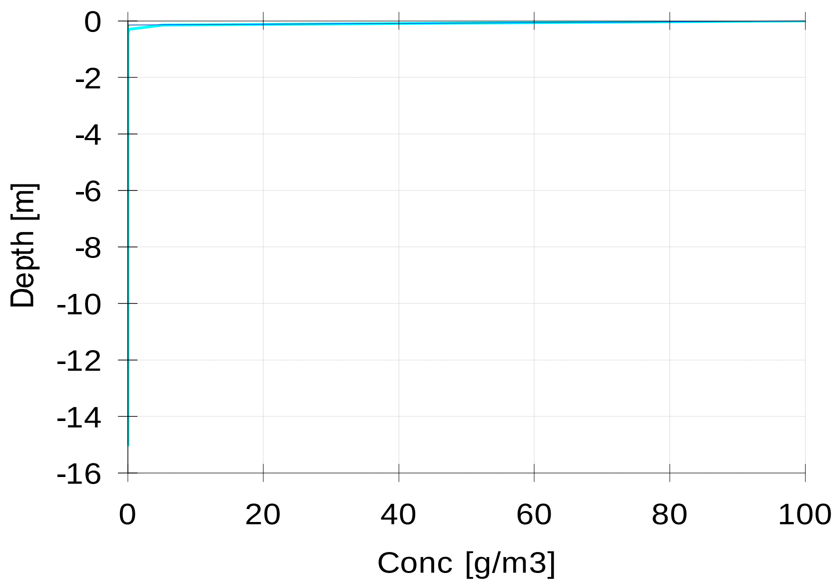


FIGURE II-2-8
CONCENTRATION CURVE: BROMODICHLOROMETHANE IN SAND
SENSITIVITY OF MOLECULAR DIFFUSION IN AIR
HYDRUS 1D SOIL ATTENUATION MODEL
RECYCLED WATER STUDY

LOW RANGE



HIGH RANGE

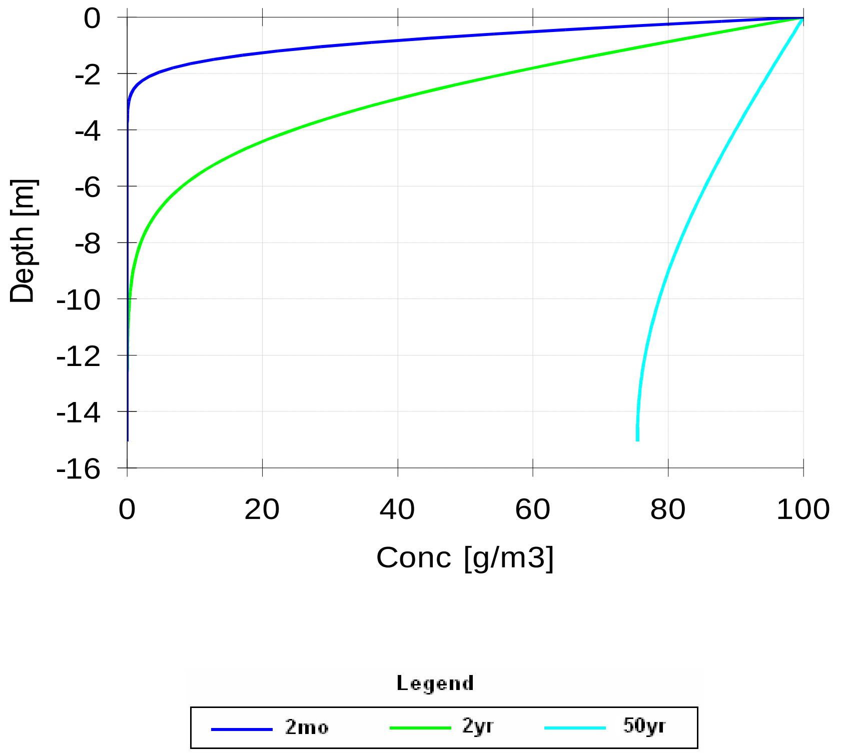
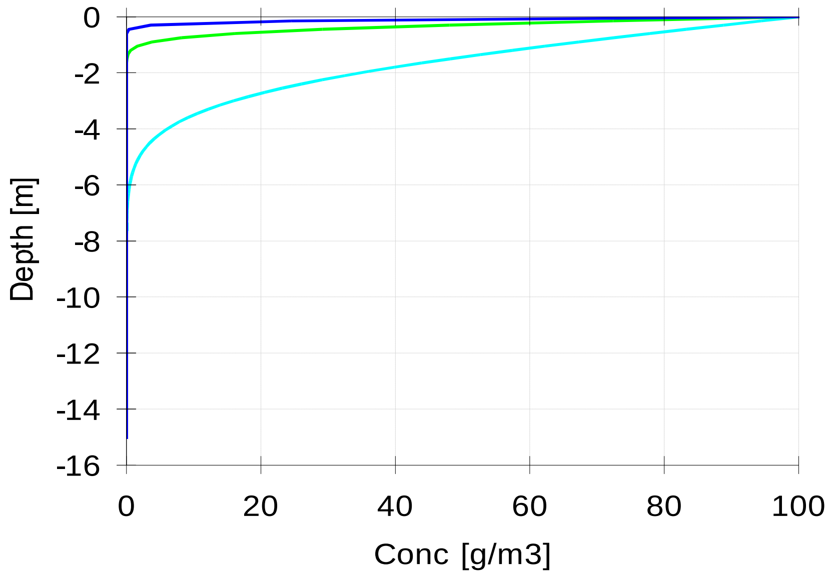
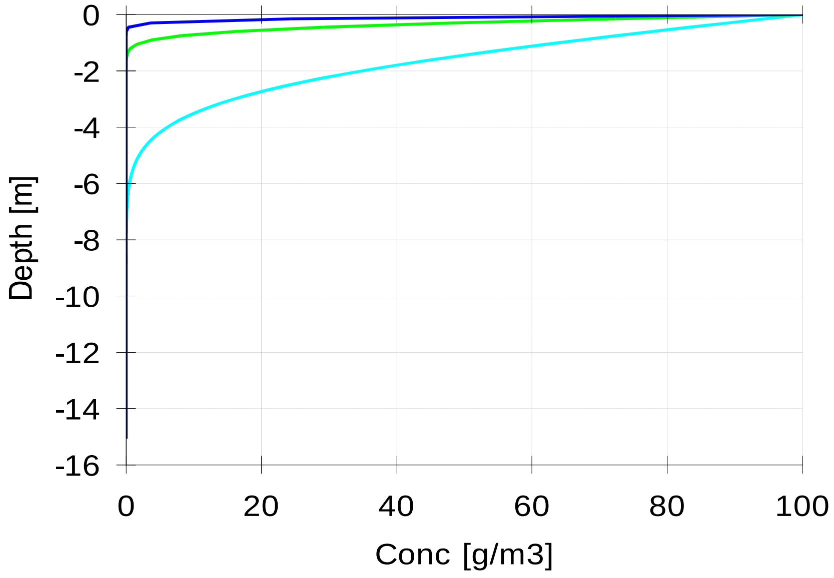


FIGURE II-2-9
CONCENTRATION CURVE: BROMODICHLOROMETHANE IN SAND
SENSITIVITY OF MOLECULAR DIFFUSION IN WATER
HYDRUS 1D SOIL ATTENUATION MODEL
RECYCLED WATER STUDY

LOW RANGE



HIGH RANGE

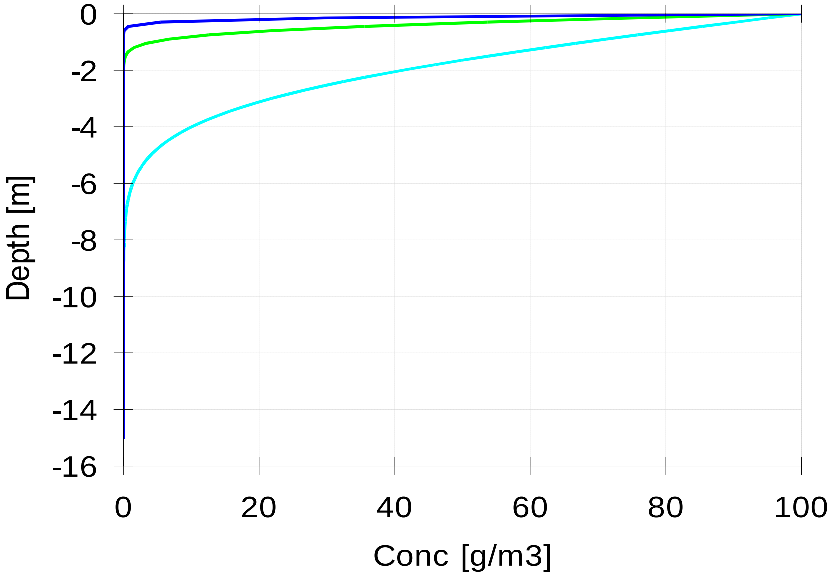


Legend

— 2mo	— 2yr	— 50yr

FIGURE II-2-10
CONCENTRATION CURVE: BROMODICHLOROMETHANE IN SAND
SENSITIVITY OF BULK DENSITY
HYDRUS 1D SOIL ATTENUATION MODEL
RECYCLED WATER STUDY

LOW RANGE



HIGH RANGE

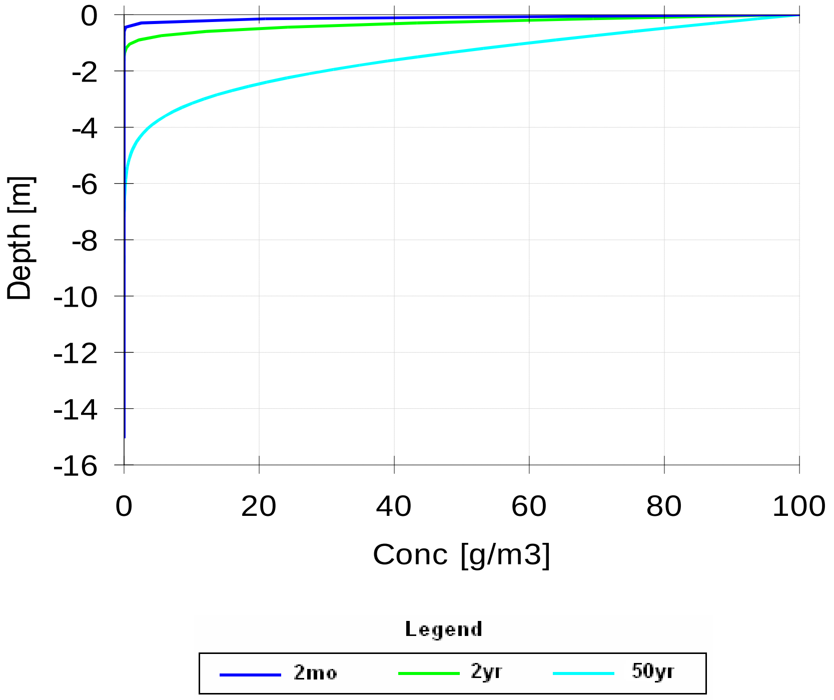


FIGURE II-2-11
CONCENTRATION CURVE: BROMODICHLOROMETHANE
SENSITIVITY TO HETEROGENEITY OF SOIL PROFILE
HYDRUS 1D SOIL ATTENUATION MODEL
RECYCLED WATER STUDY

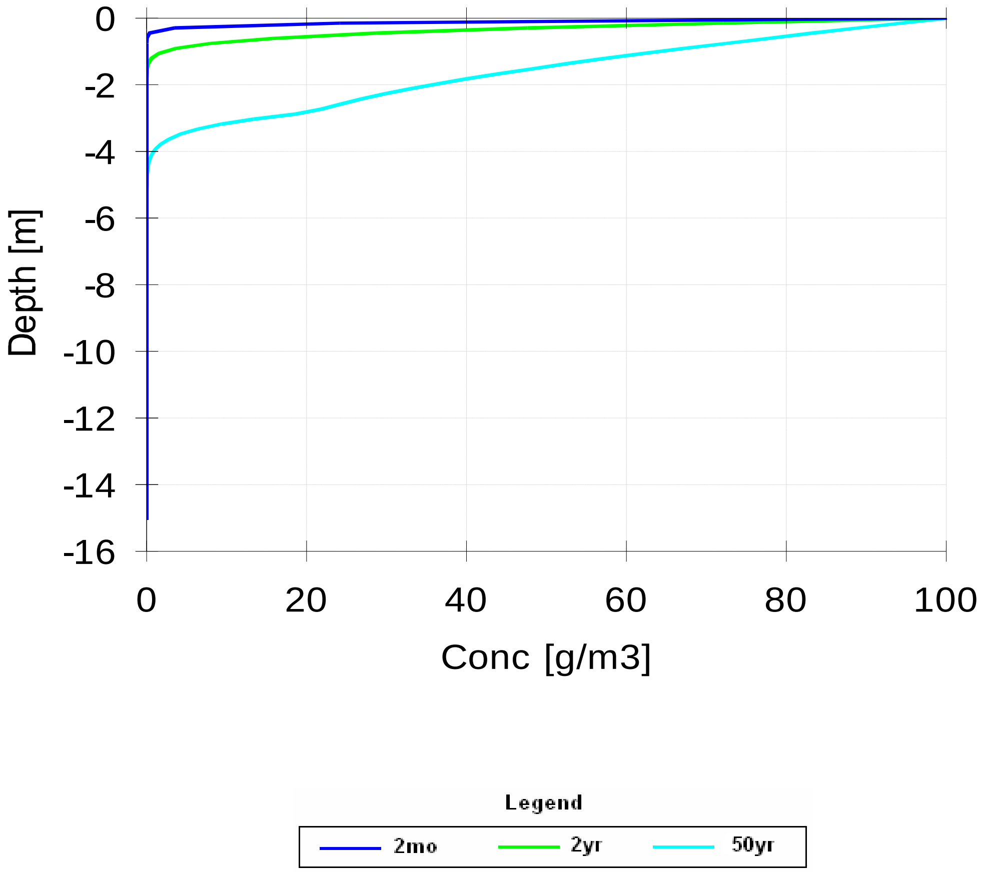


FIGURE II-3-1
BENCH TEST DRILLING LOCATIONS
SANTA CLARA VALLEY GROUNDWATER SUBBASIN

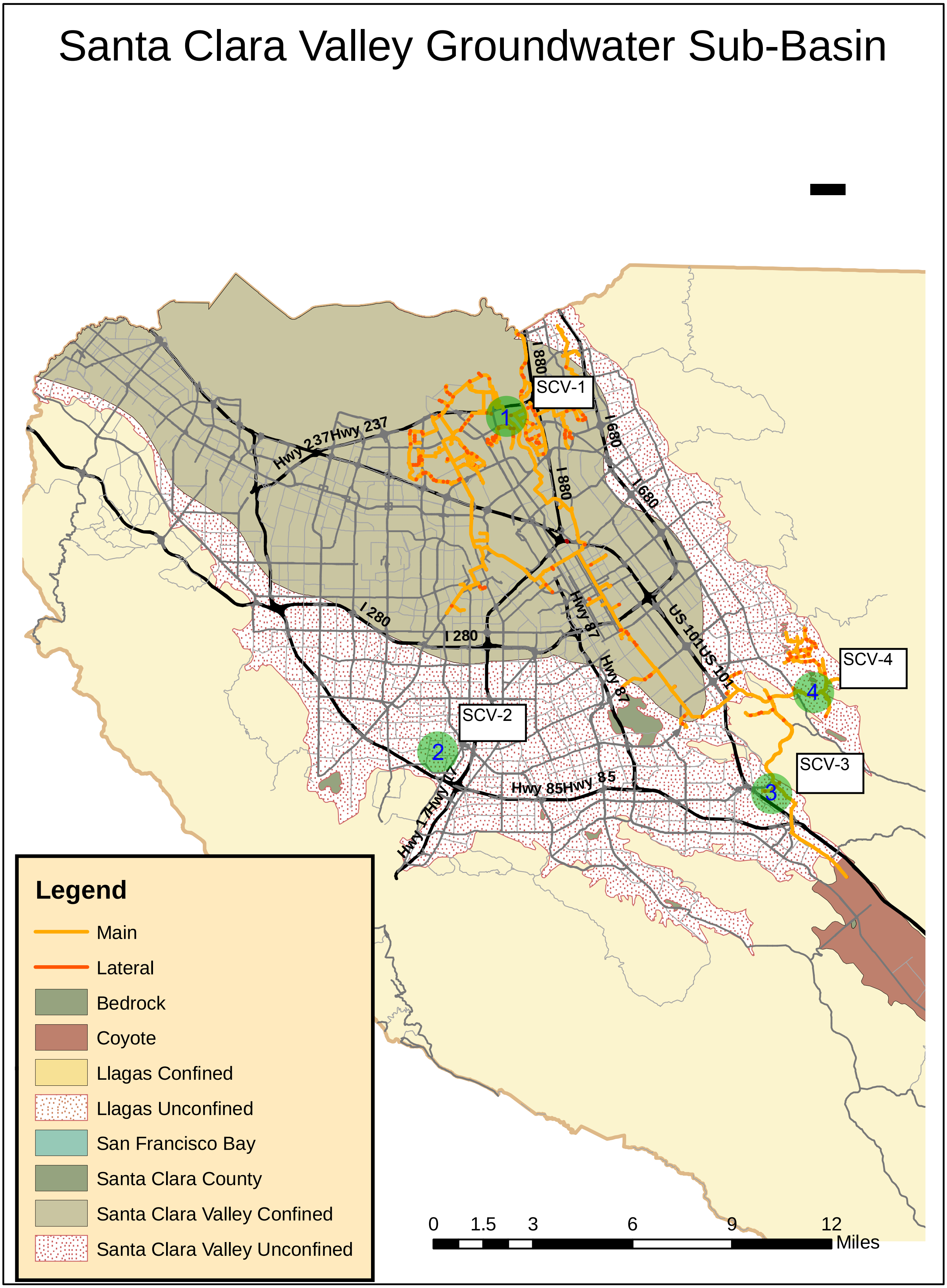


FIGURE II-3-2
BENCH TEST DRILLING LOCATIONS
LLAGAS GROUNDWATER SUBBASIN

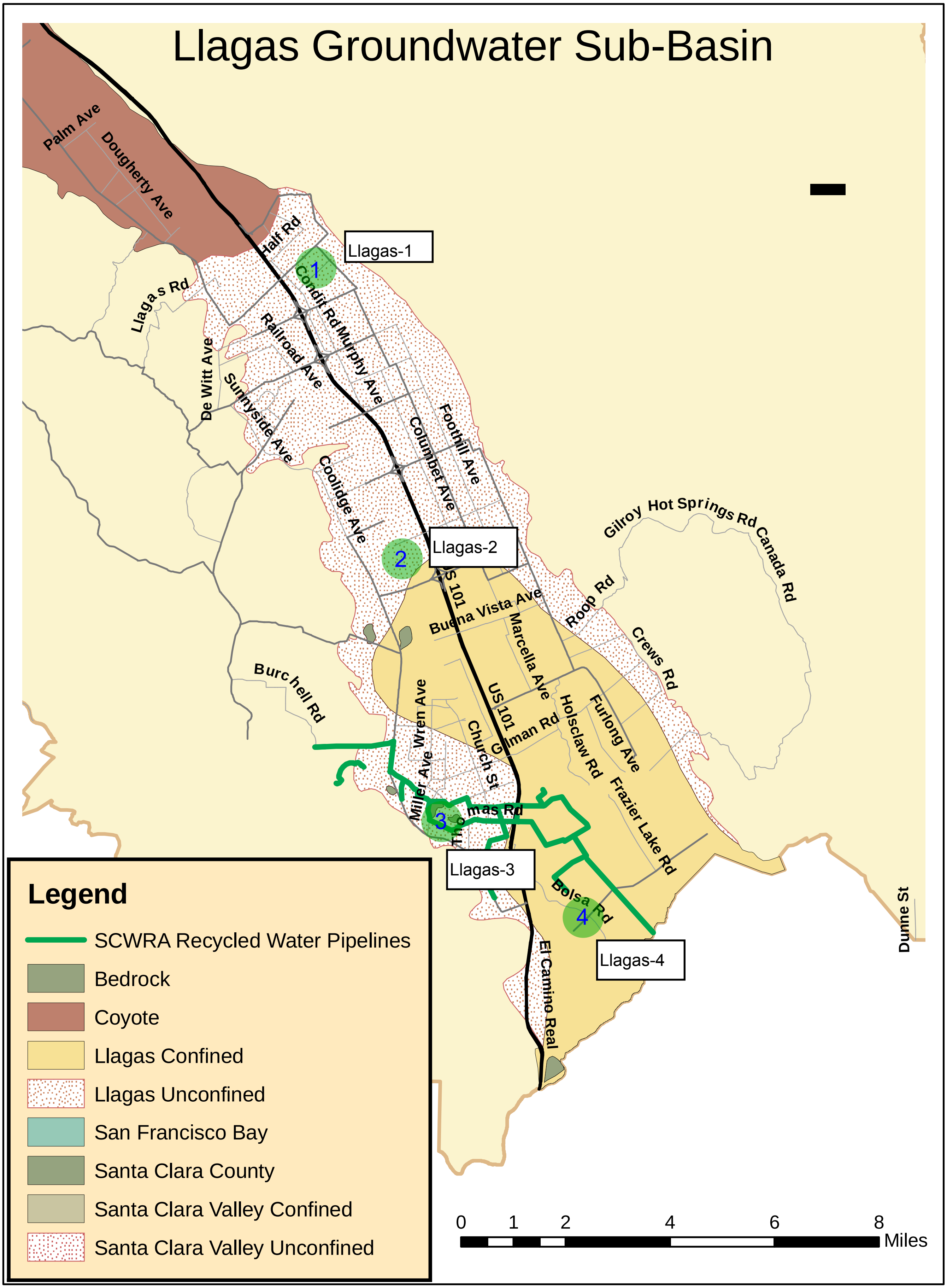


Figure II-3-3
Recycled Water Bench Test Flow Diagram

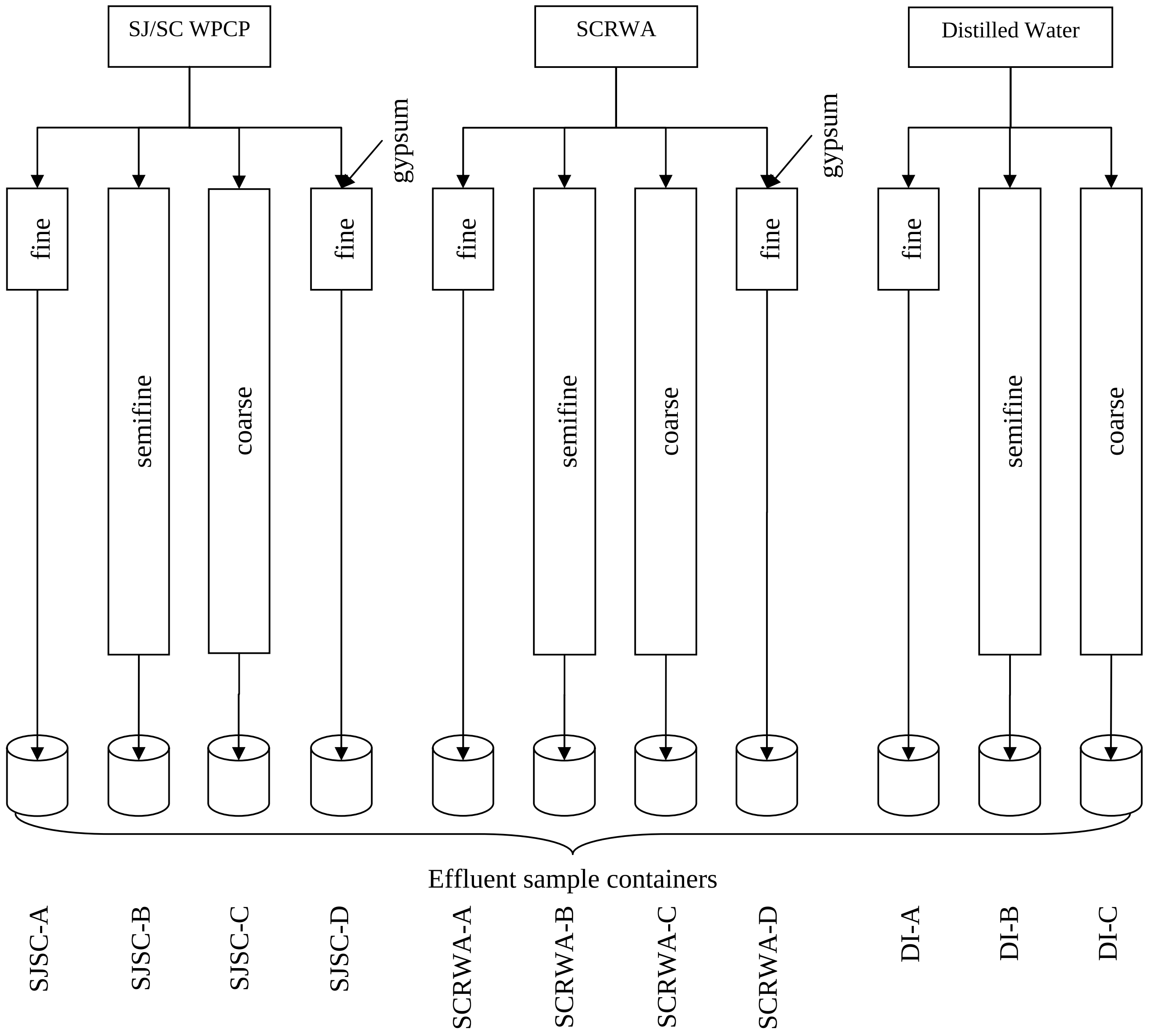


Figure II-3-4 pH

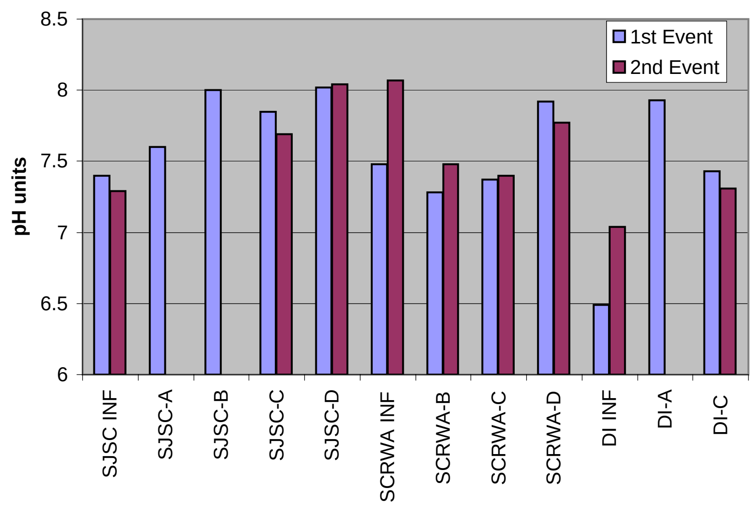


Figure II-3-5 Alkalinity as CaCO3

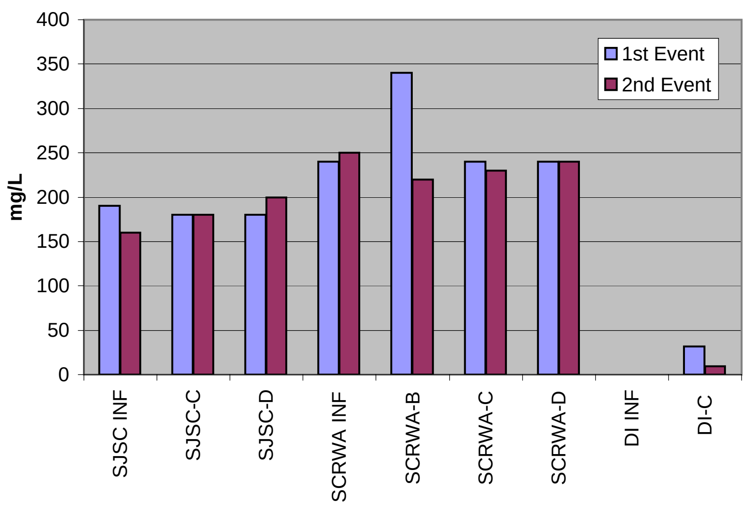


Figure II-3-6 Bicarbonate Alkalinity as HCO3

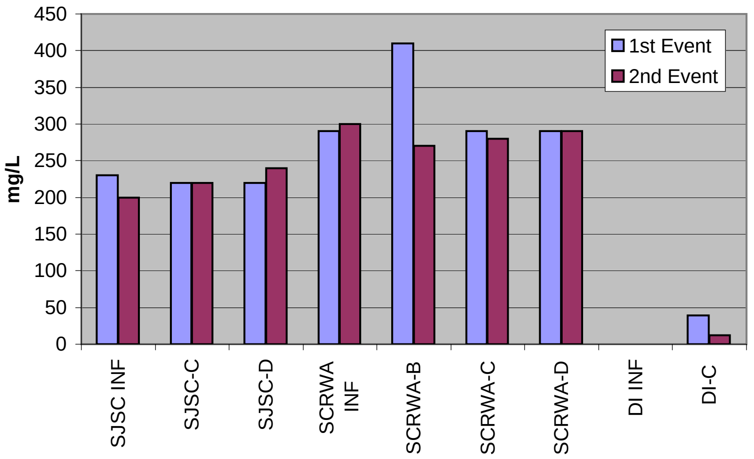
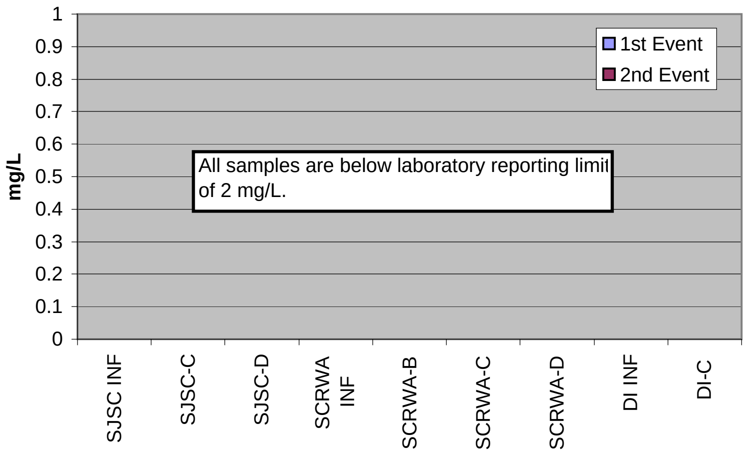


Figure II-3-7 Carbonate Alkalinity as CaCO3



All samples are below laboratory reporting limit of 2 mg/L.

Note: SJSC INF, SCRWA INF, and DI INF are influent samples.

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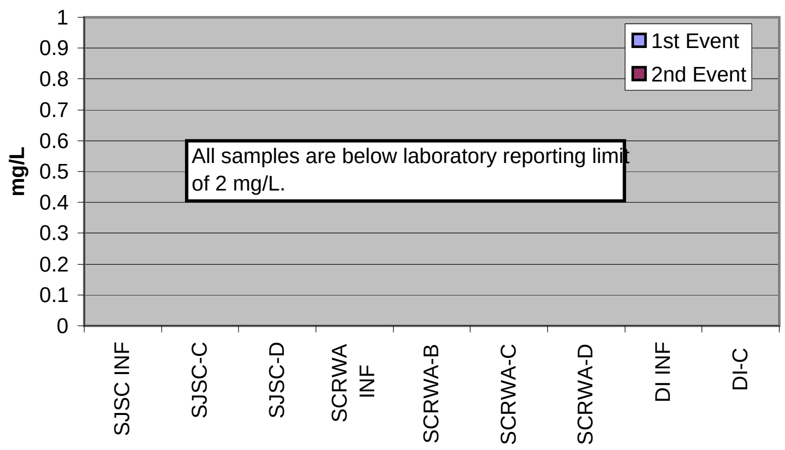
Figure II-3-8 Hydroxide Alkalinity as CaCO3



All samples are below laboratory reporting limit of 2 mg/L.

Figure II-3-9 Total Dissolved Solids

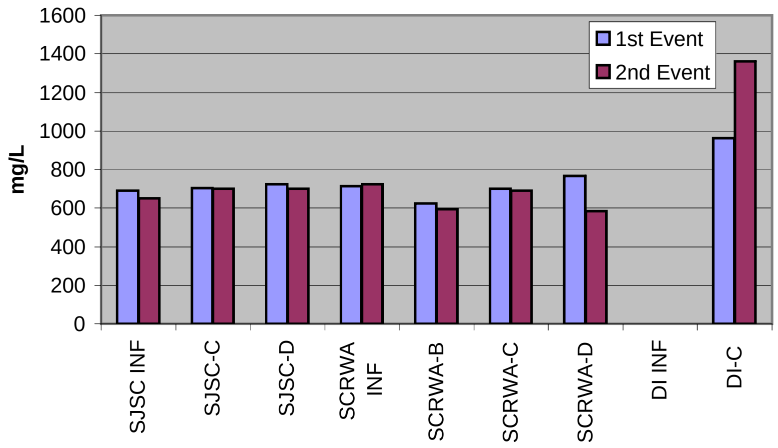


Figure II-3-10 Dissolved Organic Carbon

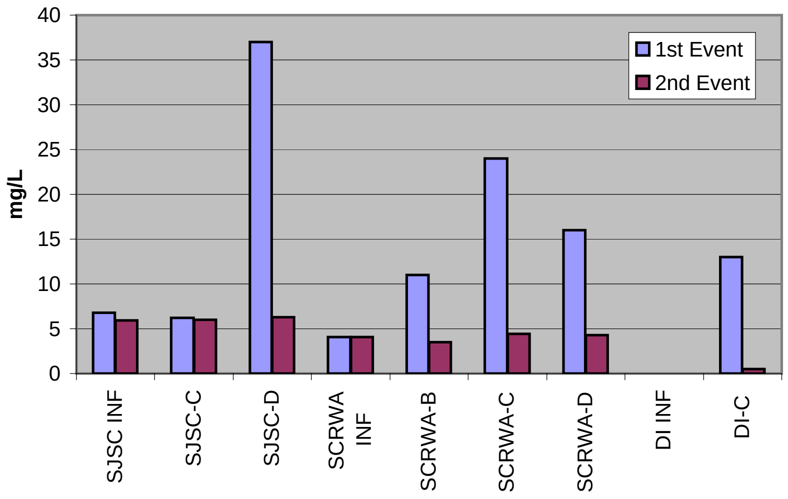
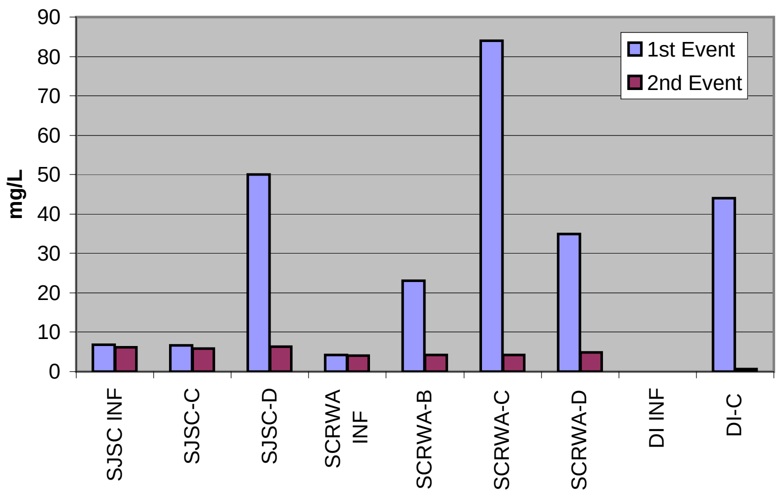


Figure II-3-11 Total Organic Carbon (TOC)



Note: SJSC INF, SCRWA INF, and DI INF are influent samples.

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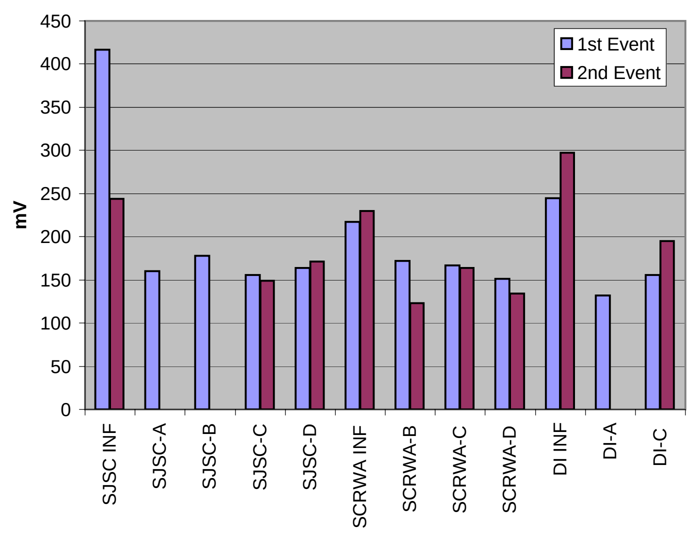


Figure II-3-12 ORP

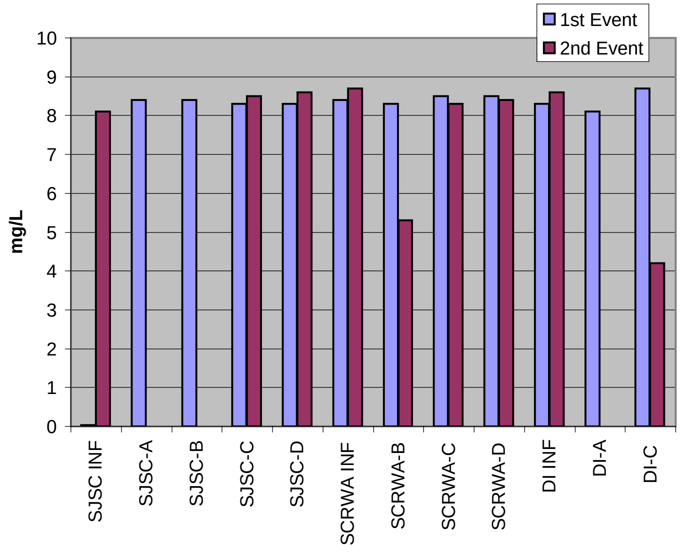


Figure II-3-13 Dissolved Oxygen (DO)

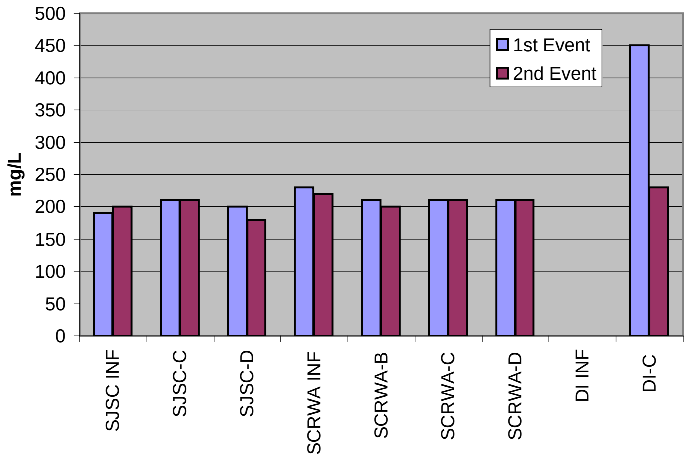


Figure II-3-14 Chloride

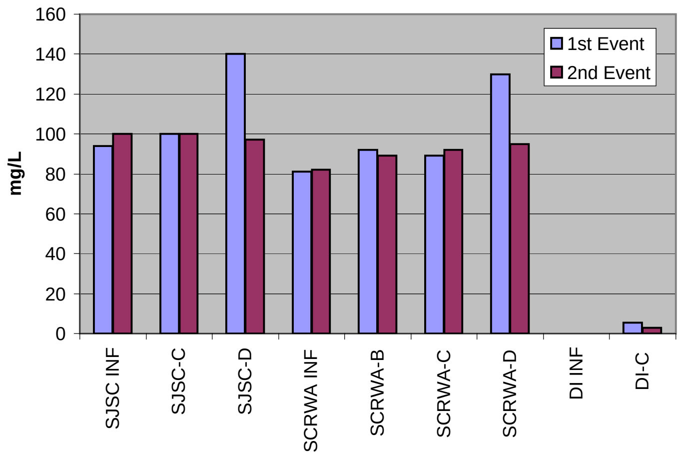


Figure II-3-15 Sulfate as SO4

Note: SJSC INF, SCRWA INF, and DI INF are influent samples.

Figure II-3-16 Bromide

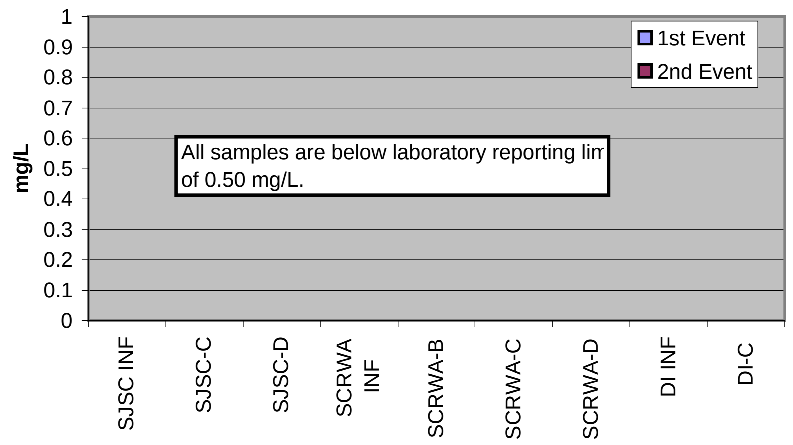


Figure II-3-17 Total Cyanide

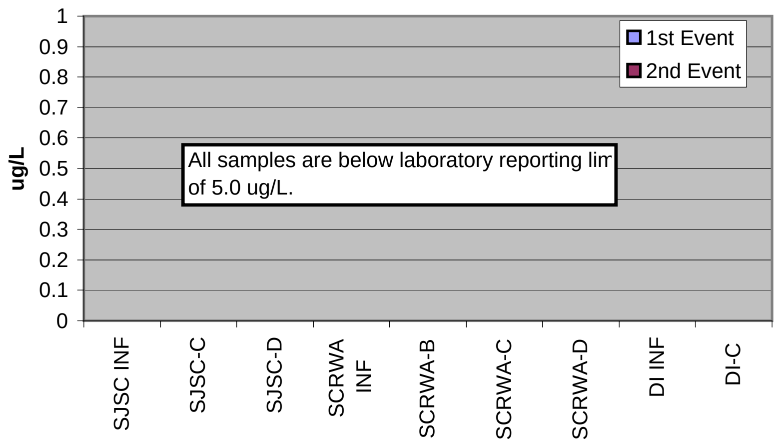


Figure II-3-18 Total Boron

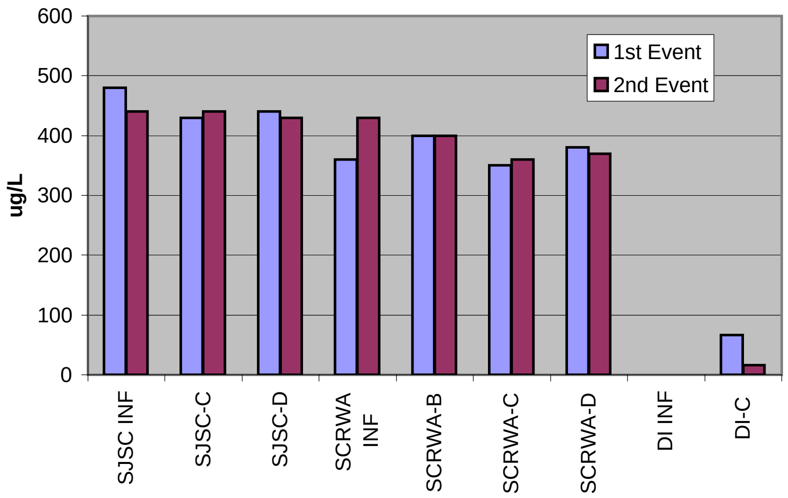
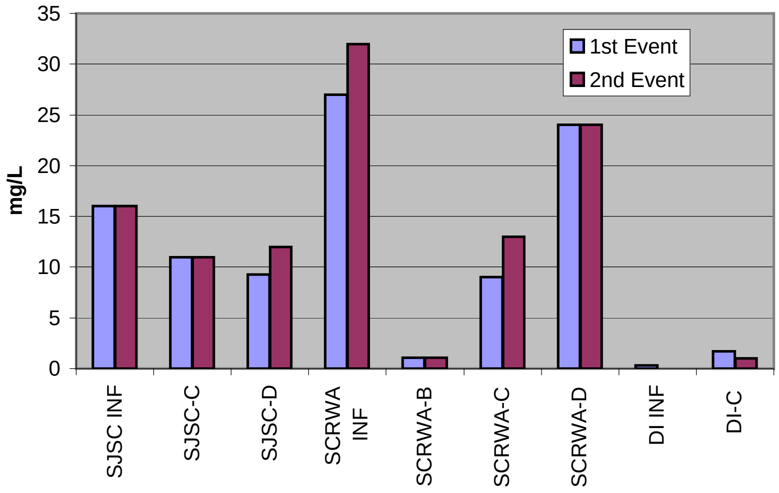


Figure II-3-19 Potassium



Note: SJSC INF, SCRWA INF, and DI INF are influent samples.

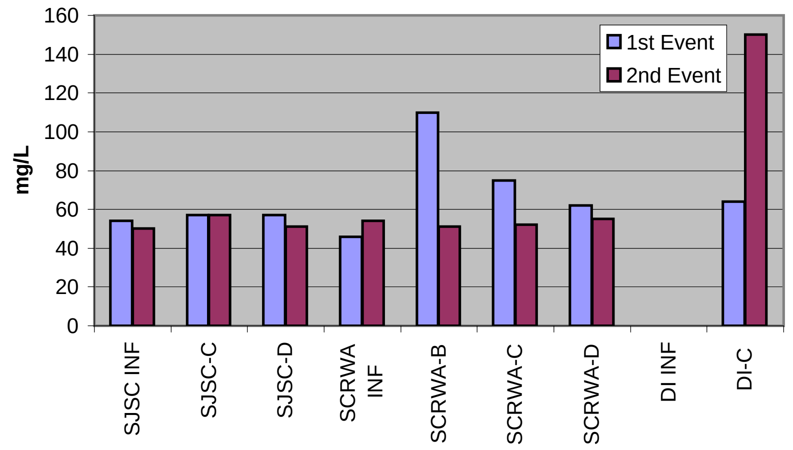


Figure II-3-20 Calcium

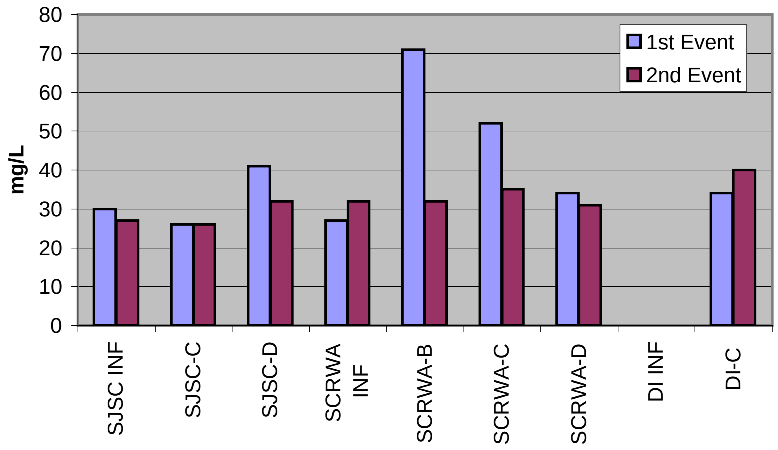


Figure II-3-21 Magnesium

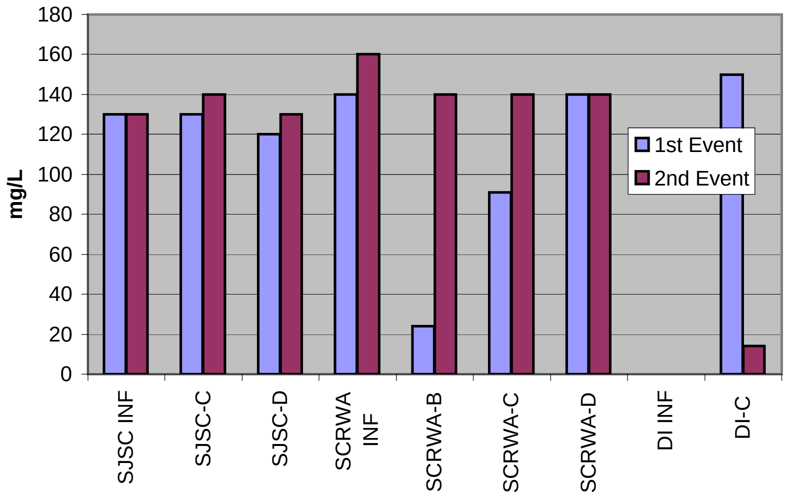


Figure II-3-22 Sodium

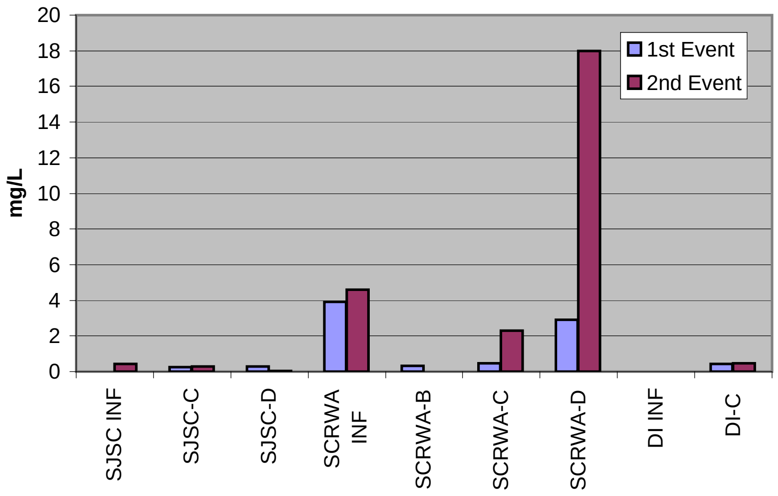


Figure II-3-23 Phosphate, Total as P

Note: SJSC INF, SCRWA INF, and DI INF are influent samples.

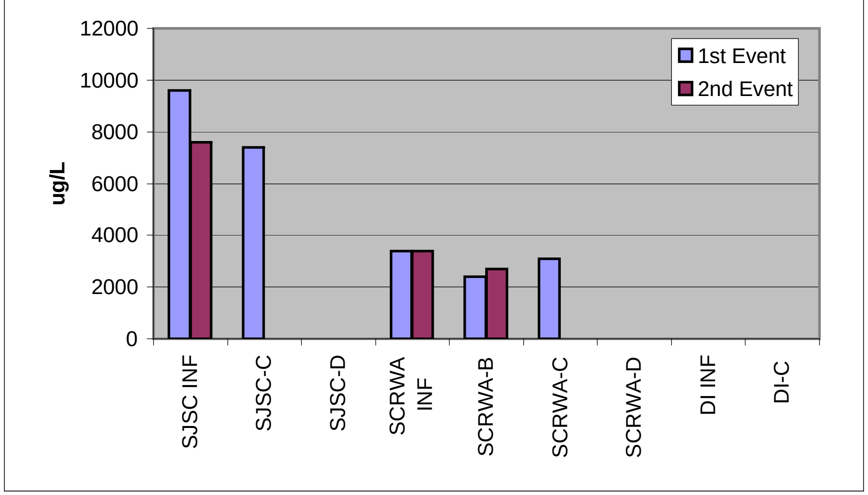


Figure II-3-24 Nitrate as N

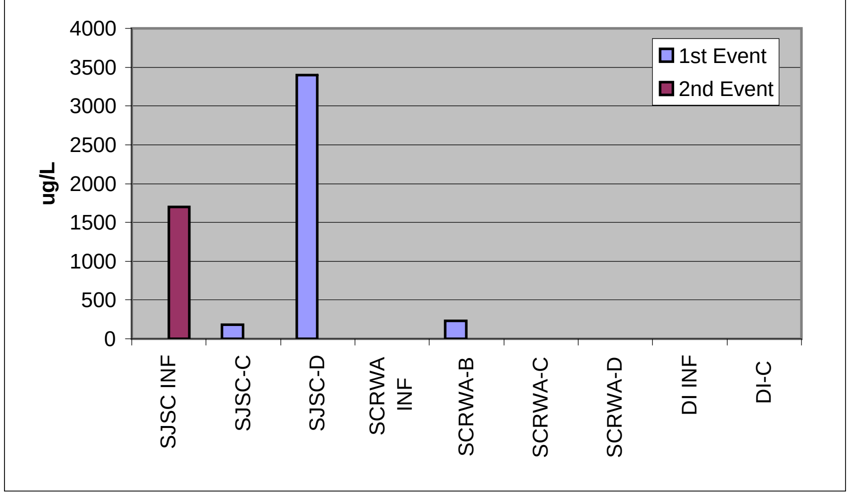


Figure II-3-25 Nitrite as N

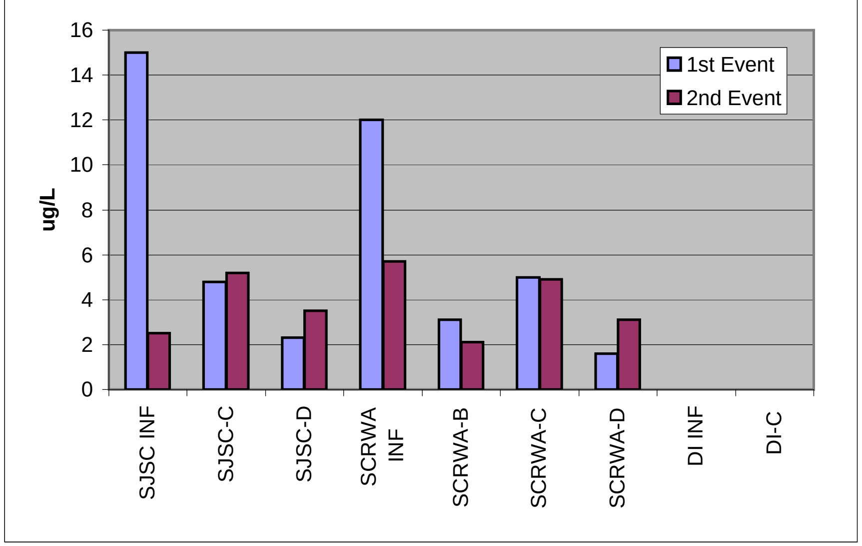


Figure II-3-26 Bromodichloromethane

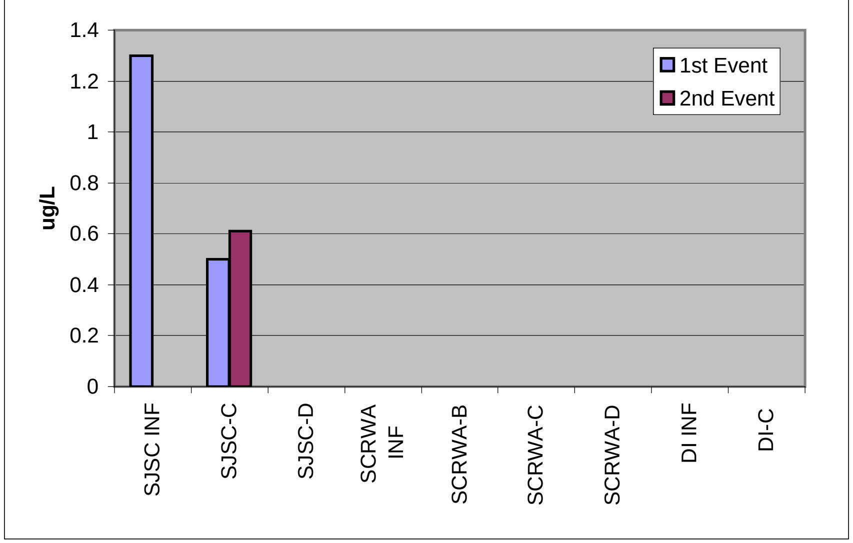


Figure II-3-27 Bromoform

Note: SJSC INF, SCRWA INF, and DI INF are influent samples.

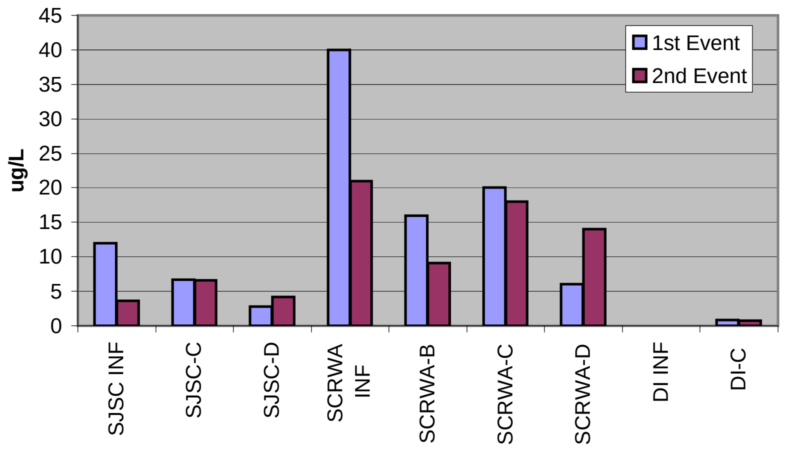


Figure II-3-28 Chloroform

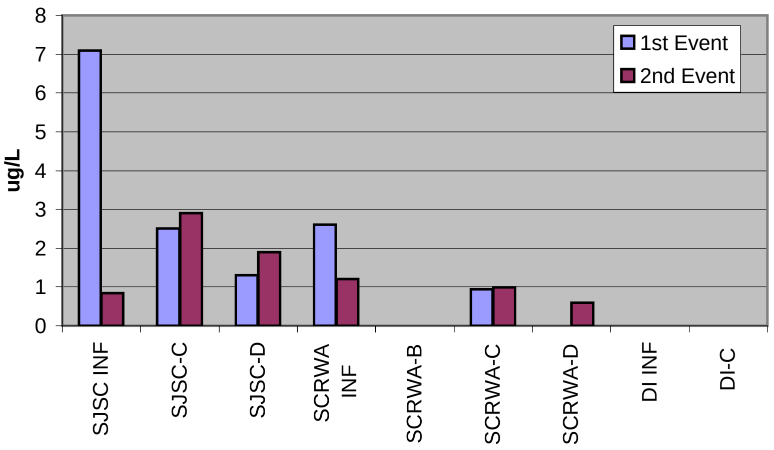


Figure II-3-29 Dibromochloromethane

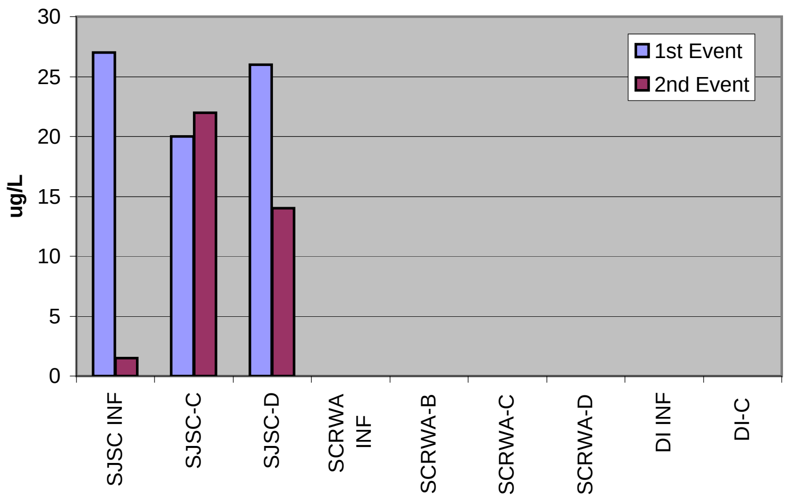


Figure II-3-30 Total HAA5

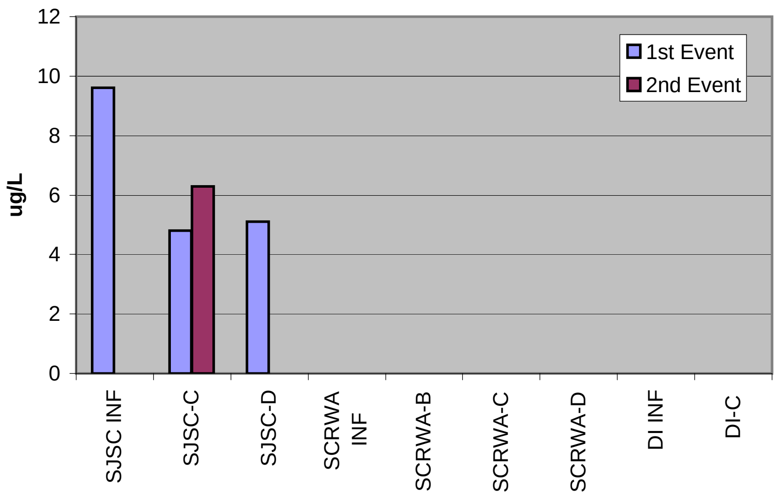


Figure II-3-31 Bromochloroacetic acid (bcaa)

Note: SJSC INF, SCRWA INF, and DI INF are influent samples.

Figure II-3-32 Dibromoacetic acid (dbaa)

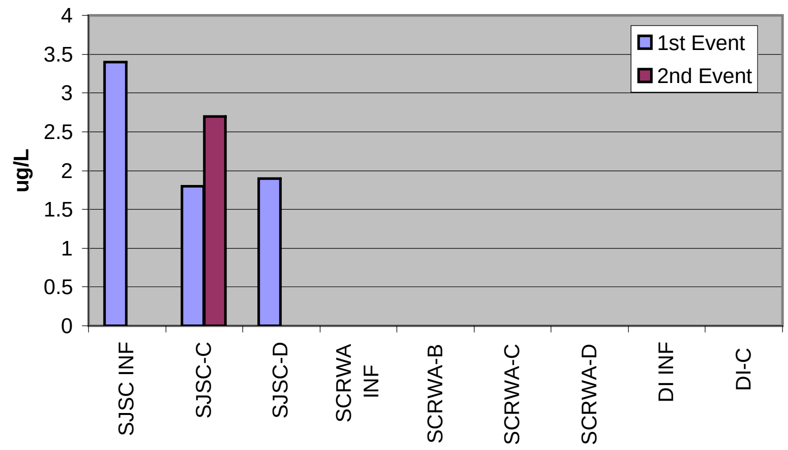


Figure II-3-33 Dichloroacetic acid (dcaa)

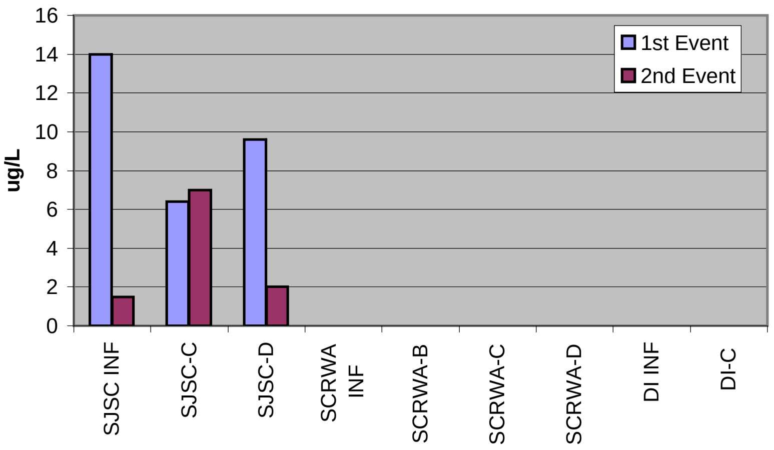
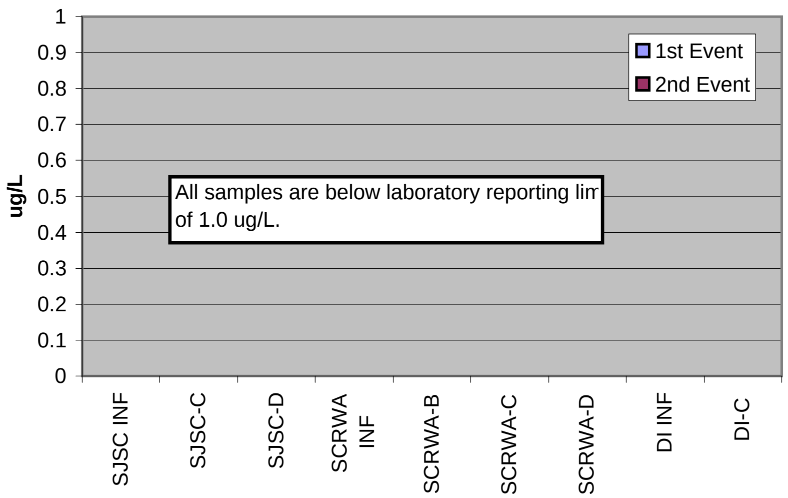
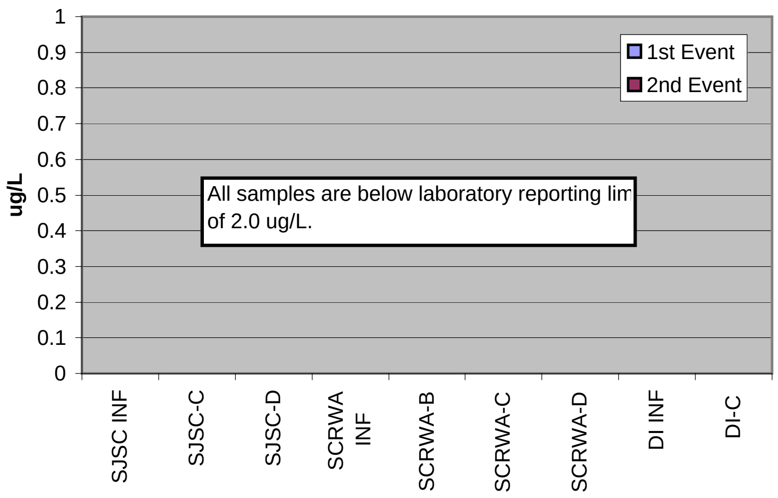


Figure II-3-34 Monobromoacetic acid (mbaa)



All samples are below laboratory reporting lim of 1.0 ug/L.

Figure II-3-35 Monochloroacetic acid (mcaa)



All samples are below laboratory reporting lim of 2.0 ug/L.

Note: SJSC INF, SCRWA INF, and DI INF are influent samples.

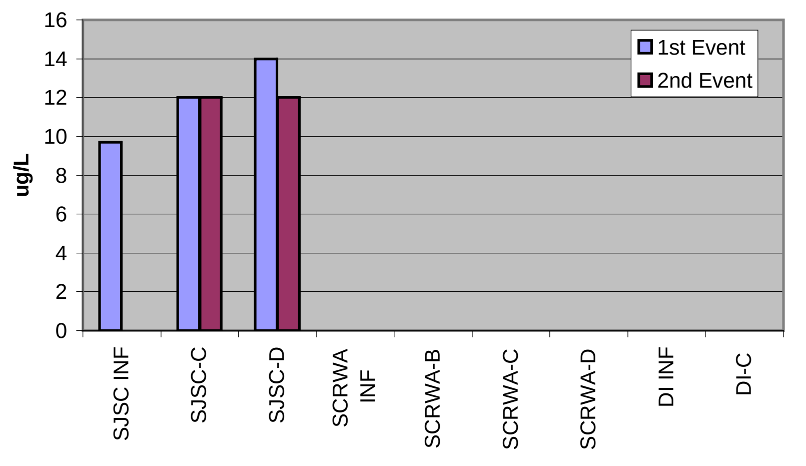


Figure II-3-36 Trichloroacetic acid (tcaa)

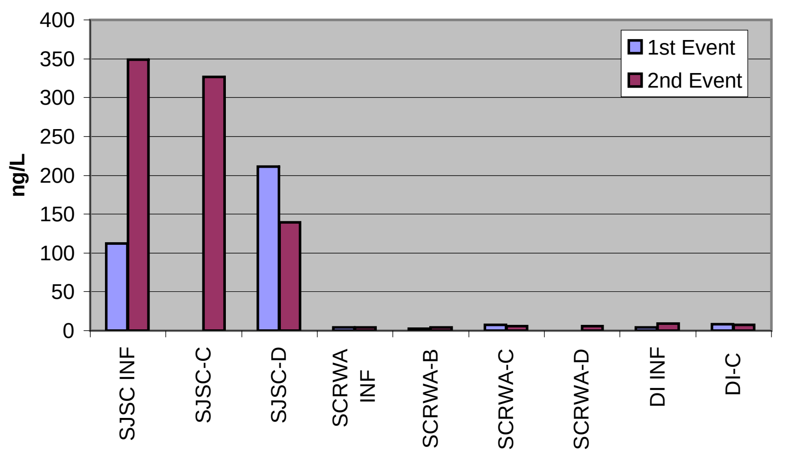


Figure II-3-37 N-Nitroso dimethylamine (NDMA)

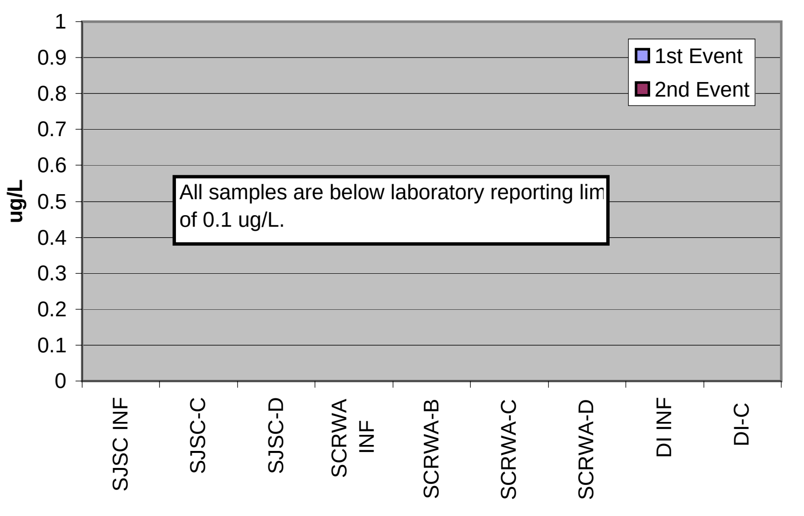


Figure II-3-38 Terbuthylazine

All samples are below laboratory reporting lim of 0.1 ug/L.

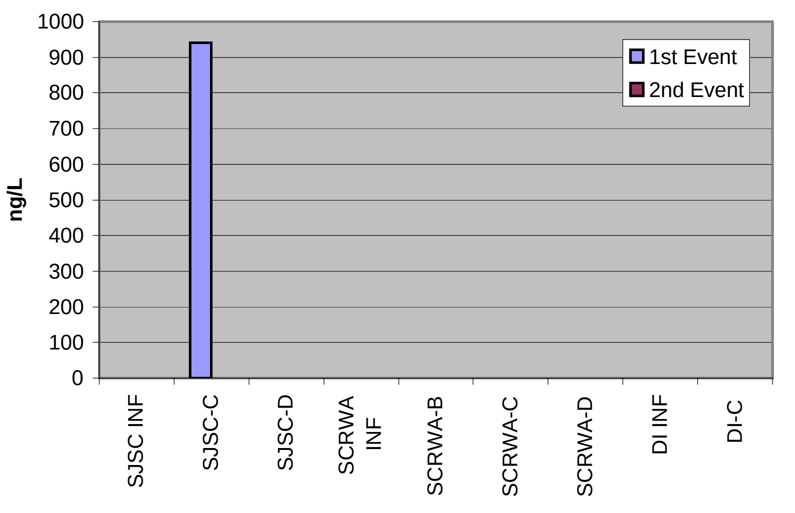


Figure II-3-39 Perfluoro butanoic acid (PFBA)

Note: SJSC INF, SCRWA INF, and DI INF are influent samples.

Figure II-3-40 Perfluoro octanesulfonate (PFOS)

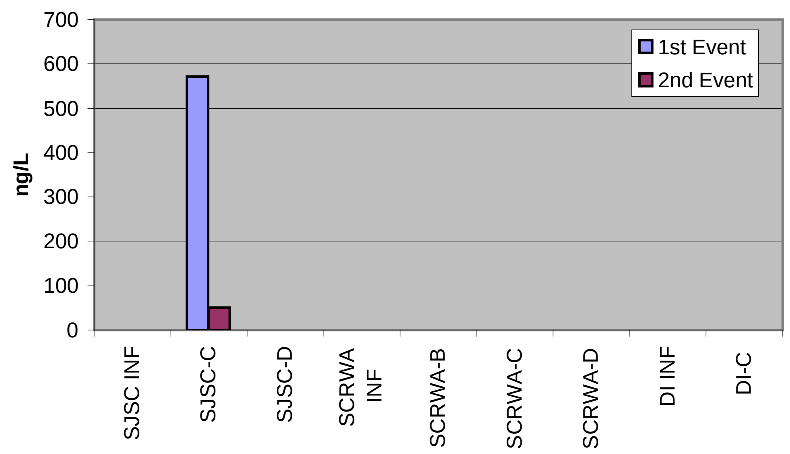


Figure II-3-41 Perfluoro octanoic acid (PFOA)

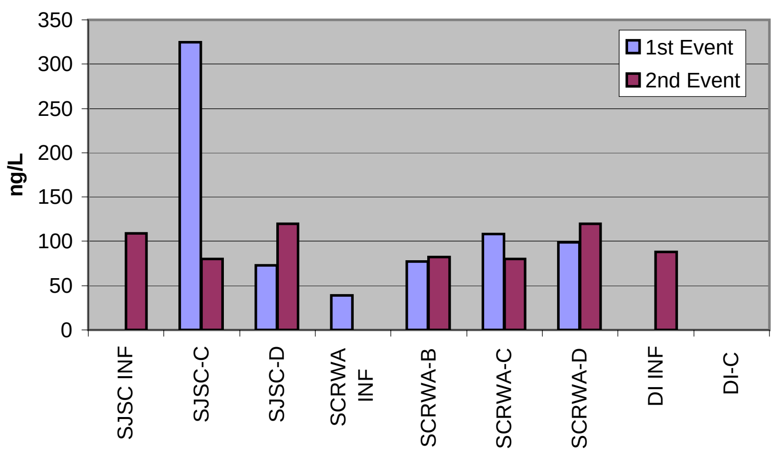
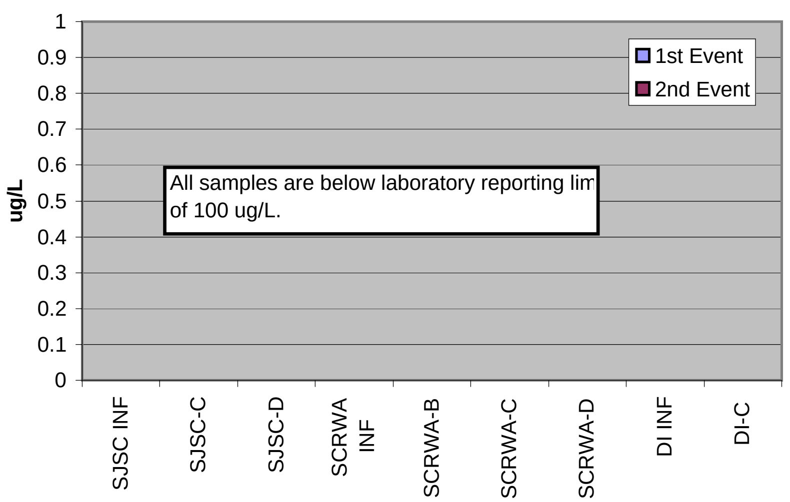
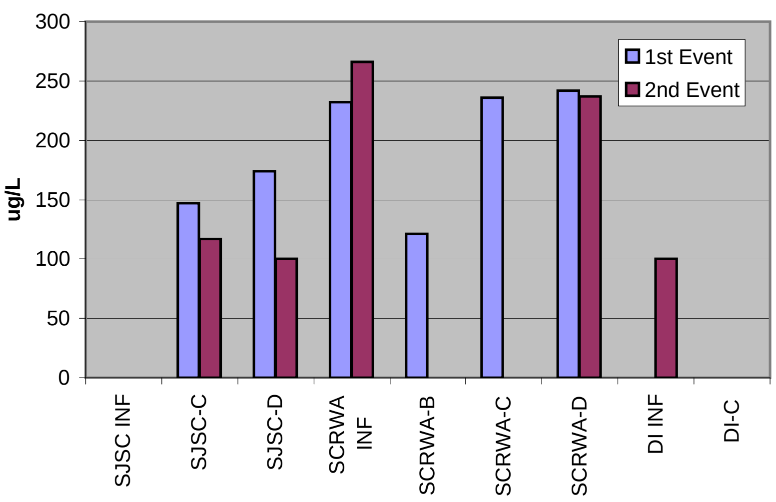


Figure II-3-42 NTA



All samples are below laboratory reporting lim
of 100 ug/L.

Figure II-3-43 EDTA



Note: SJSC INF, SCRWA INF, and DI INF are influent samples.

Figure II-3-44 Surfactants (MBAS)

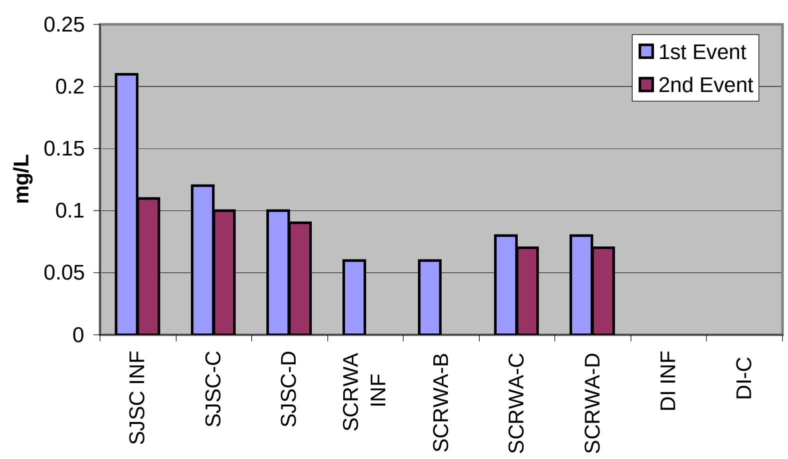


Figure II-3-45 Perchlorate

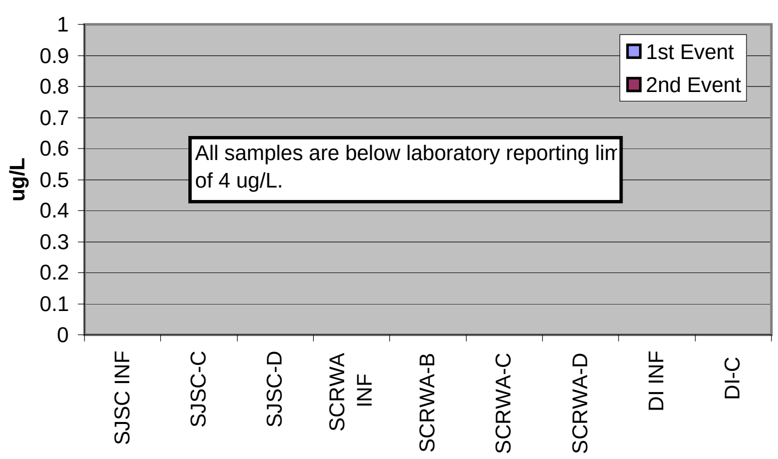


Figure II-3-46 Total Coliform

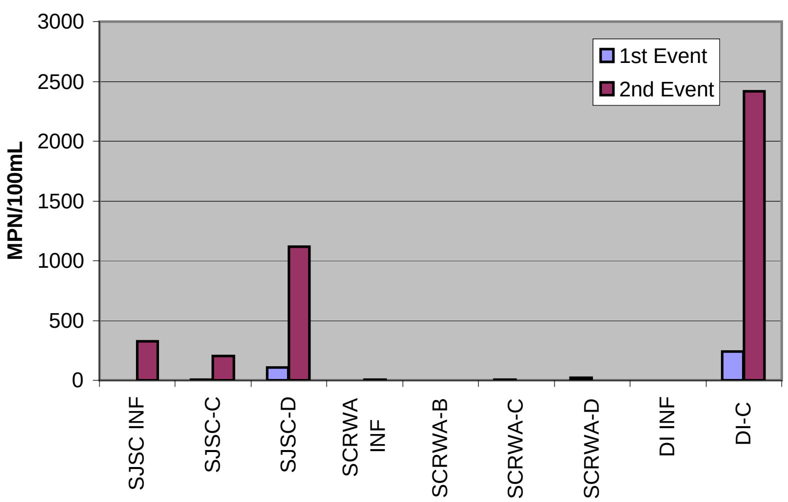
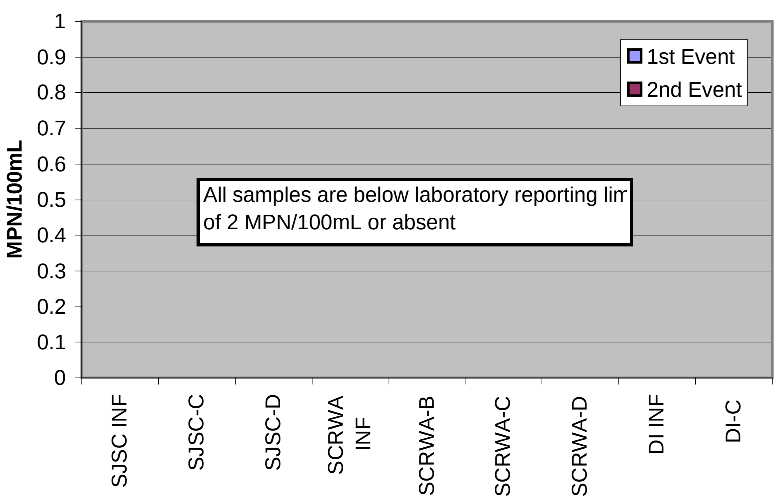
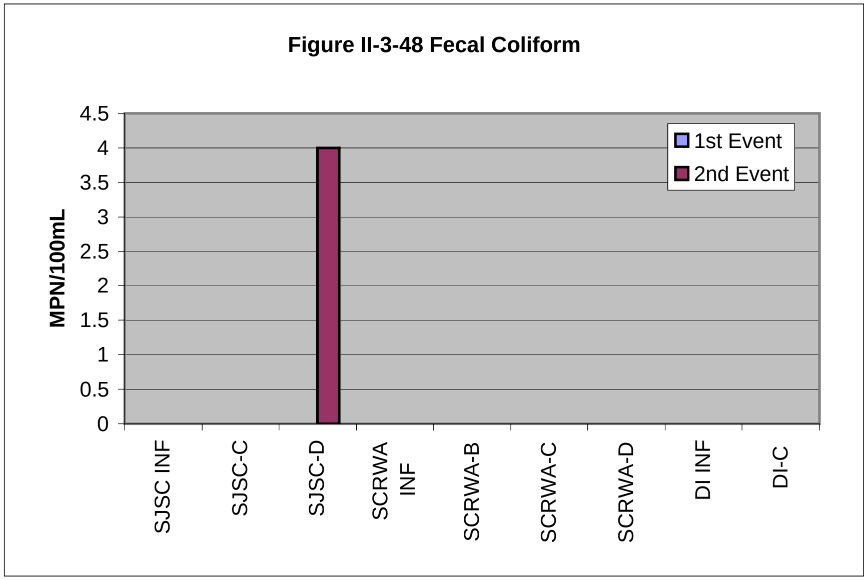


Figure II-3-47 E. Coli



Note: SJSC INF, SCRWA INF, and DI INF are influent samples.



Note: SJSC INF, SCRWA INF, and DI INF are influent samples.

TABLES

TABLE II-2-1
PARAMETER SPECIFIC DATA
HYDRUS 1D SOIL ATTENUATION MODEL
RECYCLED WATER STUDY

Parameter	Units	Bromodichloromethane	Chloroform	m-Xylene	NDMA	Assumptions	Reference
Formula weight	gram/mol	163.8	119.4	106.2	74.08		1, 2
Henry's Constant, Hcc	$(mol/L)_{gas}$ / $(mol/L)_{aq}$	6.56E-02	1.50E-01	3.00E-01	4.92E-05		1, 2
Adsorption Isotherm Coefficient, Kd	$meter^3$/gram	1.10E-07	8.00E-08	8.20E-06	5.50E-10	foc = 0.002	1, 2, 3
Diffusion Coefficient in Air	$meter^2$/day	1.99E-03	1.90E-02	3.63E-03	3.92E-05		1, 2
Diffusion Coefficient in Water	$meter^2$/day	9.16E-05	8.64E-05	6.74E-05	1.07E-04		1, 2

Notes:

1. Schwarzenbach, R.P., P.M. Gschewend, and D.M Imboden, 2003, Appendix C, Physiochemical Properties of Organic Compounds, Environmental Organic Chemistry 2nd Ed., pp. 1198-1208

2. Alabama Department of Environmental Management, 2008. Alabama Risk-Based Corrective Action Guidance Manual, Table 3-3 Physical and Chemical Properties.

3. foc = fraction of organic carbon by weight in the soil. Value of 0.002 is recommended in: U.S. EPA, 1996, Soil Screening Guidance, EPA Document Number EPA/540/R-95/128, Part 5: Chemical-Specific Parameters, July.

TABLE II-2-2
SENSITIVITY ANALYSIS INPUT DATA
HYDRUS 1D SOIL ATTENUATION MODEL
RECYCLED WATER STUDY

			Low Range of Parameter		High Range of Parameter			
Parameter	Units	Base Value	Value	Chemical	Value	Chemical	Assumptions	Reference
Henry's Constant, Hcc	$(mol/L)_{gas}$ / $(mol/L)_{aq}$	6.56E-02	1.27E-18	Cyanide	4.00E+00	Trichlorofluoromethane		1
Adsorption Isotherm Coefficient, Kd	meter^3/gram	1.10E-07	2.40E-14	Chlordane	8.80E-03	4,4' - DDE	foc = 0.002	1, 3
Diffusion Coefficient in Air	meter^2/day	1.99E-03	1.49E-11	Benzo(g,h,i)perylene	1.30E-01	Vinyl Chloride		1
Diffusion Coefficient in Water	meter^2/day	9.16E-05	1.04E-05	Vinyl Chloride	1.47E-04	Acetonitrile		1
Bulk Density	gram/meter^3	1.50E+06	1.00E+06	N/A	2.00E+06	N/A		2

Notes:

1. Alabama Department of Environmental Management, 2008. Alabama Risk-Based Corrective Action Guidance Manual, Table 3-3 Physical and Chemical Properties.
2. Tan. K.H., 2000, Environmental Soil Science, Second Edition, pp 240.
3. foc = fraction of organic carbon by weight in the soil. Value of 0.002 is recommended in: U.S. EPA, 1996, Soil Screening Guidance, EPA Document Number EPA/540/R-95/128, Part 5: Chemical-Specific Parameters, July.
4. N/A - Not Applicable.

TABLE II-3-1

RECYCLED WATER STUDY

Sampling Priority	Chemical	Method	Lab	Sample Volume (mL)	Hold time (days)
1	ORP		handheld instrument		
2	pH		handheld instrument		
3	Chlorine, Total	Hach kit	handheld instrument	0.1	0.01
4	Dissolved Oxygen	multi-meter	handheld instrument		0.01
5	Alkalinity, Total	SM2320B	Weck	50	14
6	Bicarbonate Alkalinity	SM2320B	Weck	(with alkalinity)	14
7	Boron	EPA 200.7	Weck	250	180
8	Calcium	EPA 200.7	Weck	(with boron)	180
9	Magnesium	EPA 200.7	Weck	(with boron)	180
10	Sodium	EPA 200.7	Weck	(with boron)	180
11	Potassium	EPA 200.7	Weck	(with boron)	180
12	Sulfate	EPA 300.0	Weck	250	28
13	Nitrite	EPA 300.0	Weck	(with sulfate)	2
14	Nitrate	EPA 300.0	Weck	(with sulfate)	2
15	Chloride	EPA 300.0	Weck	(with sulfate)	28
16	Bromide	EPA 300.0	Weck	(with sulfate)	28
17	Total Organic Carbon (TOC)	SM5310C	Weck	250	28
18	Total Filterable Residue at 180C (TDS)	SM2540C	Weck / Cranmer	500	7
19	Dissolved Organic Carbon	SM5310C	Weck	250	28
20	Bromodichloromethane	EPA 524.2	Weck	120	14
21	Bromoform	EPA 524.2	Weck	(with bromodichloromethane)	14
22	Chloroform	EPA 524.2	Weck	(with bromodichloromethane)	14
23	Carbon Tetrachloride	EPA 524.2	Weck	(with bromodichloromethane)	14
24	Dibromochloromethane	EPA 524.2	Weck	(with bromodichloromethane)	14
25	Xylenes, Total	EPA 524.2	Weck	(with bromodichloromethane)	14
26	Additional 8010-list VOCs	EPA 524.2	Weck	(with bromodichloromethane)	14
27	Bromochloroacetic Acid	EPA 552.2	Weck	250	14
28	Dibromoacetic Acid	EPA 552.2	Weck	(with bromochloroacetic)	14
29	Dichloroacetic Acid	EPA 552.2	Weck	(with bromochloroacetic)	14
30	Monobromoacetic Acid	EPA 552.2	Weck	(with bromochloroacetic)	14
31	Monochloroacetic Acid	EPA 552.2	Weck	(with bromochloroacetic)	14
32	Trichloroacetic Acid	EPA 552.2	Weck	(with bromochloroacetic)	14
33	Heterotrophic Plate Count	SM 9215 B	EMLab P&K / Cranmer	150	1
34	Coliforms, Total	SM 9221 B	EMLab P&K / Cranmer	(with HPC)	1
35	Fecal Coliforms	SM 9221 E	EMLab P&K / Cranmer	(with HPC)	1
36	E. Coli	SM 9221 F	EMLab P&K / Cranmer	(with HPC)	1
37	N-Nitroso Dimethylamine (NDMA)	EPA 1625	MWH	2000	7
38	Perchlorate	EPA 314.0	Weck	250	28
39	Cyanide	SM 4500CN E	Weck	500	14
40	Perfluorochemicals	MWH LC/MS/MS	MWH	125	14
41	Phosphate	EPA365.1/0.2	Weck	125	2
42	Nitrilotriacetic acid (NTA)	EPA 300 (mod)	subcontracted by MWH	125	28
43	Ethylenediaminetetraacetic acid (EDTA)	EPA 300 (mod)	subcontracted by MWH	(with NTA)	28
44	Surfactants (MBAS)	SM 5540C	EMLab P&K / Cranmer	1000	2
45	Terbuthylazine	EPA 525 plus	MWH	2000	14

	TOTAL			8195.1	

TABLE II-3-2
PHYSICAL ANALYSIS RESULTS
SOIL CORE BENCH TEST
RECYCLED WATER STUDY

	Location of Derived Sample					Bench Effluent Information				Initial Hydraulic Conductivity (by ASTM D-5084, Method C) (cm/sec)	Sieve Analysis and Hydrometer Test				Clay Mineralogy from X-Ray Diffraction		
Sample ID	Subbasin	Region	Soil Description	Grain Category	USCS Code	Pore Volume (cc)	Number of Pore Volumes Passed	Time Passed (hr)	Final Hydraulic Conductivity (cm/sec)		% Gravel	% Sand	% Silt	% Clay	Main Abundance	Minor (5-10%)	Trace (<5%)
SJSC-A	Santa Clara	Unconfined	brown lean clay	Fine	CL	N/A	<1	2880	<1.06E-06	4.70E-06	1.8	5.8	76	16.5	K, V, S, M	HIM	Q
SJSC-D	Santa Clara	Unconfined	brown silty clay	Fine	CL - ML	203.6	88	17.5	1.40E-02	3.10E-04	1.4	12.3	66.3	20	K, S, C, M	V, HIM, Q	-
SJSC-B	Santa Clara	Unconfined	brown lean clay	Semi-fine	CL	N/A	<1	2880	<1.92E-06	1.10E-08	0.2	12.9	39.9	47	K, M, V	S, Q	-
SJSC-C	Santa Clara	Unconfined	brown poorly graded gravel w/ silt and sand	Coarse	GP - GM	340.8	54	203	1.24E-03	N/A [1]	70.5	21.3	8.2		N/A [1]	N/A [1]	N/A [1]
SCRWA-A	Llagas	Confined	dark gray lean clay with sand	Fine	CL	N/A	<1	2880	<7.00E-07	2.80E-07	0	17.4	58.6	24	S, K	V	Q, M
SCRWA-D	Llagas	Confined	dark gray lean clay w/ sand	Fine	CL	228.3	63	2.42	8.15E-02	5.40E-07	0	28.8	47.2	24	S, K	M, V	Q
SCRWA-B	Llagas	Confined	brown silt w/ sand	Semi-fine	ML	885.7	18.5	63	3.57E-03	5.30E-06	0	41.5	47.5	11	S, K, M, V	-	HIM, Q
SCRWA-C	Llagas	Unconfined	brown well-graded sand w/ gravel	Coarse	SW	529.2	35	6.4	3.97E-02	1.30E-03	33.6	61.5	4.9	0	S, C, K	M, HIM, Q, F	-
DI-A	Santa Clara	Confined	brown silty clay	Fine	CL - ML	N/A	<1	2880	<1.11E-06	2.40E-04	0	1.9	79.1	19	C, K	S, V, HIM	Q
DI-B	Llagas	Unconfined	reddish brown clayey sand w/ gravel	Semi-fine	SC	N/A	<1	2880	<2.06E-06	1.10E-04	20.4	50.5	15.1	14	S, V	-	M
DI-C	Santa Clara	Unconfined	brown well-graded sand w/ silty clay and gravel	Coarse	SW - SC	802.9	23	4.1	6.18E-02	4.00E-04	25.8	63.5	6.7	4	M, K	S, Q	C, F

Notes:

1. Due to high rock content, there was only sufficient material to do a sieve analysis and hydrometer test for SJSC-C; hydraulic conductivity and x-ray diffraction test were not performed
2. SJSC-A, SJSC-B, SCRWA-A, DI-A, DI-B did not have sufficient effluent data to estimate hydraulic conductivity
3. Mineral legend: C = Chlorite, F = Feldspar, HIM = Hydroxy-Interlayered 2:1 Mineral, K = Kaolinite, M = Mica, Q = Quartz, S = Smectite, V = Vermiculite
4. Observed Hydraulic Conductivity dervived from Darcy's Law, K = Q / iA, i is taken as 1 ft/ft
5. N/A - Not applicable.
6. SJSC-D and SCRWA-D are samples with gypsum added.
7. USCS - Unified Soil Classification System
8. Quartz, feldspar, and hydryoxy-interlayer 2:1 mineral are not clay mineral but were observed in testing.

TABLE II-3-3: SJSC-A (fine-grained)
ANALYTICAL DATA
BENCH SCALE TEST
RECYCLED WATER STUDY

	Sample ID	SJ/SC WPCP Source Influent				Soil Core SJSC-A Effluent		% Rem
	Round	1st	1st (Dup)	2nd	2nd (Dup)	1st	2nd	1st
Parameter	Units							
Analytical Method: handheld instrument								
Dissolved Oxygen (DO)	mg/L	0.04	0.04	8.1	8.6	8.4	NA	-20900.0%
ORP	mV	417	417	244	221	160	NA	61.6%
pH		7.4	7.4	7.3	8.0	7.6	NA	-2.7%
Residual Chlorine	mg/L	8.8	8.8	0.0	0.0	0.0	NA	100.0%

Notes:

Dup - denotes a field duplicate sample. A percent difference above 25% is indicative of a significant difference.

NA - denotes not available. For effluent results, this indicates there was inadequate volume to collect a sample. For % Rem, this indicates the value could not be calculated.

% Rem - is the percent concentration removal from influent to effluent of the given round and can be expresed as [(influent - effluent) / inluent]. Non detected values are treated at the reporting limit. A positive value is indicative of removal.

All constituents that could be analayzed are listed in Table II-3-1. In some cases, there was not enough volume to analyze for all the constituents in Table II-3-1.

TABLE II-3-4: SJSC-B (semifine-grained)
ANALYTICAL DATA
BENCH SCALE TEST
RECYCLED WATER STUDY

	Field Sample ID	SJ/SC WPCP Source Influent				Soil Core SJSC-B Effluent		% Rem
	Round	1st	1st (Dup)	2nd	2nd (Dup)	1st	2nd	1st
Parameter	Units							
Analytical Method: handheld instrument								
Dissolved Oxygen (DO)	mg/L	0.04	0.04	8.1	8.6	8.4	NA	-20900.0%
ORP	mV	417	417	244	221	178	NA	57.3%
pH		7.4	7.4	7.3	8.0	8.0	NA	-8.1%
Residual Chlorine	mg/L	8.8	8.8	0.0	0.0	0.35	NA	96.0%

Notes:

Dup - denotes a field duplicate sample. A percent difference above 25% is indicative of a significant difference.

NA - denotes not available. For effluent results, this indicates there was inadequate volume to collect a sample. For % Rem, this indicates the value could not be calculated.

% Rem - is the percent concentration removal from influent to effluent of the given round and can be expresed as [(influent - effluent) / inluent]. Non detected values are treated at the reporting limit. A positive value is indicative of removal.

All constituents that could be analayzed are listed in Table II-3-1. In some cases, there was not enough volume to analyze for all the constituents in Table II-3-1.

TABLE II-3-5: SJSC-C (coarse-grained)
BENCH TEST: ANALYTICAL DATA
SANTA CLARA VALLEY WATER DISTRICT
RECYCLED WATER STUDY

	Sample ID	SJ/SC WPCP Source Influent				Soil Core SJSC-C Effluent		% Rem	% Rem
	Round	1st	1st (Dup)	2nd	2nd (Dup)	1st	2nd	1st	2nd
Parameter	Units								
Analytical Method: EPA 160.1/SM 2540C									
Total Dissolved Solids	mg/L	690	680	652 (C)	649	705 (C)	701	-2.2%	-7.5%
Analytical Method: EPA 1625mod									
N-Nitroso dimethylamine (NDMA)	ng/L	112	116	349	375	ND 2	327	98.2%	6.3%
Analytical Method: EPA 200.7									
Calcium	mg/l	54	53	50	52	57	57	-5.6%	-14.0%
Magnesium	mg/l	30	29	27	28	26	26	13.3%	3.7%
Potassium	mg/l	16	15	16	17	11	11	31.3%	31.3%
Sodium	mg/l	130	130	130	140	130	140	0.0%	-7.7%
Total Boron	µg/L	480	480	440	470	430	440	10.4%	0.0%
Analytical Method: EPA 300 mod									
EDTA	µg/L	ND 100	ND 100	ND 100	159	147	117	-47.0%	-17.0%
NTA	µg/L	ND 100	ND 100	ND 100	ND 100	ND 100	NT	0.0%	NA
Analytical Method: EPA 300.0									
Bromide	mg/l	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Chloride	mg/l	190	190	200	210	210	210	-10.5%	-5.0%
Nitrate as N	mg/L	9.6 (O-09)	9.3 (O-09)	7.6 (O-04)	7.5	7.4 (O-09)	NT	22.9%	NA
Nitrite as N	mg/L	ND 0.15 (O-09)	ND 0.15 (O-09)	1.7 (O-04)	1.7	0.18 (O-09)	NT	-20.0%	NA
Sulfate as SO4	mg/l	94	96	100	100	100	100	-6.4%	0.0%
Analytical Method: EPA 314.0									
Perchlorate	µg/L	ND 4.0	ND 4.0	ND 4.0	ND 4.0	ND 4.0	ND 4.0	0.0%	0.0%
Analytical Method: EPA 335.4/SM 4500 CN E									
Total Cyanide	µg/L	ND 5.0	ND 5.0	ND 5.0	ND 5.0	ND 5.0	ND 5.0	0.0%	0.0%
Analytical Method: EPA 365.3									
Phosphorus, Total as P	mg/l	NT	NT	0.44	0.54	0.26	0.27	NA	38.6%

TABLE II-3-5: SJSC-C (coarse-grained)
BENCH TEST: ANALYTICAL DATA
SANTA CLARA VALLEY WATER DISTRICT
RECYCLED WATER STUDY

	Sample ID	SJ/SC WPCP Source Influent				Soil Core SJSC-C Effluent		% Rem	% Rem
	Round	1st	1st (Dup)	2nd	2nd (Dup)	1st	2nd	1st	2nd
Parameter	Units								
Analytical Method: EPA 425.1/SM 5540C									
Surfactants (MBAS)	mg/l	0.21	0.18	0.11	ND 0.05	0.12	0.10	42.9%	9.1%
Analytical Method: EPA 524.2									
1,1,1,2-Tetrachloroethane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
1,1,1-Trichloroethane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
1,1,2,2-Tetrachloroethane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
1,1,2-Trichloroethane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
1,1-Dichloroethane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
1,1-Dichloroethene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
1,1-Dichloropropene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
1,2,3-Trichlorobenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
1,2,3-Trichloropropane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
1,2,4-Trichlorobenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
1,2,4-Trimethylbenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
1,2-Dichloroethane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
1,2-Dichloropropane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
1,3 Dichloropropene (Total)	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
1,3,5-Trimethylbenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
1,3-Dichloropropane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
2,2-Dichloropropane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
2-Butanone	µg/L	ND 5.0	ND 5.0	ND 5.0	ND 5.0	2200	54	-43900.0%	-980.0%
2-Chloroethyl vinyl ether	µg/L	ND 1.0	ND 1.0	ND 1.0	ND 1.0	ND 1.0	ND 1.0	0.0%	0.0%
2-Chlorotoluene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
2-Hexanone	µg/L	ND 5.0	ND 5.0	ND 5.0	ND 5.0	ND 5.0	ND 5.0	0.0%	0.0%
4-Chlorotoluene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
4-Methyl-2-pentanone	µg/L	ND 5.0	ND 5.0	ND 5.0	ND 5.0	ND 5.0	ND 5.0	0.0%	0.0%
Benzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Bromobenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Bromochloromethane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%

TABLE II-3-5: SJSC-C (coarse-grained)
BENCH TEST: ANALYTICAL DATA
SANTA CLARA VALLEY WATER DISTRICT
RECYCLED WATER STUDY

	Sample ID	SJ/SC WPCP Source Influent				Soil Core SJSC-C Effluent		% Rem	% Rem
	Round	1st	1st (Dup)	2nd	2nd (Dup)	1st	2nd	1st	2nd
Parameter	Units								
Analytical Method: EPA 524.2									
Bromodichloromethane	µg/L	15	16	2.5	1.4	4.8	5.2	68.0%	-108.0%
Bromoform	µg/L	1.3	1.3	ND 0.50	ND 0.50	0.50	0.61	61.5%	-22.0%
Bromomethane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Carbon tetrachloride	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Chlorobenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Chloroethane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Chloroform	µg/L	12	13	3.6	1.9	6.7	6.6	44.2%	-83.3%
Chloromethane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
cis-1,2-Dichloroethene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
cis-1,3-Dichloropropene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Di-isopropyl ether	µg/L	ND 3.0	ND 3.0	ND 3.0	ND 3.0	ND 3.0	ND 3.0	0.0%	0.0%
Dibromochloromethane	µg/L	7.1	7.8	0.84	ND 0.50	2.5	2.9	64.8%	-245.2%
Dibromomethane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Dichlorodifluoromethane (Freon 12)	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Ethyl tert-butyl ether	µg/L	ND 3.0	ND 3.0	ND 3.0	ND 3.0	ND 3.0	ND 3.0	0.0%	0.0%
Ethylbenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Freon 113	µg/L	ND 5.0	ND 5.0	ND 5.0	ND 5.0	ND 5.0	ND 5.0	0.0%	0.0%
Hexachlorobutadiene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Isopropylbenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
m,p-Xylene	µg/L	ND 1.0	ND 1.0	ND 1.0	ND 1.0	ND 1.0	ND 1.0	0.0%	0.0%
m-Dichlorobenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Methyl tert-butyl ether (MTBE)	µg/L	ND 3.0	ND 3.0	ND 3.0	ND 3.0	ND 3.0	ND 3.0	0.0%	0.0%
Methylene chloride	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
n-Butylbenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
n-Propylbenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Naphthalene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
o-Dichlorobenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
o-Xylene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%

TABLE II-3-5: SJSC-C (coarse-grained)
BENCH TEST: ANALYTICAL DATA
SANTA CLARA VALLEY WATER DISTRICT
RECYCLED WATER STUDY

	Sample ID	SJ/SC WPCP Source Influent				Soil Core SJSC-C Effluent		% Rem	% Rem
	Round	1st	1st (Dup)	2nd	2nd (Dup)	1st	2nd	1st	2nd
Parameter	Units								
Analytical Method: EPA 524.2									
p-Dichlorobenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
p-Isopropyltoluene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
sec-Butylbenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Styrene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Tert-amyl methyl ether	µg/L	ND 3.0	ND 3.0	ND 3.0	ND 3.0	ND 3.0	ND 3.0	0.0%	0.0%
tert-Butylbenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Tetrachloroethene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Toluene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.83	0.51	-66.0%	-2.0%
trans-1,2-Dichloroethene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
trans-1,3-Dichloropropene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Trichloroethene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Trichlorofluoromethane	µg/L	ND 5.0	ND 5.0	ND 5.0	ND 5.0	ND 5.0	ND 5.0	0.0%	0.0%
Vinyl chloride	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Xylenes (total)	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Analytical Method: EPA 525.2									
2,4-Dinitrotoluene	µg/L	ND 0.1 (Q5)	ND 0.1 (Q5)	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
2,6-Dinitrotoluene	µg/L	ND 0.1 (Q5)	ND 0.1 (Q5)	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
4,4'-DDD	µg/L	ND 0.1 (Q5)	ND 0.1 (Q5)	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
4,4'-DDE	µg/L	ND 0.1 (Q5)	ND 0.1 (Q5)	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
4,4'-DDT	µg/L	ND 0.1 (Q5)	ND 0.1 (Q5)	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Acenaphthene	µg/L	ND 0.1 (Q5)	ND 0.1 (Q5)	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Acenaphthylene	µg/L	ND 0.1 (Q5)	ND 0.1 (Q5)	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Acetochlor	µg/L	ND 0.1 (Q5)	ND 0.1 (Q5)	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Alachlor	µg/L	ND 0.05 (Q5)	ND 0.05 (Q5)	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Aldrin	µg/L	ND 0.05 (Q5)	ND 0.05 (Q5)	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Alpha-BHC	µg/L	ND 0.1 (Q5)	ND 0.1 (Q5)	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
alpha-Chlordane	µg/L	ND 0.05 (Q5)	ND 0.05 (Q5)	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Anthracene	µg/L	ND 0.02 (Q5)	ND 0.02 (Q5)	ND 0.02	ND 0.02	ND 0.02	ND 0.02	0.0%	0.0%

TABLE II-3-5: SJSC-C (coarse-grained)
BENCH TEST: ANALYTICAL DATA
SANTA CLARA VALLEY WATER DISTRICT
RECYCLED WATER STUDY

	Sample ID	SJ/SC WPCP Source Influent				Soil Core SJSC-C Effluent		% Rem	% Rem
	Round	1st	1st (Dup)	2nd	2nd (Dup)	1st	2nd	1st	2nd
Parameter	Units								
Analytical Method: EPA 525.2									
Atrazine	µg/L	ND 0.05 (Q5)	ND 0.05 (Q5)	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Benz(a)Anthracene	µg/L	ND 0.05 (Q5)	ND 0.05 (Q5)	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Benzo(a)pyrene	µg/L	ND 0.02 (Q5)	ND 0.02 (Q5)	ND 0.02	ND 0.02	ND 0.02	ND 0.02	0.0%	0.0%
Benzo(b)Fluoranthene	µg/L	ND 0.02 (Q5)	ND 0.02 (Q5)	ND 0.02	ND 0.02	ND 0.02	ND 0.02	0.0%	0.0%
Benzo(g,h,i)perylene	µg/L	ND 0.05 (Q5)	ND 0.05 (Q5)	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Benzo(k)Fluoranthene	µg/L	ND 0.02 (Q5)	ND 0.02 (Q5)	ND 0.02	ND 0.02	ND 0.02	ND 0.02	0.0%	0.0%
Beta-BHC	µg/L	ND 0.1 (Q5)	ND 0.1 (Q5)	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Bromacil	µg/L	ND 0.2 (Q5)	ND 0.2 (Q5)	ND 0.2	ND 0.2	ND 0.2	ND 0.2	0.0%	0.0%
Butachlor	µg/L	ND 0.05 (Q5)	ND 0.05 (Q5)	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
butylbenzylphthalate	µg/L	ND 0.5 (Q5)	ND 0.5 (Q5)	ND 0.5	ND 0.5	ND 0.5	ND 0.5	0.0%	0.0%
Caffeine by method 525mod	µg/L	ND 0.02 (Q5)	ND 0.02 (Q5)	ND 0.02	ND 0.02	ND 0.02	ND 0.02	0.0%	0.0%
Chlorobenzilate	µg/L	ND 0.1 (Q5)	ND 0.1 (Q5)	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Chloroneb	µg/L	ND 0.1 (Q5)	ND 0.1 (Q5)	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Chlorothalonil(Draconil,Bravo)	µg/L	ND 0.1 (Q5)	ND 0.1 (Q5)	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Chlorpyrifos (Dursban)	µg/L	ND 0.05 (Q5)	ND 0.05 (Q5)	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Chyrsene	µg/L	ND 0.02 (Q5)	ND 0.02 (Q5)	ND 0.02	ND 0.02	ND 0.02	ND 0.02	0.0%	0.0%
Delta-BHC	µg/L	ND 0.1 (Q5)	ND 0.1 (Q5)	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Di(2-Ethylhexyl)phthalate	µg/L	ND 0.6 (Q5)	ND 0.6 (Q5)	ND 0.6	ND 0.6	ND 0.6	ND 0.6	0.0%	0.0%
Di-(2-Ethylhexyl)adipate	µg/L	ND 0.6 (Q5)	ND 0.6 (Q5)	ND 0.6	ND 0.6	ND 0.6	ND 0.6	0.0%	0.0%
Di-n-Butylphthalate	µg/L	ND 1 (Q5)	ND 1 (Q5)	ND 1	ND 1	ND 1	ND 1	0.0%	0.0%
Di-N-octylphthalate	µg/L	ND 0.1 (Q5)	ND 0.1 (Q5)	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Diazinon (Qualitative)	µg/L	ND 0.1 (Q5)	ND 0.1 (Q5)	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Dibenz(a,h)Anthracene	µg/L	ND 0.05 (Q5)	ND 0.05 (Q5)	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Dichlorvos (DDVP)	µg/L	ND 0.05 (Q5)	ND 0.05 (Q5)	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Dieldrin	µg/L	ND 0.2 (Q5)	ND 0.2 (Q5)	ND 0.2	ND 0.2	ND 0.2	ND 0.2	0.0%	0.0%
Diethylphthalate	µg/L	ND 0.5 (Q5)	ND 0.5 (Q5)	1.3	1.3	ND 0.5	ND 0.5	0.0%	61.5%
Dimethoate	µg/L	ND 0.1 (Q5)	ND 0.1 (Q5)	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Dimethylphthalate	µg/L	ND 0.5 (Q5)	ND 0.5 (Q5)	ND 0.5	ND 0.5	ND 0.5	ND 0.5	0.0%	0.0%

TABLE II-3-5: SJSC-C (coarse-grained)
BENCH TEST: ANALYTICAL DATA
SANTA CLARA VALLEY WATER DISTRICT
RECYCLED WATER STUDY

	Sample ID	SJ/SC WPCP Source Influent				Soil Core SJSC-C Effluent		% Rem	% Rem
	Round	1st	1st (Dup)	2nd	2nd (Dup)	1st	2nd	1st	2nd
Parameter	Units								
Analytical Method: EPA 525.2									
Endosulfan I (Alpha)	µg/L	ND 0.1 (Q5)	ND 0.1 (Q5)	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Endosulfan II (Beta)	µg/L	ND 0.1 (Q5)	ND 0.1 (Q5)	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Endosulfan Sulfate	µg/L	ND 0.1 (Q5)	ND 0.1 (Q5)	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Endrin Aldehyde	µg/L	ND 0.1 (Q5)	ND 0.1 (Q5)	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Endrin	µg/L	ND 0.2 (Q5)	ND 0.2 (Q5)	ND 0.2	ND 0.2	ND 0.2	ND 0.2	0.0%	0.0%
EPTC	µg/L	ND 0.1 (Q5)	ND 0.1 (Q5)	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Fluoranthene	µg/L	ND 0.1 (Q5)	ND 0.1 (Q5)	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Fluorene	µg/L	ND 0.05 (Q5)	ND 0.05 (Q5)	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
gamma-Chlordane	µg/L	ND 0.05 (Q5)	ND 0.05 (Q5)	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Heptachlor Epoxide (isomer B)	µg/L	ND 0.05 (Q5)	ND 0.05 (Q5)	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Heptachlor	µg/L	ND 0.03 (Q5)	ND 0.03 (Q5)	ND 0.03	ND 0.03	ND 0.03	ND 0.03	0.0%	0.0%
Hexachlorobenzene	µg/L	ND 0.05 (Q5)	ND 0.05 (Q5)	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Hexachlorocyclopentadiene	µg/L	ND 0.05 (Q5)	ND 0.05 (Q5)	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Indeno(1,2,3,c,d)Pyrene	µg/L	ND 0.05 (Q5)	ND 0.05 (Q5)	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Isophorone	µg/L	ND 0.5 (Q5)	ND 0.5 (Q5)	ND 0.5	ND 0.5	ND 0.5	ND 0.5	0.0%	0.0%
Lindane	µg/L	ND 0.04 (Q5)	ND 0.04 (Q5)	ND 0.04	ND 0.04	ND 0.04	ND 0.04	0.0%	0.0%
Malathion	µg/L	ND 0.1 (Q5)	ND 0.1 (Q5)	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Methoxychlor	µg/L	ND 0.1 (Q5)	ND 0.1 (Q5)	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Metolachlor	µg/L	ND 0.05 (Q5)	ND 0.05 (Q5)	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
metribuzin	µg/L	ND 0.05 (Q5)	ND 0.05 (Q5)	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Molinate	µg/L	ND 0.1 (Q5)	ND 0.1 (Q5)	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Naphthalene	µg/L	ND 0.1 (Q5)	ND 0.1 (Q5)	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Parathion	µg/L	ND 0.1 (Q5)	ND 0.1 (Q5)	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Pendimethalin	µg/L	ND 0.1 (Q5)	ND 0.1 (Q5)	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Pentachlorophenol	µg/L	ND 1 (Q5)	ND 1 (Q5)	ND 1	ND 1	ND 1	ND 1	0.0%	0.0%
Permethrin (mixed isomers)	µg/L	ND 0.1 (Q5)	ND 0.1 (Q5)	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Phenanthrene	µg/L	ND 0.04 (Q5)	ND 0.04 (Q5)	ND 0.04	ND 0.04	ND 0.04	ND 0.04	0.0%	0.0%
Propachlor	µg/L	ND 0.05 (Q5)	ND 0.05 (Q5)	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%

TABLE II-3-5: SJSC-C (coarse-grained)
BENCH TEST: ANALYTICAL DATA
SANTA CLARA VALLEY WATER DISTRICT
RECYCLED WATER STUDY

	Sample ID	SJ/SC WPCP Source Influent				Soil Core SJSC-C Effluent		% Rem	% Rem
	Round	1st	1st (Dup)	2nd	2nd (Dup)	1st	2nd	1st	2nd
Parameter	Units								
Analytical Method: EPA 525.2									
Pyrene	µg/L	ND 0.05 (Q5)	ND 0.05 (Q5)	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Simazine	µg/L	ND 0.05 (Q5)	ND 0.05 (Q5)	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Terbacil	µg/L	ND 0.1 (Q5)	ND 0.1 (Q5)	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Terbuthylazine	µg/L	ND 0.1 (Q5)	ND 0.1 (Q5)	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Thiobencarb	µg/L	ND 0.2 (Q5)	ND 0.2 (Q5)	ND 0.2	ND 0.2	ND 0.2	ND 0.2	0.0%	0.0%
trans-Nonachlor	µg/L	ND 0.05 (Q5)	ND 0.05 (Q5)	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Trifluralin	µg/L	ND 0.1 (Q5)	ND 0.1 (Q5)	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Analytical Method: EPA 552.2									
Bromochloroacetic acid (bcaa)	µg/L	9.6	10	ND 1.0	ND 1.0	4.8	6.3	50.0%	-530.0%
Dibromoacetic acid (dbaa)	µg/L	3.4	3.3	ND 1.0	ND 1.0	1.8	2.7	47.1%	-170.0%
Dichloroacetic acid (dcaa)	µg/L	14	15	1.5	1.2	6.4	7.0	54.3%	-366.7%
Monobromoacetic acid (mbaa)	µg/L	ND 1.0	ND 1.0	ND 1.0	ND 1.0	ND 1.0	ND 1.0	0.0%	0.0%
Monochloroacetic acid (mcaa)	µg/L	ND 2.0	ND 2.0	ND 2.0	ND 2.0	ND 2.0	ND 2.0	0.0%	0.0%
Total HAA5	µg/L	27	29	1.5	1.2	20	22	25.9%	-1366.7%
Trichloroacetic acid (tcaa)	µg/L	9.7	11	ND 1.0	ND 1.0	12	12	-23.7%	-1100.0%
Analytical Method: handheld instrument									
Dissolved Oxygen (DO)	mg/L	0.040	NT	8.1	8.6	8.3	8.5	-20650.0%	-4.9%
ORP	mV	417	NT	244	221	156	149	62.6%	38.9%
pH		7.4	NT	7.3	8.0	7.9	7.7	-6.8%	-5.5%
Residual Chlorine	mg/L	8.8	NT	0.0	0.0	1.2	0.52	86.4%	NA
Analytical Method: MWH PFC									
Perfluoro butanoic acid (PFBA)	ng/L	ND 50	ND 50	ND 50	ND 50	940	ND 50	-1780.0%	0.0%
Perfluoro octanesulfonate (PFOS)	ng/L	ND 50	ND 50	ND 50	ND 50	572	51	-1044.0%	-2.0%
Perfluoro octanoic acid (PFOA)	ng/L	ND 20	29	109	80	325	80	-1525.0%	26.6%
Analytical Method: SM 2320B									
Alkalinity as CaCO3	mg/l	190	190	160	170	180	180	5.3%	-12.5%
Bicarbonate Alkalinity as HCO3	mg/l	230	230	200	210	220	220	4.3%	-10.0%
Carbonate Alkalinity as CaCO3	mg/l	ND 2.0	ND 2.0	ND 2.0	ND 2.0	ND 2.0	ND 2.0	0.0%	0.0%

TABLE II-3-5: SJSC-C (coarse-grained)
BENCH TEST: ANALYTICAL DATA
SANTA CLARA VALLEY WATER DISTRICT
RECYCLED WATER STUDY

	Sample ID	SJ/SC WPCP Source Influent				Soil Core SJSC-C Effluent		% Rem	% Rem
	Round	1st	1st (Dup)	2nd	2nd (Dup)	1st	2nd	1st	2nd
Parameter	Units								
Analytical Method: SM 2320B									
Hydroxide Alkalinity as CaCO3	mg/l	ND 2.0	ND 2.0	ND 2.0	ND 2.0	ND 2.0	ND 2.0	0.0%	0.0%
Analytical Method: SM 5310C									
Dissolved Organic Carbon	mg/l	6.8	7.0	5.9	6.0	6.2	6.0	8.8%	-1.7%
Total Organic Carbon (TOC)	mg/l	6.9	6.9	6.1	6.0	6.7	5.9	2.9%	3.3%
Analytical Method: SM 9215B									
Heterotrophic Plate Count (HPC)	CFU/mL	2.0	6.0	41765	68090	Too High	1779500	NA	-4160.7%
Analytical Method: SM 9221/9221B									
Total Coliform	MPN/100mL	ND 2	ND 2	9.0 (C)	4.0	8.0	80	-300.0%	-788.9%
Analytical Method: SM 9221/9221E									
Fecal Coliform	MPN/100mL	ND 2	ND 2	ND 2 (C)	ND 2	ND 2	ND 2	0.0%	0.0%
Analytical Method: SM 9221F/9223									
E. coli	MPN/100mL	ND 2	ND 2	Absent (C)	Absent	Absent	Absent	NA	NA
Total Coliform	MPN/100mL	NT	NT	326 (C)	411	4.1	205	NA	37.1%

Notes:

ND - denotes result was below the detection limit
NT - dentoes sample was not tested
Dup - denotes a field duplicate sample. A percent difference above 25% is indicative of a significant difference.
NA - denotes not available. For effluent results, this indicates there was inadequate volume to collect a sample. For % Rem, this indicates the value could not be calculated.
% Rem - is the percent concentration removal from influent to effluent of the given round and can be expresed as [(influent - effluent) / inluent]. Non detected values are treated at the reporting limit. A positive value is indicative of removal.
Nitrate and Nitrite not tested in the core effluent secound round because hold time of sample would have been significantly exceeded
All constituents that could be analayzed are listed in Table II-3-1. In some cases, there was not enough volume to analyze for all the constituents in Table II-3-1.

Flags:

C - The sample was analyzed beyond holding time
Q5 - Sample received with inadequate chemcial perservation, but perserved by the laboratory.
O-04 - This analysis was performed outside the EPA recommended holding time.
O-09 - This sample was received with the EPA recommended holding time expired.

TABLE II-3-6: SJSC-D (fine-grained with gypsum)
BENCH TEST: ANALYTICAL DATA
SANTA CLARA VALLEY WATER DISTRICT
RECYCLED WATER STUDY

	Sample ID	SJ/SC WPCP Source Influent				Soil Core SJSC-D Effluent		% Rem	% Rem
	Round	1st	1st (Dup)	2nd	2nd (Dup)	1st	2nd	1st	2nd
Parameter	Units								
Analytical Method: EPA 160.1/SM 2540C									
Total Dissolved Solids	mg/L	690	680	652 (C)	649	723 (C)	700	-4.8%	-7.4%
Analytical Method: EPA 1625mod									
N-Nitroso dimethylamine (NDMA)	ng/L	112	116	349	375	211	139	-88.4%	60.2%
Analytical Method: EPA 200.7									
Calcium	mg/l	54	53	50	52	57	51	-5.6%	-2.0%
Magnesium	mg/l	30	29	27	28	41	32	-36.7%	-18.5%
Potassium	mg/l	16	15	16	17	9.3	12	41.9%	25.0%
Sodium	mg/l	130	130	130	140	120	130	7.7%	0.0%
Total Boron	µg/L	480	480	440	470	440	430	8.3%	2.3%
Analytical Method: EPA 300 mod									
EDTA	µg/L	ND 100	ND 100	ND 100	159	174	100	-74.0%	0.0%
NTA	µg/L	ND 100	ND 100	ND 100	ND 100	ND 100	ND 100	0.0%	0.0%
Analytical Method: EPA 300.0									
Bromide	mg/l	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Chloride	mg/l	190	190	200	210	200	180	-5.3%	10.0%
Nitrate as N	mg/L	9.6 (O-09)	9.3 (O-09)	7.6 (O-04)	7.5	ND 0.11 (O-09)	NT	98.9%	NA
Nitrite as N	mg/L	ND 0.15 (O-09)	ND 0.15 (O-09)	1.7 (O-04)	1.7	3.4 (O-09)	NT	-2166.7%	NA
Sulfate as SO4	mg/l	94	96	100	100	140	97	-48.9%	3.0%
Analytical Method: EPA 314.0									
Perchlorate	µg/L	ND 4.0	ND 4.0	ND 4.0	ND 4.0	ND 4.0	ND 4.0	0.0%	0.0%
Analytical Method: EPA 335.4/SM 4500 CN E									
Total Cyanide	µg/L	ND 5.0	ND 5.0	ND 5.0	ND 5.0	ND 5.0	ND 5.0	0.0%	0.0%
Analytical Method: EPA 365.3									
Phosphorus, Total as P	mg/l	NT	NT	0.44	0.54	0.28	0.053	NA	88.0%

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TABLE II-3-6: SJSC-D (fine-grained with gypsum)
BENCH TEST: ANALYTICAL DATA
SANTA CLARA VALLEY WATER DISTRICT
RECYCLED WATER STUDY

	Sample ID	SJ/SC WPCP Source Influent				Soil Core SJSC-D Effluent		% Rem	% Rem
	Round	1st	1st (Dup)	2nd	2nd (Dup)	1st	2nd	1st	2nd
Parameter	Units								
Analytical Method: EPA 425.1/SM 5540C									
Surfactants (MBAS)	mg/L	0.21	0.18	0.11	ND 0.05	0.10	0.090	52.4%	18.2%
Analytical Method: EPA 524.2									
1,1,1,2-Tetrachloroethane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
1,1,1-Trichloroethane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
1,1,2,2-Tetrachloroethane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
1,1,2-Trichloroethane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
1,1-Dichloroethane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
1,1-Dichloroethene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
1,1-Dichloropropene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
1,2,3-Trichlorobenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
1,2,3-Trichloropropane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
1,2,4-Trichlorobenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
1,2,4-Trimethylbenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
1,2-Dichloroethane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
1,2-Dichloropropane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
1,3 Dichloropropene (Total)	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
1,3,5-Trimethylbenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
1,3-Dichloropropane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
2,2-Dichloropropane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
2-Butanone	µg/L	ND 5.0	ND 5.0	ND 5.0	ND 5.0	62000	14	-1239900%	-180.0%
2-Chloroethyl vinyl ether	µg/L	ND 1.0	ND 1.0	ND 1.0	ND 1.0	ND 1.0	ND 1.0	0.0%	0.0%
2-Chlorotoluene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
2-Hexanone	µg/L	ND 5.0	ND 5.0	ND 5.0	ND 5.0	ND 5.0	ND 5.0	0.0%	0.0%
4-Chlorotoluene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
4-Methyl-2-pentanone	µg/L	ND 5.0	ND 5.0	ND 5.0	ND 5.0	ND 5.0	ND 5.0	0.0%	0.0%
Benzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Bromobenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Bromochloromethane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%

TABLE II-3-6: SJSC-D (fine-grained with gypsum)
BENCH TEST: ANALYTICAL DATA
SANTA CLARA VALLEY WATER DISTRICT
RECYCLED WATER STUDY

	Sample ID	SJ/SC WPCP Source Influent				Soil Core SJSC-D Effluent		% Rem	% Rem
	Round	1st	1st (Dup)	2nd	2nd (Dup)	1st	2nd	1st	2nd
Parameter	Units								
Analytical Method: EPA 524.2									
Bromodichloromethane	µg/L	15	16	2.5	1.4	2.3	3.5	84.7%	-40.0%
Bromoform	µg/L	1.3	1.3	ND 0.50	ND 0.50	ND 0.50	ND 0.50	61.5%	0.0%
Bromomethane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Carbon tetrachloride	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Chlorobenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Chloroethane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Chloroform	µg/L	12	13	3.6	1.9	2.8	4.2	76.7%	-16.7%
Chloromethane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.61	ND 0.50	-22.0%	0.0%
cis-1,2-Dichloroethene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
cis-1,3-Dichloropropene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Di-isopropyl ether	µg/L	ND 3.0	ND 3.0	ND 3.0	ND 3.0	ND 3.0	ND 3.0	0.0%	0.0%
Dibromochloromethane	µg/L	7.1	7.8	0.84	ND 0.50	1.3	1.9	81.7%	-126.2%
Dibromomethane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Dichlorodifluoromethane (Freon 12)	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Ethyl tert-butyl ether	µg/L	ND 3.0	ND 3.0	ND 3.0	ND 3.0	ND 3.0	ND 3.0	0.0%	0.0%
Ethylbenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Freon 113	µg/L	ND 5.0	ND 5.0	ND 5.0	ND 5.0	ND 5.0	ND 5.0	0.0%	0.0%
Hexachlorobutadiene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Isopropylbenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
m,p-Xylene	µg/L	ND 1.0	ND 1.0	ND 1.0	ND 1.0	ND 1.0	ND 1.0	0.0%	0.0%
m-Dichlorobenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Methyl tert-butyl ether (MTBE)	µg/L	ND 3.0	ND 3.0	ND 3.0	ND 3.0	ND 3.0	ND 3.0	0.0%	0.0%
Methylene chloride	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.60	ND 0.50	-20.0%	0.0%
n-Butylbenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
n-Propylbenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Naphthalene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
o-Dichlorobenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
o-Xylene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%

TABLE II-3-6: SJSC-D (fine-grained with gypsum)
BENCH TEST: ANALYTICAL DATA
SANTA CLARA VALLEY WATER DISTRICT
RECYCLED WATER STUDY

	Sample ID	SJ/SC WPCP Source Influent				Soil Core SJSC-D Effluent		% Rem	% Rem
	Round	1st	1st (Dup)	2nd	2nd (Dup)	1st	2nd	1st	2nd
Parameter	Units								
Analytical Method: EPA 524.2									
p-Dichlorobenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
p-Isopropyltoluene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
sec-Butylbenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Styrene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Tert-amyl methyl ether	µg/L	ND 3.0	ND 3.0	ND 3.0	ND 3.0	ND 3.0	ND 3.0	0.0%	0.0%
tert-Butylbenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Tetrachloroethene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Toluene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.96	ND 0.50	-92.0%	0.0%
trans-1,2-Dichloroethene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
trans-1,3-Dichloropropene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Trichloroethene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Trichlorofluoromethane	µg/L	ND 5.0	ND 5.0	ND 5.0	ND 5.0	ND 5.0	ND 5.0	0.0%	0.0%
Vinyl chloride	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Xylenes (total)	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Analytical Method: EPA 525.2									
2,4-Dinitrotoluene	µg/L	ND 0.1 (Q5)	ND 0.1 (Q5)	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
2,6-Dinitrotoluene	µg/L	ND 0.1 (Q5)	ND 0.1 (Q5)	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
4,4'-DDD	µg/L	ND 0.1 (Q5)	ND 0.1 (Q5)	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
4,4'-DDE	µg/L	ND 0.1 (Q5)	ND 0.1 (Q5)	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
4,4'-DDT	µg/L	ND 0.1 (Q5)	ND 0.1 (Q5)	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Acenaphthene	µg/L	ND 0.1 (Q5)	ND 0.1 (Q5)	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Acenaphthylene	µg/L	ND 0.1 (Q5)	ND 0.1 (Q5)	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Acetochlor	µg/L	ND 0.1 (Q5)	ND 0.1 (Q5)	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Alachlor	µg/L	ND 0.05 (Q5)	ND 0.05 (Q5)	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Aldrin	µg/L	ND 0.05 (Q5)	ND 0.05 (Q5)	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Alpha-BHC	µg/L	ND 0.1 (Q5)	ND 0.1 (Q5)	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
alpha-Chlordane	µg/L	ND 0.05 (Q5)	ND 0.05 (Q5)	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Anthracene	µg/L	ND 0.02 (Q5)	ND 0.02 (Q5)	ND 0.02	ND 0.02	ND 0.02	ND 0.02	0.0%	0.0%

TABLE II-3-6: SJSC-D (fine-grained with gypsum)
BENCH TEST: ANALYTICAL DATA
SANTA CLARA VALLEY WATER DISTRICT
RECYCLED WATER STUDY

	Sample ID	SJ/SC WPCP Source Influent				Soil Core SJSC-D Effluent		% Rem	% Rem
	Round	1st	1st (Dup)	2nd	2nd (Dup)	1st	2nd	1st	2nd
Parameter	Units								
Analytical Method: EPA 525.2									
Atrazine	µg/L	ND 0.05 (Q5)	ND 0.05 (Q5)	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Benz(a)Anthracene	µg/L	ND 0.05 (Q5)	ND 0.05 (Q5)	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Benzo(a)pyrene	µg/L	ND 0.02 (Q5)	ND 0.02 (Q5)	ND 0.02	ND 0.02	ND 0.02	ND 0.02	0.0%	0.0%
Benzo(b)Fluoranthene	µg/L	ND 0.02 (Q5)	ND 0.02 (Q5)	ND 0.02	ND 0.02	ND 0.02	ND 0.02	0.0%	0.0%
Benzo(g,h,i)perylene	µg/L	ND 0.05 (Q5)	ND 0.05 (Q5)	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Benzo(k)Fluoranthene	µg/L	ND 0.02 (Q5)	ND 0.02 (Q5)	ND 0.02	ND 0.02	ND 0.02	ND 0.02	0.0%	0.0%
Beta-BHC	µg/L	ND 0.1 (Q5)	ND 0.1 (Q5)	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Bromacil	µg/L	ND 0.2 (Q5)	ND 0.2 (Q5)	ND 0.2	ND 0.2	ND 0.2	ND 0.2	0.0%	0.0%
Butachlor	µg/L	ND 0.05 (Q5)	ND 0.05 (Q5)	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
butylbenzylphthalate	µg/L	ND 0.5 (Q5)	ND 0.5 (Q5)	ND 0.5	ND 0.5	ND 0.5	ND 0.5	0.0%	0.0%
Caffeine by method 525mod	µg/L	ND 0.02 (Q5)	ND 0.02 (Q5)	ND 0.02	ND 0.02	ND 0.02	ND 0.02	0.0%	0.0%
Chlorobenzilate	µg/L	ND 0.1 (Q5)	ND 0.1 (Q5)	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Chloroneb	µg/L	ND 0.1 (Q5)	ND 0.1 (Q5)	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Chlorothalonil(Draconil,Bravo)	µg/L	ND 0.1 (Q5)	ND 0.1 (Q5)	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Chlorpyrifos (Dursban)	µg/L	ND 0.05 (Q5)	ND 0.05 (Q5)	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Chyrsene	µg/L	ND 0.02 (Q5)	ND 0.02 (Q5)	ND 0.02	ND 0.02	ND 0.02	ND 0.02	0.0%	0.0%
Delta-BHC	µg/L	ND 0.1 (Q5)	ND 0.1 (Q5)	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Di(2-Ethylhexyl)phthalate	µg/L	ND 0.6 (Q5)	ND 0.6 (Q5)	ND 0.6	ND 0.6	ND 0.6	ND 0.6	0.0%	0.0%
Di-(2-Ethylhexyl)adipate	µg/L	ND 0.6 (Q5)	ND 0.6 (Q5)	ND 0.6	ND 0.6	ND 0.6	ND 0.6	0.0%	0.0%
Di-n-Butylphthalate	µg/L	ND 1 (Q5)	ND 1 (Q5)	ND 1	ND 1	ND 1	ND 1	0.0%	0.0%
Di-N-octylphthalate	µg/L	ND 0.1 (Q5)	ND 0.1 (Q5)	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Diazinon (Qualitative)	µg/L	ND 0.1 (Q5)	ND 0.1 (Q5)	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Dibenz(a,h)Anthracene	µg/L	ND 0.05 (Q5)	ND 0.05 (Q5)	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Dichlorvos (DDVP)	µg/L	ND 0.05 (Q5)	ND 0.05 (Q5)	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Dieldrin	µg/L	ND 0.2 (Q5)	ND 0.2 (Q5)	ND 0.2	ND 0.2	ND 0.2	ND 0.2	0.0%	0.0%
Diethylphthalate	µg/L	ND 0.5 (Q5)	ND 0.5 (Q5)	1.3	1.3	ND 0.5	ND 0.5	0.0%	61.5%
Dimethoate	µg/L	ND 0.1 (Q5)	ND 0.1 (Q5)	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Dimethylphthalate	µg/L	ND 0.5 (Q5)	ND 0.5 (Q5)	ND 0.5	ND 0.5	ND 0.5	ND 0.5	0.0%	0.0%

TABLE II-3-6: SJSC-D (fine-grained with gypsum)
BENCH TEST: ANALYTICAL DATA
SANTA CLARA VALLEY WATER DISTRICT
RECYCLED WATER STUDY

	Sample ID	SJ/SC WPCP Source Influent				Soil Core SJSC-D Effluent		% Rem	% Rem
	Round	1st	1st (Dup)	2nd	2nd (Dup)	1st	2nd	1st	2nd
Parameter	Units								
Analytical Method: EPA 525.2									
Endosulfan I (Alpha)	µg/L	ND 0.1 (Q5)	ND 0.1 (Q5)	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Endosulfan II (Beta)	µg/L	ND 0.1 (Q5)	ND 0.1 (Q5)	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Endosulfan Sulfate	µg/L	ND 0.1 (Q5)	ND 0.1 (Q5)	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Endrin Aldehyde	µg/L	ND 0.1 (Q5)	ND 0.1 (Q5)	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Endrin	µg/L	ND 0.2 (Q5)	ND 0.2 (Q5)	ND 0.2	ND 0.2	ND 0.2	ND 0.2	0.0%	0.0%
EPTC	µg/L	ND 0.1 (Q5)	ND 0.1 (Q5)	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Fluoranthene	µg/L	ND 0.1 (Q5)	ND 0.1 (Q5)	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Fluorene	µg/L	ND 0.05 (Q5)	ND 0.05 (Q5)	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
gamma-Chlordane	µg/L	ND 0.05 (Q5)	ND 0.05 (Q5)	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Heptachlor Epoxide (isomer B)	µg/L	ND 0.05 (Q5)	ND 0.05 (Q5)	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Heptachlor	µg/L	ND 0.03 (Q5)	ND 0.03 (Q5)	ND 0.03	ND 0.03	ND 0.03	ND 0.03	0.0%	0.0%
Hexachlorobenzene	µg/L	ND 0.05 (Q5)	ND 0.05 (Q5)	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Hexachlorocyclopentadiene	µg/L	ND 0.05 (Q5)	ND 0.05 (Q5)	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Indeno(1,2,3,c,d)Pyrene	µg/L	ND 0.05 (Q5)	ND 0.05 (Q5)	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Isophorone	µg/L	ND 0.5 (Q5)	ND 0.5 (Q5)	ND 0.5	ND 0.5	ND 0.5	ND 0.5	0.0%	0.0%
Lindane	µg/L	ND 0.04 (Q5)	ND 0.04 (Q5)	ND 0.04	ND 0.04	ND 0.04	ND 0.04	0.0%	0.0%
Malathion	µg/L	ND 0.1 (Q5)	ND 0.1 (Q5)	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Methoxychlor	µg/L	ND 0.1 (Q5)	ND 0.1 (Q5)	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Metolachlor	µg/L	ND 0.05 (Q5)	ND 0.05 (Q5)	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
metribuzin	µg/L	ND 0.05 (Q5)	ND 0.05 (Q5)	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Molinate	µg/L	ND 0.1 (Q5)	ND 0.1 (Q5)	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Naphthalene	µg/L	ND 0.1 (Q5)	ND 0.1 (Q5)	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Parathion	µg/L	ND 0.1 (Q5)	ND 0.1 (Q5)	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Pendimethalin	µg/L	ND 0.1 (Q5)	ND 0.1 (Q5)	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Pentachlorophenol	µg/L	ND 1 (Q5)	ND 1 (Q5)	ND 1	ND 1	ND 1	ND 1	0.0%	0.0%
Permethrin (mixed isomers)	µg/L	ND 0.1 (Q5)	ND 0.1 (Q5)	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Phenanthrene	µg/L	ND 0.04 (Q5)	ND 0.04 (Q5)	ND 0.04	ND 0.04	ND 0.04	ND 0.04	0.0%	0.0%
Propachlor	µg/L	ND 0.05 (Q5)	ND 0.05 (Q5)	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%

TABLE II-3-6: SJSC-D (fine-grained with gypsum)
BENCH TEST: ANALYTICAL DATA
SANTA CLARA VALLEY WATER DISTRICT
RECYCLED WATER STUDY

	Sample ID	SJ/SC WPCP Source Influent				Soil Core SJSC-D Effluent		% Rem	% Rem
	Round	1st	1st (Dup)	2nd	2nd (Dup)	1st	2nd	1st	2nd
Parameter	Units								
Analytical Method: EPA 525.2									
Pyrene	µg/L	ND 0.05 (Q5)	ND 0.05 (Q5)	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Simazine	µg/L	ND 0.05 (Q5)	ND 0.05 (Q5)	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Terbacil	µg/L	ND 0.1 (Q5)	ND 0.1 (Q5)	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Terbuthylazine	µg/L	ND 0.1 (Q5)	ND 0.1 (Q5)	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Thiobencarb	µg/L	ND 0.2 (Q5)	ND 0.2 (Q5)	ND 0.2	ND 0.2	ND 0.2	ND 0.2	0.0%	0.0%
trans-Nonachlor	µg/L	ND 0.05 (Q5)	ND 0.05 (Q5)	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Trifluralin	µg/L	ND 0.1 (Q5)	ND 0.1 (Q5)	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Analytical Method: EPA 552.2									
Bromochloroacetic acid (bcaa)	µg/L	9.6	10	ND 1.0	ND 1.0	5.1	ND 1.0	46.9%	0.0%
Dibromoacetic acid (dbaa)	µg/L	3.4	3.3	ND 1.0	ND 1.0	1.9	ND 1.0	44.1%	0.0%
Dichloroacetic acid (dcaa)	µg/L	14	15	1.5	1.2	9.6	2.0	31.4%	-33.3%
Monobromoacetic acid (mbaa)	µg/L	ND 1.0	ND 1.0	ND 1.0	ND 1.0	ND 1.0	ND 1.0	0.0%	0.0%
Monochloroacetic acid (mcaa)	µg/L	ND 2.0	ND 2.0	ND 2.0	ND 2.0	ND 2.0	ND 2.0	0.0%	0.0%
Total HAA5	µg/L	27	29	1.5	1.2	26	14	3.7%	-833.3%
Trichloroacetic acid (tcaa)	µg/L	9.7	11	ND 1.0	ND 1.0	14	12	-44.3%	-1100.0%
Analytical Method: handheld instrument									
Dissolved Oxygen (DO)	mg/L	0.040	NT	8.1	8.6	8.3	8.6	-20650.0%	-6.2%
ORP	mV	417	NT	244	221	164	171	60.7%	29.9%
pH		7.4	NT	7.3	8.0	8.0	8.0	-8.1%	-9.6%
Residual Chlorine	mg/L	8.8	NT	0.0	0.0	0.0	0.0	100.0%	NA
Analytical Method: MWH PFC									
Perfluoro butanoic acid (PFBA)	ng/L	ND 50	ND 50	ND 50	ND 50	ND 50	ND 50	0.0%	0.0%
Perfluoro octanesulfonate (PFOS)	ng/L	ND 50	ND 50	ND 50	ND 50	ND 50	ND 50	0.0%	0.0%
Perfluoro octanoic acid (PFOA)	ng/L	ND 20	29	109	80	73	120	-265.0%	-10.1%
Analytical Method: SM 2320B									
Alkalinity as CaCO3	mg/l	190	190	160	170	180	200	5.3%	-25.0%
Bicarbonate Alkalinity as HCO3	mg/l	230	230	200	210	220	240	4.3%	-20.0%
Carbonate Alkalinity as CaCO3	mg/l	ND 2.0	ND 2.0	ND 2.0	ND 2.0	ND 2.0	ND 2.0	0.0%	0.0%

TABLE II-3-6: SJSC-D (fine-grained with gypsum)
BENCH TEST: ANALYTICAL DATA
SANTA CLARA VALLEY WATER DISTRICT
RECYCLED WATER STUDY

	Sample ID	SJ/SC WPCP Source Influent				Soil Core SJSC-D Effluent		% Rem	% Rem
	Round	1st	1st (Dup)	2nd	2nd (Dup)	1st	2nd	1st	2nd
Parameter	Units								
Analytical Method: SM 2320B									
Hydroxide Alkalinity as CaCO3	mg/l	ND 2.0	ND 2.0	ND 2.0	ND 2.0	ND 2.0	ND 2.0	0.0%	0.0%
Analytical Method: SM 5310C									
Dissolved Organic Carbon	mg/l	6.8	7.0	5.9	6.0	37	6.3	-444.1%	-6.8%
Total Organic Carbon (TOC)	mg/l	6.9	6.9	6.1	6.0	50	6.4	-624.6%	-4.9%
Analytical Method: SM 9215B									
Heterotrophic Plate Count (HPC)	CFU/mL	2.0	6.0	41765	68090	Too High	ND 1	NA	100.0%
Analytical Method: SM 9221/9221B									
Total Coliform	MPN/100mL	ND 2	ND 2	9.0 (C)	4.0	ND 2	21	0.0%	-133.3%
Analytical Method: SM 9221/9221E									
Fecal Coliform	MPN/100mL	ND 2	ND 2	ND 2 (C)	ND 2	ND 2	4.0	0.0%	-100.0%
Analytical Method: SM 9221F/9223									
E. coli	MPN/100mL	ND 2	ND 2	Absent (C)	Absent	Absent	Absent	NA	NA
Total Coliform	MPN/100mL	NT	NT	326 (C)	411	106	1120	NA	-243.6%

Notes:

ND - denotes result was below the detection limit
NT - dentoes sample was not tested
Dup - denotes a field duplicate sample. A percent difference above 25% is indicative of a significant difference.
NA - denotes not available. For effluent results, this indicates there was inadequate volume to collect a sample. For % Rem, this indicates the value could not be calculated.
% Rem - is the percent concentration removal from influent to effluent of the given round and can be expresed as [(influent - effluent) / inluent]. Non detected values are treated at the reporting limit. A positive value is indicative of removal.
Nitrate and Nitrite not tested in the core effluent secound round because hold time of sample would have been significantly exceeded
All constituents that could be analayzed are listed in Table II-3-1. In some cases, there was not enough volume to analyze for all the constituents in Table II-3-1.

Flags:

C - The sample was analyzed beyond holding time
Q5 - Sample received with inadequate chemcial perservation, but perserved by the laboratory.
O-04 - This analysis was performed outside the EPA recommended holding time.
O-09 - This sample was received with the EPA recommended holding time expired.

TABLE II-3-7: SCRWA-B (semifine-grained)
BENCH TEST: ANALYTICAL DATA
SANTA CLARA VALLEY WATER DISTRICT
RECYCLED WATER STUDY

	Sample ID	SCRWA Source Influent		Soil Core SCRWA-B Effluent		% Rem	% Rem
	Round	1st	2nd	1st	2nd	1st	2nd
Parameter	Units						
Analytical Method: EPA 160.1							
Total Dissolved Solids	mg/L	714 (C)	725	625	593	12.5%	18.2%
Analytical Method: EPA 1625mod							
N-Nitroso dimethylamine (NDMA)	ng/L	4.1	4.0	2.5	4.3	39.0%	-7.5%
Analytical Method: EPA 200.7							
Calcium	mg/l	46	54	110	51	-139.1%	5.6%
Magnesium	mg/l	27	32	71	32	-163.0%	0.0%
Potassium	mg/l	27	32	1.1	1.1	95.9%	96.6%
Sodium	mg/l	140	160	24	140	82.9%	12.5%
Total Boron	µg/L	360	430	400	400	-11.1%	7.0%
Analytical Method: EPA 300 mod							
EDTA	µg/L	232	266	121	ND 100	47.8%	62.4%
NTA	µg/L	ND 100	ND 100	ND 100	NT	0.0%	NA
Analytical Method: EPA 300.0							
Bromide	mg/l	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Chloride	mg/l	230	220	210	200	8.7%	9.1%
Nitrate as N	mg/L	3.4	3.4	2.4 (O-09)	2.7 (O-04)	29.4%	20.6%
Nitrite as N	mg/L	ND 0.15	ND 0.15	0.23 (O-09)	ND 0.15 (O-04)	-53.3%	0.0%
Sulfate as SO4	mg/l	81	82	92	89	-13.6%	-8.5%
Analytical Method: EPA 314.0							
Perchlorate	µg/L	ND 4.0	ND 4.0	ND 4.0	ND 4.0	0.0%	0.0%
Analytical Method: EPA 335.4							
Total Cyanide	µg/L	ND 5.0	ND 5.0	ND 5.0	ND 5.0	0.0%	0.0%
Analytical Method: EPA 365.3							
Phosphorus, Total as P	mg/l	3.9	4.6	0.32	ND 0.050	91.8%	98.9%
Analytical Method: EPA 425.1							
Surfactants (MBAS)	mg/L	0.060	ND 0.05	0.060	ND 0.05	0.0%	0.0%
Analytical Method: EPA 524.2							
1,1,1,2-Tetrachloroethane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
1,1,1-Trichloroethane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
1,1,2,2-Tetrachloroethane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
1,1,2-Trichloroethane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%

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TABLE II-3-7: SCRWA-B (semifine-grained)
BENCH TEST: ANALYTICAL DATA
SANTA CLARA VALLEY WATER DISTRICT
RECYCLED WATER STUDY

	Sample ID	SCRWA Source Influent		Soil Core SCRWA-B Effluent		% Rem	% Rem
	Round	1st	2nd	1st	2nd	1st	2nd
Parameter	Units						
Analytical Method: EPA 524.2							
1,1-Dichloroethane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
1,1-Dichloroethene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
1,1-Dichloropropene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
1,2,3-Trichlorobenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
1,2,3-Trichloropropane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
1,2,4-Trichlorobenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
1,2,4-Trimethylbenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
1,2-Dichloroethane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
1,2-Dichloropropane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
1,3 Dichloropropene (Total)	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
1,3,5-Trimethylbenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
1,3-Dichloropropane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
2,2-Dichloropropane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
2-Butanone	µg/L	ND 5.0	ND 5.0	ND 5.0	5.2	0.0%	-4.0%
2-Chloroethyl vinyl ether	µg/L	ND 1.0	ND 1.0	ND 1.0	ND 1.0	0.0%	0.0%
2-Chlorotoluene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
2-Hexanone	µg/L	ND 5.0	ND 5.0	ND 5.0	ND 5.0	0.0%	0.0%
4-Chlorotoluene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
4-Methyl-2-pentanone	µg/L	ND 5.0	ND 5.0	ND 5.0	ND 5.0	0.0%	0.0%
Benzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Bromobenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Bromochloromethane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Bromodichloromethane	µg/L	12	5.7	3.1	2.1	74.2%	63.2%
Bromoform	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Bromomethane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Carbon tetrachloride	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Chlorobenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Chloroethane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Chloroform	µg/L	40	21	16	9.1	60.0%	56.7%
Chloromethane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
cis-1,2-Dichloroethene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
cis-1,3-Dichloropropene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%

TABLE II-3-7: SCRWA-B (semifine-grained)
BENCH TEST: ANALYTICAL DATA
SANTA CLARA VALLEY WATER DISTRICT
RECYCLED WATER STUDY

	Sample ID	SCRWA Source Influent		Soil Core SCRWA-B Effluent		% Rem	% Rem
	Round	1st	2nd	1st	2nd	1st	2nd
Parameter	Units						
Analytical Method: EPA 524.2							
Di-isopropyl ether	µg/L	ND 3.0	ND 3.0	ND 3.0	ND 3.0	0.0%	0.0%
Dibromochloromethane	µg/L	2.6	1.2	ND 0.50	ND 0.50	80.8%	58.3%
Dibromomethane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Dichlorodifluoromethane (Freon 12)	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Ethyl tert-butyl ether	µg/L	ND 3.0	ND 3.0	ND 3.0	ND 3.0	0.0%	0.0%
Ethylbenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Freon 113	µg/L	ND 5.0	ND 5.0	ND 5.0	ND 5.0	0.0%	0.0%
Hexachlorobutadiene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Isopropylbenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
m,p-Xylene	µg/L	ND 1.0	ND 1.0	ND 1.0	ND 1.0	0.0%	0.0%
m-Dichlorobenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Methyl tert-butyl ether (MTBE)	µg/L	ND 3.0	ND 3.0	ND 3.0	ND 3.0	0.0%	0.0%
Methylene chloride	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
n-Butylbenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
n-Propylbenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Naphthalene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
o-Dichlorobenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
o-Xylene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
p-Dichlorobenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
p-Isopropyltoluene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
sec-Butylbenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Styrene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Tert-amyl methyl ether	µg/L	ND 3.0	ND 3.0	ND 3.0	ND 3.0	0.0%	0.0%
tert-Butylbenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Tetrachloroethene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Toluene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
trans-1,2-Dichloroethene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
trans-1,3-Dichloropropene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Trichloroethene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Trichlorofluoromethane	µg/L	ND 5.0	ND 5.0	ND 5.0	ND 5.0	0.0%	0.0%
Vinyl chloride	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Xylenes (total)	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%

TABLE II-3-7: SCRWA-B (semifine-grained)
BENCH TEST: ANALYTICAL DATA
SANTA CLARA VALLEY WATER DISTRICT
RECYCLED WATER STUDY

	Sample ID	SCRWA Source Influent		Soil Core SCRWA-B Effluent		% Rem	% Rem
	Round	1st	2nd	1st	2nd	1st	2nd
Parameter	Units						
Analytical Method: EPA 525.2							
2,4-Dinitrotoluene	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
2,6-Dinitrotoluene	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
4,4'-DDD	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
4,4'-DDE	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
4,4'-DDT	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Acenaphthene	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Acenaphthylene	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Acetochlor	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Alachlor	µg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Aldrin	µg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Alpha-BHC	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
alpha-Chlordane	µg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Anthracene	µg/L	ND 0.02	ND 0.02	ND 0.02	ND 0.02	0.0%	0.0%
Atrazine	µg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Benz(a)Anthracene	µg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Benzo(a)pyrene	µg/L	ND 0.02	ND 0.02	ND 0.02	ND 0.02	0.0%	0.0%
Benzo(b)Fluoranthene	µg/L	ND 0.02	ND 0.02	ND 0.02	ND 0.02	0.0%	0.0%
Benzo(g,h,i)perylene	µg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Benzo(k)Fluoranthene	µg/L	ND 0.02	ND 0.02	ND 0.02	ND 0.02	0.0%	0.0%
Beta-BHC	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Bromacil	µg/L	ND 0.2	ND 0.2	ND 0.2	ND 0.2	0.0%	0.0%
Butachlor	µg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
butylbenzylphthalate	µg/L	ND 0.5	ND 0.5	ND 0.5	ND 0.5	0.0%	0.0%
Caffeine by method 525mod	µg/L	ND 0.02	ND 0.02	ND 0.02	0.50	0.0%	-2400.0%
Chlorobenzilate	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Chloroneb	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Chlorothalonil(Draconil,Bravo)	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Chlorpyrifos (Dursban)	µg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Chyrsene	µg/L	ND 0.02	ND 0.02	ND 0.02	ND 0.02	0.0%	0.0%
Delta-BHC	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Di(2-Ethylhexyl)phthalate	µg/L	ND 0.6	ND 0.6	ND 0.6	ND 0.6	0.0%	0.0%
Di-(2-Ethylhexyl)adipate	µg/L	ND 0.6	ND 0.6	ND 0.6	ND 0.6	0.0%	0.0%

TABLE II-3-7: SCRWA-B (semifine-grained)
BENCH TEST: ANALYTICAL DATA
SANTA CLARA VALLEY WATER DISTRICT
RECYCLED WATER STUDY

	Sample ID	SCRWA Source Influent		Soil Core SCRWA-B Effluent		% Rem	% Rem
	Round	1st	2nd	1st	2nd	1st	2nd
Parameter	Units						
Analytical Method: EPA 525.2							
Di-n-Butylphthalate	µg/L	ND 1	ND 1	ND 1	ND 1	0.0%	0.0%
Di-N-octylphthalate	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Diazinon (Qualitative)	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Dibenz(a,h)Anthracene	µg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Dichlorvos (DDVP)	µg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Dieldrin	µg/L	ND 0.2	ND 0.2	ND 0.2	ND 0.2	0.0%	0.0%
Diethylphthalate	µg/L	ND 0.5	ND 0.5	ND 0.5	ND 0.5	0.0%	0.0%
Dimethoate	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Dimethylphthalate	µg/L	ND 0.5	ND 0.5	ND 0.5	ND 0.5	0.0%	0.0%
Endosulfan I (Alpha)	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Endosulfan II (Beta)	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Endosulfan Sulfate	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Endrin Aldehyde	µg/L	ND 0.1	ND 0.1 (M2)	ND 0.1	ND 0.1	0.0%	0.0%
Endrin	µg/L	ND 0.2	ND 0.2	ND 0.2	ND 0.2	0.0%	0.0%
EPTC	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Fluoranthene	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Fluorene	µg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
gamma-Chlordane	µg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Heptachlor Epoxide (isomer B)	µg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Heptachlor	µg/L	ND 0.03	ND 0.03	ND 0.03	ND 0.03	0.0%	0.0%
Hexachlorobenzene	µg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Hexachlorocyclopentadiene	µg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Indeno(1,2,3,c,d)Pyrene	µg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Isophorone	µg/L	ND 0.5	ND 0.5	ND 0.5	ND 0.5	0.0%	0.0%
Lindane	µg/L	ND 0.04	ND 0.04	ND 0.04	ND 0.04	0.0%	0.0%
Malathion	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Methoxychlor	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Metolachlor	µg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
metribuzin	µg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Molinate	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Naphthalene	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Parathion	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%

TABLE II-3-7: SCRWA-B (semifine-grained)
BENCH TEST: ANALYTICAL DATA
SANTA CLARA VALLEY WATER DISTRICT
RECYCLED WATER STUDY

	Sample ID	SCRWA Source Influent		Soil Core SCRWA-B Effluent		% Rem	% Rem
	Round	1st	2nd	1st	2nd	1st	2nd
Parameter	Units						
Analytical Method: EPA 525.2							
Pendimethalin	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Pentachlorophenol	µg/L	ND 1 (L3)	ND 1	ND 1	ND 1	0.0%	0.0%
Permethrin (mixed isomers)	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Phenanthrene	µg/L	ND 0.04	ND 0.04	ND 0.04	ND 0.04	0.0%	0.0%
Propachlor	µg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Pyrene	µg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Simazine	µg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Terbacil	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Terbuthylazine	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Thiobencarb	µg/L	ND 0.2	ND 0.2	ND 0.2	ND 0.2	0.0%	0.0%
trans-Nonachlor	µg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Trifluralin	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Analytical Method: EPA 552.2							
Bromochloroacetic acid (bcaa)	µg/L	ND 1.0	ND 1.0	ND 1.0	ND 1.0	0.0%	0.0%
Dibromoacetic acid (dbaa)	µg/L	ND 1.0	ND 1.0	ND 1.0	ND 1.0	0.0%	0.0%
Dichloroacetic acid (dcaa)	µg/L	ND 1.0	ND 1.0	ND 1.0	ND 1.0	0.0%	0.0%
Monobromoacetic acid (mbaa)	µg/L	ND 1.0	ND 1.0	ND 1.0	ND 1.0	0.0%	0.0%
Monochloroacetic acid (mcaa)	µg/L	ND 2.0	ND 2.0	ND 2.0	ND 2.0	0.0%	0.0%
Total HAA5	µg/L	ND 5.0	ND 5.0	ND 5.0	ND 5.0	0.0%	0.0%
Trichloroacetic acid (tcaa)	µg/L	ND 1.0	ND 1.0	ND 1.0	ND 1.0	0.0%	0.0%
Analytical Method: handheld instrument							
Dissolved Oxygen (DO)	mg/L	8.4	8.7	8.3	5.3	1.2%	39.1%
ORP	mV	217	230	172	123	20.7%	46.5%
pH		7.5	8.1	7.3	7.5	2.7%	7.4%
Residual Chlorine	mg/L	0.0	0.0	0.36	0.0	NA	NA
Analytical Method: MWH PFC							
Perfluoro butanoic acid (PFBA)	ng/L	ND 50	ND 50	ND 50	ND 50	0.0%	0.0%
Perfluoro octanesulfonate (PFOS)	ng/L	ND 50	ND 50	ND 50	ND 50	0.0%	0.0%
Perfluoro octanoic acid (PFOA)	ng/L	39	ND 20	77	82	-97.4%	-310.0%
Analytical Method: SM 2320B							
Alkalinity as CaCO3	mg/l	240	250	340	220	-41.7%	12.0%
Bicarbonate Alkalinity as HCO3	mg/l	290	300	410	270	-41.4%	10.0%

TABLE II-3-7: SCRWA-B (semifine-grained)
BENCH TEST: ANALYTICAL DATA
SANTA CLARA VALLEY WATER DISTRICT
RECYCLED WATER STUDY

	Sample ID	SCRWA Source Influent		Soil Core SCRWA-B Effluent		% Rem	% Rem
	Round	1st	2nd	1st	2nd	1st	2nd
Parameter	Units						
Analytical Method: SM 2320B							
Carbonate Alkalinity as CaCO3	mg/l	ND 2.0	ND 2.0	ND 2.0	ND 2.0	0.0%	0.0%
Hydroxide Alkalinity as CaCO3	mg/l	ND 2.0	ND 2.0	ND 2.0	ND 2.0	0.0%	0.0%
Analytical Method: SM 5310C							
Dissolved Organic Carbon	mg/l	4.1	4.1	11	3.5	-168.3%	14.6%
Total Organic Carbon (TOC)	mg/l	4.2	4.0	23	4.3	-447.6%	-7.5%
Analytical Method: SM 9215B							
Heterotrophic Plate Count (HPC)	CFU/mL	24295	33635	Too High	56550	NA	-68.1%
Analytical Method: SM 9221							
Fecal Coliform	MPN/100mL	ND 2	ND 2	ND 2	ND 2	0.0%	0.0%
Total Coliform	MPN/100mL	ND 2	ND 2	ND 2	ND 2	0.0%	0.0%
Analytical Method: SM 9223							
E. coli	MPN/100mL	Absent	Absent	Absent	Absent	NA	NA
Total Coliform	MPN/100mL	2.0	4.1	Absent	Absent	NA	NA

Notes:

ND - denotes result was below the detection limit

NT - dentoes sample was not tested

NA - denotes not available. For effluent results, this indicates there was inadequate volume to collect a sample. For % Rem, this indicates the value could not be calculated.

% Rem - is the percent concentration removal from influent to effluent of the given round and can be expresed as [(influent - effluent) / inluent]. Non detected values are treated at the reporting limit. A positive value is indicative of removal.

All constituents that could be analayzed are listed in Table II-3-1. In some cases, there was not enough volume to analyze for all the constituents in Table II-3-1.

Flags:

C - The sample was analyzed beyond holding time

O-04 - This analysis was performed outside the EPA recommended holding time.

O-09 - This sample was received with the EPA recommended holding time expired.

M2 - Matrix spike reovery was low; the associated blank spike recovery was acceptable

L3 - The associated blank spike recovered was above method acceptance limits

TABLE II-3-8: SCRWA-C (coarse-grained)
BENCH TEST: ANALYTICAL DATA
SANTA CLARA VALLEY WATER DISTRICT
RECYCLED WATER STUDY

	Sample ID	SCRWA Source Influent		Soil Core SCRWA-C Effluent		% Rem	% Rem
	Round	1st	2nd	1st	2nd	1st	2nd
Parameter	Units						
Analytical Method: EPA 160.1							
Total Dissolved Solids	mg/L	714 (C)	725	699 (C)	691	2.1%	4.7%
Analytical Method: EPA 1625mod							
N-Nitroso dimethylamine (NDMA)	ng/L	4.1	4.0	7.3	6.0	-78.0%	-50.0%
Analytical Method: EPA 200.7							
Calcium	mg/l	46	54	75	52	-63.0%	3.7%
Magnesium	mg/l	27	32	52	35	-92.6%	-9.4%
Potassium	mg/l	27	32	9.0	13	66.7%	59.4%
Sodium	mg/l	140	160	91	140	35.0%	12.5%
Total Boron	µg/L	360	430	350	360	2.8%	16.3%
Analytical Method: EPA 300 mod							
EDTA	µg/L	232	266	236	ND 100	-1.7%	62.4%
NTA	µg/L	ND 100	ND 100	ND 100	NT	0.0%	NA
Analytical Method: EPA 300.0							
Bromide	mg/l	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Chloride	mg/l	230	220	210	210	8.7%	4.5%
Nitrate as N	mg/L	3.4	3.4	3.1 (O-09)	NT	8.8%	NA
Nitrite as N	mg/L	ND 0.15	ND 0.15	ND 0.15 (O-09)	NT	0.0%	NA
Sulfate as SO4	mg/l	81	82	89	92	-9.9%	-12.2%
Analytical Method: EPA 314.0							
Perchlorate	µg/L	ND 4.0	ND 4.0	ND 4.0	ND 4.0	0.0%	0.0%
Analytical Method: EPA 335.4							
Total Cyanide	µg/L	ND 5.0	ND 5.0	ND 5.0	ND 5.0	0.0%	0.0%
Analytical Method: EPA 365.3							
Phosphorus, Total as P	mg/l	3.9	4.6	0.46	2.3	88.2%	50.0%
Analytical Method: EPA 425.1							
Surfactants (MBAS)	mg/L	0.060	ND 0.05	0.080	0.070	-33.3%	-40.0%
Analytical Method: EPA 524.2							
1,1,1,2-Tetrachloroethane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
1,1,1-Trichloroethane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
1,1,2,2-Tetrachloroethane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
1,1,2-Trichloroethane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%

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TABLE II-3-8: SCRWA-C (coarse-grained)
BENCH TEST: ANALYTICAL DATA
SANTA CLARA VALLEY WATER DISTRICT
RECYCLED WATER STUDY

	Sample ID	SCRWA Source Influent		Soil Core SCRWA-C Effluent		% Rem	% Rem
	Round	1st	2nd	1st	2nd	1st	2nd
Parameter	Units						
Analytical Method: EPA 524.2							
1,1-Dichloroethane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
1,1-Dichloroethene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
1,1-Dichloropropene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
1,2,3-Trichlorobenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
1,2,3-Trichloropropane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
1,2,4-Trichlorobenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
1,2,4-Trimethylbenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
1,2-Dichloroethane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
1,2-Dichloropropane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
1,3 Dichloropropene (Total)	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
1,3,5-Trimethylbenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
1,3-Dichloropropane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
2,2-Dichloropropane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
2-Butanone	µg/L	ND 5.0	ND 5.0	7300	9.6	-145900.0%	-92.0%
2-Chloroethyl vinyl ether	µg/L	ND 1.0	ND 1.0	ND 1.0	ND 1.0	0.0%	0.0%
2-Chlorotoluene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
2-Hexanone	µg/L	ND 5.0	ND 5.0	ND 5.0	ND 5.0	0.0%	0.0%
4-Chlorotoluene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
4-Methyl-2-pentanone	µg/L	ND 5.0	ND 5.0	ND 5.0	ND 5.0	0.0%	0.0%
Benzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Bromobenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Bromochloromethane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Bromodichloromethane	µg/L	12	5.7	5.0	4.9	58.3%	14.0%
Bromoform	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Bromomethane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Carbon tetrachloride	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Chlorobenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Chloroethane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Chloroform	µg/L	40	21	20	18	50.0%	14.3%
Chloromethane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
cis-1,2-Dichloroethene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
cis-1,3-Dichloropropene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%

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TABLE II-3-8: SCRWA-C (coarse-grained)
BENCH TEST: ANALYTICAL DATA
SANTA CLARA VALLEY WATER DISTRICT
RECYCLED WATER STUDY

	Sample ID	SCRWA Source Influent		Soil Core SCRWA-C Effluent		% Rem	% Rem
	Round	1st	2nd	1st	2nd	1st	2nd
Parameter	Units						
Analytical Method: EPA 524.2							
Di-isopropyl ether	µg/L	ND 3.0	ND 3.0	ND 3.0	ND 3.0	0.0%	0.0%
Dibromochloromethane	µg/L	2.6	1.2	0.94	0.99	63.8%	17.5%
Dibromomethane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Dichlorodifluoromethane (Freon 12)	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Ethyl tert-butyl ether	µg/L	ND 3.0	ND 3.0	ND 3.0	ND 3.0	0.0%	0.0%
Ethylbenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Freon 113	µg/L	ND 5.0	ND 5.0	ND 5.0	ND 5.0	0.0%	0.0%
Hexachlorobutadiene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Isopropylbenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
m,p-Xylene	µg/L	ND 1.0	ND 1.0	ND 1.0	ND 1.0	0.0%	0.0%
m-Dichlorobenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Methyl tert-butyl ether (MTBE)	µg/L	ND 3.0	ND 3.0	ND 3.0	ND 3.0	0.0%	0.0%
Methylene chloride	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
n-Butylbenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
n-Propylbenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Naphthalene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
o-Dichlorobenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
o-Xylene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
p-Dichlorobenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
p-Isopropyltoluene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
sec-Butylbenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Styrene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Tert-amyl methyl ether	µg/L	ND 3.0	ND 3.0	ND 3.0	ND 3.0	0.0%	0.0%
tert-Butylbenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Tetrachloroethene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Toluene	µg/L	ND 0.50	ND 0.50	0.50	ND 0.50	0.0%	0.0%
trans-1,2-Dichloroethene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
trans-1,3-Dichloropropene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Trichloroethene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Trichlorofluoromethane	µg/L	ND 5.0	ND 5.0	ND 5.0	ND 5.0	0.0%	0.0%
Vinyl chloride	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Xylenes (total)	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%

TABLE II-3-8: SCRWA-C (coarse-grained)
BENCH TEST: ANALYTICAL DATA
SANTA CLARA VALLEY WATER DISTRICT
RECYCLED WATER STUDY

	Sample ID	SCRWA Source Influent		Soil Core SCRWA-C Effluent		% Rem	% Rem
	Round	1st	2nd	1st	2nd	1st	2nd
Parameter	Units						
Analytical Method: EPA 525.2							
2,4-Dinitrotoluene	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
2,6-Dinitrotoluene	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
4,4'-DDD	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
4,4'-DDE	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
4,4'-DDT	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Acenaphthene	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Acenaphthylene	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Acetochlor	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Alachlor	µg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Aldrin	µg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Alpha-BHC	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
alpha-Chlordane	µg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Anthracene	µg/L	ND 0.02	ND 0.02	ND 0.02	ND 0.02	0.0%	0.0%
Atrazine	µg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Benz(a)Anthracene	µg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Benzo(a)pyrene	µg/L	ND 0.02	ND 0.02	ND 0.02	ND 0.02	0.0%	0.0%
Benzo(b)Fluoranthene	µg/L	ND 0.02	ND 0.02	ND 0.02	ND 0.02	0.0%	0.0%
Benzo(g,h,i)perylene	µg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Benzo(k)Fluoranthene	µg/L	ND 0.02	ND 0.02	ND 0.02	ND 0.02	0.0%	0.0%
Beta-BHC	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Bromacil	µg/L	ND 0.2	ND 0.2	ND 0.2	ND 0.2	0.0%	0.0%
Butachlor	µg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
butylbenzylphthalate	µg/L	ND 0.5	ND 0.5	ND 0.5	ND 0.5	0.0%	0.0%
Caffeine by method 525mod	µg/L	ND 0.02	ND 0.02	ND 0.02	ND 0.02	0.0%	0.0%
Chlorobenzilate	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Chloroneb	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Chlorothalonil(Draconil,Bravo)	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Chlorpyrifos (Dursban)	µg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Chyrsene	µg/L	ND 0.02	ND 0.02	ND 0.02	ND 0.02	0.0%	0.0%
Delta-BHC	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Di(2-Ethylhexyl)phthalate	µg/L	ND 0.6	ND 0.6	ND 0.6	ND 0.6	0.0%	0.0%
Di-(2-Ethylhexyl)adipate	µg/L	ND 0.6	ND 0.6	ND 0.6	ND 0.6	0.0%	0.0%

TABLE II-3-8: SCRWA-C (coarse-grained)
BENCH TEST: ANALYTICAL DATA
SANTA CLARA VALLEY WATER DISTRICT
RECYCLED WATER STUDY

	Sample ID	SCRWA Source Influent		Soil Core SCRWA-C Effluent		% Rem	% Rem
	Round	1st	2nd	1st	2nd	1st	2nd
Parameter	Units						
Analytical Method: EPA 525.2							
Di-n-Butylphthalate	µg/L	ND 1	ND 1	ND 1	ND 1	0.0%	0.0%
Di-N-octylphthalate	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Diazinon (Qualitative)	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Dibenz(a,h)Anthracene	µg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Dichlorvos (DDVP)	µg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Dieldrin	µg/L	ND 0.2	ND 0.2	ND 0.2	ND 0.2	0.0%	0.0%
Diethylphthalate	µg/L	ND 0.5	ND 0.5	ND 0.5	ND 0.5	0.0%	0.0%
Dimethoate	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Dimethylphthalate	µg/L	ND 0.5	ND 0.5	ND 0.5	ND 0.5	0.0%	0.0%
Endosulfan I (Alpha)	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Endosulfan II (Beta)	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Endosulfan Sulfate	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Endrin Aldehyde	µg/L	ND 0.1	ND 0.1 (M2)	ND 0.1	ND 0.1	0.0%	0.0%
Endrin	µg/L	ND 0.2	ND 0.2	ND 0.2	ND 0.2	0.0%	0.0%
EPTC	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Fluoranthene	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Fluorene	µg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
gamma-Chlordane	µg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Heptachlor Epoxide (isomer B)	µg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Heptachlor	µg/L	ND 0.03	ND 0.03	ND 0.03	ND 0.03	0.0%	0.0%
Hexachlorobenzene	µg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Hexachlorocyclopentadiene	µg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Indeno(1,2,3,c,d)Pyrene	µg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Isophorone	µg/L	ND 0.5	ND 0.5	ND 0.5	ND 0.5	0.0%	0.0%
Lindane	µg/L	ND 0.04	ND 0.04	ND 0.04	ND 0.04	0.0%	0.0%
Malathion	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Methoxychlor	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Metolachlor	µg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
metribuzin	µg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Molinate	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Naphthalene	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Parathion	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%

TABLE II-3-8: SCRWA-C (coarse-grained)
BENCH TEST: ANALYTICAL DATA
SANTA CLARA VALLEY WATER DISTRICT
RECYCLED WATER STUDY

	Sample ID	SCRWA Source Influent		Soil Core SCRWA-C Effluent		% Rem	% Rem
	Round	1st	2nd	1st	2nd	1st	2nd
Parameter	Units						
Analytical Method: EPA 525.2							
Pendimethalin	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Pentachlorophenol	µg/L	ND 1 (L3)	ND 1	ND 1	ND 1	0.0%	0.0%
Permethrin (mixed isomers)	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Phenanthrene	µg/L	ND 0.04	ND 0.04	ND 0.04	ND 0.04	0.0%	0.0%
Propachlor	µg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Pyrene	µg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Simazine	µg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Terbacil	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Terbuthylazine	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Thiobencarb	µg/L	ND 0.2	ND 0.2	ND 0.2	ND 0.2	0.0%	0.0%
trans-Nonachlor	µg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Trifluralin	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Analytical Method: EPA 552.2							
Bromochloroacetic acid (bcaa)	µg/L	ND 1.0	ND 1.0	ND 1.0	ND 1.0	0.0%	0.0%
Dibromoacetic acid (dbaa)	µg/L	ND 1.0	ND 1.0	ND 1.0	ND 1.0	0.0%	0.0%
Dichloroacetic acid (dcaa)	µg/L	ND 1.0	ND 1.0	ND 1.0	ND 1.0	0.0%	0.0%
Monobromoacetic acid (mbaa)	µg/L	ND 1.0	ND 1.0	ND 1.0	ND 1.0	0.0%	0.0%
Monochloroacetic acid (mcaa)	µg/L	ND 2.0	ND 2.0	ND 2.0	ND 2.0	0.0%	0.0%
Total HAA5	µg/L	ND 5.0	ND 5.0	ND 5.0	ND 5.0	0.0%	0.0%
Trichloroacetic acid (tcaa)	µg/L	ND 1.0	ND 1.0	ND 1.0	ND 1.0	0.0%	0.0%
Analytical Method: handheld instrument							
Dissolved Oxygen (DO)	mg/L	8.4	8.7	8.5	8.3	-1.2%	4.6%
ORP	mV	217	230	167	164	23.0%	28.7%
pH		7.5	8.1	7.4	7.4	1.3%	8.6%
Residual Chlorine	mg/L	0.0	0.0	0.40	0.020	NA	NA
Analytical Method: MWH PFC							
Perfluoro butanoic acid (PFBA)	ng/L	ND 50	ND 50	ND 50	ND 50	0.0%	0.0%
Perfluoro octanesulfonate (PFOS)	ng/L	ND 50	ND 50	ND 50	ND 50	0.0%	0.0%
Perfluoro octanoic acid (PFOA)	ng/L	39	ND 20	108	80	-176.9%	-300.0%
Analytical Method: SM 2320B							
Alkalinity as CaCO3	mg/l	240	250	240	230	0.0%	8.0%
Bicarbonate Alkalinity as HCO3	mg/l	290	300	290	280	0.0%	6.7%

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TABLE II-3-8: SCRWA-C (coarse-grained)
BENCH TEST: ANALYTICAL DATA
SANTA CLARA VALLEY WATER DISTRICT
RECYCLED WATER STUDY

	Sample ID	SCRWA Source Influent		Soil Core SCRWA-C Effluent		% Rem	% Rem
	Round	1st	2nd	1st	2nd	1st	2nd
Parameter	Units						
Analytical Method: SM 2320B							
Carbonate Alkalinity as CaCO3	mg/l	ND 2.0	ND 2.0	ND 2.0	ND 2.0	0.0%	0.0%
Hydroxide Alkalinity as CaCO3	mg/l	ND 2.0	ND 2.0	ND 2.0	ND 2.0	0.0%	0.0%
Analytical Method: SM 5310C							
Dissolved Organic Carbon	mg/l	4.1	4.1	24	4.4	-485.4%	-7.3%
Total Organic Carbon (TOC)	mg/l	4.2	4.0	84	4.3	-1900.0%	-7.5%
Analytical Method: SM 9215B							
Heterotrophic Plate Count (HPC)	CFU/mL	24295	33635	Too High	1763500	NA	-5143.1%
Analytical Method: SM 9221							
Fecal Coliform	MPN/100mL	ND 2	ND 2	ND 2	ND 2	0.0%	0.0%
Total Coliform	MPN/100mL	ND 2	ND 2	ND 2	ND 2	0.0%	0.0%
Analytical Method: SM 9223							
E. coli	MPN/100mL	Absent	Absent	Absent	Absent	NA	NA
Total Coliform	MPN/100mL	2.0	4.1	4.1	Absent	-105.0%	NA

Notes:

ND - denotes result was below the detection limit

NT - dentoes sample was not tested

NA - denotes not available. For effluent results, this indicates there was inadequate volume to collect a sample. For % Rem, this indicates the value could not be calculated.

% Rem - is the percent concentration removal from influent to effluent of the given round and can be expresed as [(influent - effluent) / inluent]. Non detected values are treated at the reporting limit. A positive value is indicative of removal.

Nitrate and Nitrite not tested in the core effluent secound round because hold time of sample would have been significantly exceeded

All constituents that could be analayzed are listed in Table II-3-1. In some cases, there was not enough volume to analyze for all the constituents in Table II-3-1.

Flags:

C - The sample was analyzed beyond holding time

O-09 - This sample was received with the EPA recommended holding time expired.

M2 - Matrix spike reovery was low; the associated blank spike recovery was acceptable

L3 - The associated blank spike recovered was above method acceptance limits

TABLE II-3-9: SCRWA-D (fine-grained with gypsum)
BENCH TEST: ANALYTICAL DATA
SANTA CLARA VALLEY WATER DISTRICT
RECYCLED WATER STUDY

	Sample ID	SCRWA Source Influent		Soil Core SCRWA-D Effluent		% Rem	% Rem
	Round	1st	2nd	1st	2nd	1st	2nd
Parameter	Units						
Analytical Method: EPA 160.1							
Total Dissolved Solids	mg/L	714 (C)	725	768 (C)	585	-7.6%	19.3%
Analytical Method: EPA 1625mod							
N-Nitroso dimethylamine (NDMA)	ng/L	4.1	4.0	ND 2	5.4	51.2%	-35.0%
Analytical Method: EPA 200.7							
Calcium	mg/l	46	54	62	55	-34.8%	-1.9%
Magnesium	mg/l	27	32	34	31	-25.9%	3.1%
Potassium	mg/l	27	32	24	24	11.1%	25.0%
Sodium	mg/l	140	160	140	140	0.0%	12.5%
Total Boron	µg/L	360	430	380	370	-5.6%	14.0%
Analytical Method: EPA 300 mod							
EDTA	µg/L	232	266	242	237	-4.3%	10.9%
NTA	µg/L	ND 100	ND 100	ND 100	NT	0.0%	NA
Analytical Method: EPA 300.0							
Bromide	mg/l	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Chloride	mg/l	230	220	210	210	8.7%	4.5%
Nitrate as N	mg/L	3.4	3.4	ND 0.11 (O-09)	NT*	96.8%	NA
Nitrite as N	mg/L	ND 0.15	ND 0.15	ND 0.15 (O-09)	NT*	0.0%	NA
Sulfate as SO4	mg/l	81	82	130	95	-60.5%	-15.9%
Analytical Method: EPA 314.0							
Perchlorate	µg/L	ND 4.0	ND 4.0	ND 4.0	ND 4.0	0.0%	0.0%
Analytical Method: EPA 335.4							
Total Cyanide	µg/L	ND 5.0	ND 5.0	ND 5.0	ND 5.0	0.0%	0.0%
Analytical Method: EPA 365.3							
Phosphorus, Total as P	mg/l	3.9	4.6	2.9	18	25.6%	-291.3%
Analytical Method: EPA 425.1							
Surfactants (MBAS)	mg/L	0.060	ND 0.05	0.080	0.070	-33.3%	-40.0%
Analytical Method: EPA 524.2							
1,1,1,2-Tetrachloroethane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
1,1,1-Trichloroethane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
1,1,2,2-Tetrachloroethane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
1,1,2-Trichloroethane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%

TABLE II-3-9: SCRWA-D (fine-grained with gypsum)
BENCH TEST: ANALYTICAL DATA
SANTA CLARA VALLEY WATER DISTRICT
RECYCLED WATER STUDY

	Sample ID	SCRWA Source Influent		Soil Core SCRWA-D Effluent		% Rem	% Rem
	Round	1st	2nd	1st	2nd	1st	2nd
Parameter	Units						
Analytical Method: EPA 524.2							
1,1-Dichloroethane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
1,1-Dichloroethene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
1,1-Dichloropropene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
1,2,3-Trichlorobenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
1,2,3-Trichloropropane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
1,2,4-Trichlorobenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
1,2,4-Trimethylbenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
1,2-Dichloroethane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
1,2-Dichloropropane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
1,3 Dichloropropene (Total)	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
1,3,5-Trimethylbenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
1,3-Dichloropropane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
2,2-Dichloropropane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
2-Butanone	µg/L	ND 5.0	ND 5.0	180000	ND 5.0	-3599900.0%	0.0%
2-Chloroethyl vinyl ether	µg/L	ND 1.0	ND 1.0	ND 1.0	ND 1.0	0.0%	0.0%
2-Chlorotoluene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
2-Hexanone	µg/L	ND 5.0	ND 5.0	ND 5.0	ND 5.0	0.0%	0.0%
4-Chlorotoluene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
4-Methyl-2-pentanone	µg/L	ND 5.0	ND 5.0	ND 5.0	ND 5.0	0.0%	0.0%
Benzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Bromobenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Bromochloromethane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Bromodichloromethane	µg/L	12	5.7	1.6	3.1	86.7%	45.6%
Bromoform	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Bromomethane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Carbon tetrachloride	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Chlorobenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Chloroethane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Chloroform	µg/L	40	21	6.0	14	85.0%	33.3%
Chloromethane	µg/L	ND 0.50	ND 0.50	0.67	ND 0.50	-34.0%	0.0%
cis-1,2-Dichloroethene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
cis-1,3-Dichloropropene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%

TABLE II-3-9: SCRWA-D (fine-grained with gypsum)
BENCH TEST: ANALYTICAL DATA
SANTA CLARA VALLEY WATER DISTRICT
RECYCLED WATER STUDY

	Sample ID	SCRWA Source Influent		Soil Core SCRWA-D Effluent		% Rem	% Rem
	Round	1st	2nd	1st	2nd	1st	2nd
Parameter	Units						
Analytical Method: EPA 524.2							
Di-isopropyl ether	µg/L	ND 3.0	ND 3.0	ND 3.0	ND 3.0	0.0%	0.0%
Dibromochloromethane	µg/L	2.6	1.2	ND 0.50	0.59	80.8%	50.8%
Dibromomethane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Dichlorodifluoromethane (Freon 12)	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Ethyl tert-butyl ether	µg/L	ND 3.0	ND 3.0	ND 3.0	ND 3.0	0.0%	0.0%
Ethylbenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Freon 113	µg/L	ND 5.0	ND 5.0	ND 5.0	ND 5.0	0.0%	0.0%
Hexachlorobutadiene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Isopropylbenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
m,p-Xylene	µg/L	ND 1.0	ND 1.0	ND 1.0	ND 1.0	0.0%	0.0%
m-Dichlorobenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Methyl tert-butyl ether (MTBE)	µg/L	ND 3.0	ND 3.0	ND 3.0	ND 3.0	0.0%	0.0%
Methylene chloride	µg/L	ND 0.50	ND 0.50	0.78	ND 0.50	-56.0%	0.0%
n-Butylbenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
n-Propylbenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Naphthalene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
o-Dichlorobenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
o-Xylene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
p-Dichlorobenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
p-Isopropyltoluene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
sec-Butylbenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Styrene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Tert-amyl methyl ether	µg/L	ND 3.0	ND 3.0	ND 3.0	ND 3.0	0.0%	0.0%
tert-Butylbenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Tetrachloroethene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Toluene	µg/L	ND 0.50	ND 0.50	0.82	ND 0.50	-64.0%	0.0%
trans-1,2-Dichloroethene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
trans-1,3-Dichloropropene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Trichloroethene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Trichlorofluoromethane	µg/L	ND 5.0	ND 5.0	ND 5.0	ND 5.0	0.0%	0.0%
Vinyl chloride	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Xylenes (total)	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%

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TABLE II-3-9: SCRWA-D (fine-grained with gypsum)
BENCH TEST: ANALYTICAL DATA
SANTA CLARA VALLEY WATER DISTRICT
RECYCLED WATER STUDY

	Sample ID	SCRWA Source Influent		Soil Core SCRWA-D Effluent		% Rem	% Rem
	Round	1st	2nd	1st	2nd	1st	2nd
Parameter	Units						
Analytical Method: EPA 525.2							
2,4-Dinitrotoluene	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
2,6-Dinitrotoluene	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
4,4'-DDD	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
4,4'-DDE	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
4,4'-DDT	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Acenaphthene	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Acenaphthylene	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Acetochlor	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Alachlor	µg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Aldrin	µg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Alpha-BHC	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
alpha-Chlordane	µg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Anthracene	µg/L	ND 0.02	ND 0.02	ND 0.02	ND 0.02	0.0%	0.0%
Atrazine	µg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Benz(a)Anthracene	µg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Benzo(a)pyrene	µg/L	ND 0.02	ND 0.02	ND 0.02	ND 0.02	0.0%	0.0%
Benzo(b)Fluoranthene	µg/L	ND 0.02	ND 0.02	ND 0.02	ND 0.02	0.0%	0.0%
Benzo(g,h,i)perylene	µg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Benzo(k)Fluoranthene	µg/L	ND 0.02	ND 0.02	ND 0.02	ND 0.02	0.0%	0.0%
Beta-BHC	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Bromacil	µg/L	ND 0.2	ND 0.2	ND 0.2	ND 0.2	0.0%	0.0%
Butachlor	µg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
butylbenzylphthalate	µg/L	ND 0.5	ND 0.5	ND 0.5	ND 0.5	0.0%	0.0%
Caffeine by method 525mod	µg/L	ND 0.02	ND 0.02	ND 0.02	ND 0.02	0.0%	0.0%
Chlorobenzilate	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Chloroneb	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Chlorothalonil(Draconil,Bravo)	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Chlorpyrifos (Dursban)	µg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Chyrsene	µg/L	ND 0.02	ND 0.02	ND 0.02	ND 0.02	0.0%	0.0%
Delta-BHC	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Di(2-Ethylhexyl)phthalate	µg/L	ND 0.6	ND 0.6	ND 0.6	ND 0.6	0.0%	0.0%
Di-(2-Ethylhexyl)adipate	µg/L	ND 0.6	ND 0.6	ND 0.6	ND 0.6	0.0%	0.0%

TABLE II-3-9: SCRWA-D (fine-grained with gypsum)
BENCH TEST: ANALYTICAL DATA
SANTA CLARA VALLEY WATER DISTRICT
RECYCLED WATER STUDY

	Sample ID	SCRWA Source Influent		Soil Core SCRWA-D Effluent		% Rem	% Rem
	Round	1st	2nd	1st	2nd	1st	2nd
Parameter	Units						
Analytical Method: EPA 525.2							
Di-n-Butylphthalate	µg/L	ND 1	ND 1	ND 1	ND 1	0.0%	0.0%
Di-N-octylphthalate	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Diazinon (Qualitative)	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Dibenz(a,h)Anthracene	µg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Dichlorvos (DDVP)	µg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Dieldrin	µg/L	ND 0.2	ND 0.2	ND 0.2	ND 0.2	0.0%	0.0%
Diethylphthalate	µg/L	ND 0.5	ND 0.5	ND 0.5	ND 0.5	0.0%	0.0%
Dimethoate	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Dimethylphthalate	µg/L	ND 0.5	ND 0.5	ND 0.5	ND 0.5	0.0%	0.0%
Endosulfan I (Alpha)	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Endosulfan II (Beta)	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Endosulfan Sulfate	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Endrin Aldehyde	µg/L	ND 0.1	ND 0.1 (M2)	ND 0.1	ND 0.1	0.0%	0.0%
Endrin	µg/L	ND 0.2	ND 0.2	ND 0.2	ND 0.2	0.0%	0.0%
EPTC	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Fluoranthene	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Fluorene	µg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
gamma-Chlordane	µg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Heptachlor Epoxide (isomer B)	µg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Heptachlor	µg/L	ND 0.03	ND 0.03	ND 0.03	ND 0.03	0.0%	0.0%
Hexachlorobenzene	µg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Hexachlorocyclopentadiene	µg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Indeno(1,2,3,c,d)Pyrene	µg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Isophorone	µg/L	ND 0.5	ND 0.5	ND 0.5	ND 0.5	0.0%	0.0%
Lindane	µg/L	ND 0.04	ND 0.04	ND 0.04	ND 0.04	0.0%	0.0%
Malathion	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Methoxychlor	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Metolachlor	µg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
metribuzin	µg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Molinate	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Naphthalene	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Parathion	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%

TABLE II-3-9: SCRWA-D (fine-grained with gypsum)
BENCH TEST: ANALYTICAL DATA
SANTA CLARA VALLEY WATER DISTRICT
RECYCLED WATER STUDY

	Sample ID	SCRWA Source Influent		Soil Core SCRWA-D Effluent		% Rem	% Rem
	Round	1st	2nd	1st	2nd	1st	2nd
Parameter	Units						
Analytical Method: EPA 525.2							
Pendimethalin	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Pentachlorophenol	µg/L	ND 1 (L3)	ND 1	ND 1	ND 1	0.0%	0.0%
Permethrin (mixed isomers)	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Phenanthrene	µg/L	ND 0.04	ND 0.04	ND 0.04	ND 0.04	0.0%	0.0%
Propachlor	µg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Pyrene	µg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Simazine	µg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Terbacil	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Terbuthylazine	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Thiobencarb	µg/L	ND 0.2	ND 0.2	ND 0.2	ND 0.2	0.0%	0.0%
trans-Nonachlor	µg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Trifluralin	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Analytical Method: EPA 552.2							
Bromochloroacetic acid (bcaa)	µg/L	ND 1.0	ND 1.0	ND 1.0	ND 1.0	0.0%	0.0%
Dibromoacetic acid (dbaa)	µg/L	ND 1.0	ND 1.0	ND 1.0	ND 1.0	0.0%	0.0%
Dichloroacetic acid (dcaa)	µg/L	ND 1.0	ND 1.0	ND 1.0	ND 1.0	0.0%	0.0%
Monobromoacetic acid (mbaa)	µg/L	ND 1.0	ND 1.0	ND 1.0	ND 1.0	0.0%	0.0%
Monochloroacetic acid (mcaa)	µg/L	ND 2.0	ND 2.0	ND 2.0	ND 2.0	0.0%	0.0%
Total HAA5	µg/L	ND 5.0	ND 5.0	ND 5.0	ND 5.0	0.0%	0.0%
Trichloroacetic acid (tcaa)	µg/L	ND 1.0	ND 1.0	ND 1.0	ND 1.0	0.0%	0.0%
Analytical Method: handheld instrument							
Dissolved Oxygen (DO)	mg/L	8.4	8.7	8.5	8.4	-1.2%	3.4%
ORP	mV	217	230	151	134	30.4%	41.7%
pH		7.5	8.1	7.9	7.8	-5.3%	3.7%
Residual Chlorine	mg/L	0.0	0.0	1.4	0.0	NA	NA
Analytical Method: MWH PFC							
Perfluoro butanoic acid (PFBA)	ng/L	ND 50	ND 50	ND 50	ND 50	0.0%	0.0%
Perfluoro octanesulfonate (PFOS)	ng/L	ND 50	ND 50	ND 50	ND 50	0.0%	0.0%
Perfluoro octanoic acid (PFOA)	ng/L	39	ND 20	99	120	-153.8%	-500.0%
Analytical Method: SM 2320B							
Alkalinity as CaCO3	mg/l	240	250	240	240	0.0%	4.0%
Bicarbonate Alkalinity as HCO3	mg/l	290	300	290	290	0.0%	3.3%

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TABLE II-3-9: SCRWA-D (fine-grained with gypsum)
BENCH TEST: ANALYTICAL DATA
SANTA CLARA VALLEY WATER DISTRICT
RECYCLED WATER STUDY

	Sample ID	SCRWA Source Influent		Soil Core SCRWA-D Effluent		% Rem	% Rem
	Round	1st	2nd	1st	2nd	1st	2nd
Parameter	Units						
Analytical Method: SM 2320B							
Carbonate Alkalinity as CaCO3	mg/l	ND 2.0	ND 2.0	ND 2.0	ND 2.0	0.0%	0.0%
Hydroxide Alkalinity as CaCO3	mg/l	ND 2.0	ND 2.0	ND 2.0	ND 2.0	0.0%	0.0%
Analytical Method: SM 5310C							
Dissolved Organic Carbon	mg/l	4.1	4.1	16	4.3	-290.2%	-4.9%
Total Organic Carbon (TOC)	mg/l	4.2	4.0	35	4.9	-733.3%	-22.5%
Analytical Method: SM 9215B							
Heterotrophic Plate Count (HPC)	CFU/mL	24295	33635	Too High	308000	NA	-815.7%
Analytical Method: SM 9221							
Fecal Coliform	MPN/100mL	ND 2	ND 2	ND 2	ND 2	0.0%	0.0%
Total Coliform	MPN/100mL	ND 2	ND 2	7.0	2.0	-250.0%	0.0%
Analytical Method: SM 9223							
E. coli	MPN/100mL	Absent	Absent	Absent	Absent	NA	NA
Total Coliform	MPN/100mL	2.0	4.1	19	Absent	-850.0%	NA

Notes:

ND - denotes result was below the detection limit

NT - dentoes sample was not tested

NA - denotes not available. For effluent results, this indicates there was inadequate volume to collect a sample. For % Rem, this indicates the value could not be calculated.

% Rem - is the percent concentration removal from influent to effluent of the given round and can be expresed as [(influent - effluent) / inluent]. Non detected values are treated at the reporting limit. A positive value is indicative of removal.

Nitrate and Nitrite not tested in the core effluent secound round because hold time of sample would have been significantly exceeded

All constituents that could be analayzed are listed in Table II-3-1. In some cases, there was not enough volume to analyze for all the constituents in Table II-3-1.

Flags:

C - The sample was analyzed beyond holding time

O-09 - This sample was received with the EPA recommended holding time expired.

M2 - Matrix spike reovery was low; the associated blank spike recovery was acceptable

L3 - The associated blank spike recovered was above method acceptance limits

TABLE II-3-10: DI-A (fine-grained)
ANALYTICAL DATA
BENCH SCALE TEST
RECYCLED WATER STUDY

	Field Sample ID	DI Source Influent		Soil Core DI-A Effluent		% Rem
	Round	1st	2nd	1st	2nd	1st
Parameter	Units					
Analytical Method: handheld instrument						
Dissolved Oxygen (DO)	mg/L	8.3	8.6	8.1	NA	2.4%
ORP	mV	245	297	132	NA	46.1%
pH		6.5	7.0	7.9	NA	-21.5%
Residual Chlorine	mg/L	0.0	0.0	1.7	NA	NA

Notes:

NA - denotes not available. For effluent results, this indicates there was inadequate volume to collect a sample. For % Rem, this indicates the value could not be calculated.

% Rem - is the percent concentration removal from influent to effluent of the given round and can be expresed as [(influent - effluent) / inluent]. Non detected values are treated at the reporting limit. A positive value is indicative of removal.

All constituents that could be analayzed are listed in Table II-3-1. In some cases, there was not enough volume to analyze for all the constituents in Table II-3-1.

TABLE II-3-11: DI-C (coarse-grained)
BENCH TEST: ANALYTICAL DATA
SANTA CLARA VALLEY WATER DISTRICT
RECYCLED WATER STUDY

	Sample ID	DI Source Influent		Soil Core DI-C Effluent		% Rem	% Rem
	Round	1st	2nd	1st	2nd	1st	2nd
Parameter	Units						
Analytical Method: EPA 160.1							
Total Dissolved Solids	mg/L	ND 10	ND 10	964 (C)	1360	-9540.0%	-13500.0%
Analytical Method: EPA 1625mod							
N-Nitroso dimethylamine (NDMA)	ng/L	4.0	8.7	8.6	7.8	-115.0%	10.3%
Analytical Method: EPA 200.7							
Calcium	mg/l	ND 0.10	ND 0.10	64	150	-63900.0%	-149900.0%
Magnesium	mg/l	ND 0.10	ND 0.10	34	40	-33900.0%	-39900.0%
Potassium	mg/l	0.29	ND 0.10	1.7	0.98	-486.2%	-880.0%
Sodium	mg/l	ND 0.50	ND 0.50	150	14	-29900.0%	-2700.0%
Total Boron	µg/L	ND 10	ND 10	66	16	-560.0%	-60.0%
Analytical Method: EPA 300 mod							
EDTA	µg/L	ND 100	100	ND 100	ND 100	0.0%	0.0%
NTA	µg/L	ND 100	ND 100	ND 100	NT	0.0%	NA
Analytical Method: EPA 300.0							
Bromide	mg/l	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Chloride	mg/l	ND 0.50	ND 0.50	450	230	-89900.0%	-45900.0%
Nitrate as N	mg/L	ND 0.11	ND 0.11	ND 0.11 (O-09)	NT	0.0%	NA
Nitrite as N	mg/L	ND 0.15	ND 0.15	ND 0.15 (O-09)	NT	0.0%	NA
Sulfate as SO4	mg/l	ND 0.50	ND 0.50	5.3	3.0	-960.0%	-500.0%
Analytical Method: EPA 314.0							
Perchlorate	µg/L	ND 4.0	ND 4.0	ND 4.0	ND 4.0	0.0%	0.0%
Analytical Method: EPA 335.4							
Total Cyanide	µg/L	ND 5.0	ND 5.0	ND 5.0	ND 5.0	0.0%	0.0%
Analytical Method: EPA 365.3							
Phosphorus, Total as P	mg/l	ND 0.050	ND 0.050	0.42	0.48	-740.0%	-860.0%
Analytical Method: EPA 425.1							
Surfactants (MBAS)	mg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Analytical Method: EPA 524.2							
1,1,1,2-Tetrachloroethane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
1,1,1-Trichloroethane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
1,1,2,2-Tetrachloroethane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
1,1,2-Trichloroethane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%

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TABLE II-3-11: DI-C (coarse-grained)
BENCH TEST: ANALYTICAL DATA
SANTA CLARA VALLEY WATER DISTRICT
RECYCLED WATER STUDY

	Sample ID	DI Source Influent		Soil Core DI-C Effluent		% Rem	% Rem
	Round	1st	2nd	1st	2nd	1st	2nd
Parameter	Units						
Analytical Method: EPA 524.2							
1,1-Dichloroethane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
1,1-Dichloroethene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
1,1-Dichloropropene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
1,2,3-Trichlorobenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
1,2,3-Trichloropropane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
1,2,4-Trichlorobenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
1,2,4-Trimethylbenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
1,2-Dichloroethane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
1,2-Dichloropropane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
1,3 Dichloropropene (Total)	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
1,3,5-Trimethylbenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
1,3-Dichloropropane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
2,2-Dichloropropane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
2-Butanone	µg/L	ND 5.0	16	6400	160	-127900.0%	-900.0%
2-Chloroethyl vinyl ether	µg/L	ND 1.0	ND 1.0	ND 1.0	ND 1.0	0.0%	0.0%
2-Chlorotoluene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
2-Hexanone	µg/L	ND 5.0	ND 5.0	ND 5.0	ND 5.0	0.0%	0.0%
4-Chlorotoluene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
4-Methyl-2-pentanone	µg/L	ND 5.0	ND 5.0	ND 5.0	ND 5.0	0.0%	0.0%
Benzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Bromobenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Bromochloromethane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Bromodichloromethane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Bromoform	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Bromomethane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Carbon tetrachloride	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Chlorobenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Chloroethane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Chloroform	µg/L	ND 0.50	ND 0.50	0.84	0.77	-68.0%	-54.0%
Chloromethane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
cis-1,2-Dichloroethene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
cis-1,3-Dichloropropene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%

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TABLE II-3-11: DI-C (coarse-grained)
BENCH TEST: ANALYTICAL DATA
SANTA CLARA VALLEY WATER DISTRICT
RECYCLED WATER STUDY

	Sample ID	DI Source Influent		Soil Core DI-C Effluent		% Rem	% Rem
	Round	1st	2nd	1st	2nd	1st	2nd
Parameter	Units						
Analytical Method: EPA 524.2							
Di-isopropyl ether	µg/L	ND 3.0	ND 3.0	ND 3.0	ND 3.0	0.0%	0.0%
Dibromochloromethane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Dibromomethane	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Dichlorodifluoromethane (Freon 12)	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Ethyl tert-butyl ether	µg/L	ND 3.0	ND 3.0	ND 3.0	ND 3.0	0.0%	0.0%
Ethylbenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Freon 113	µg/L	ND 5.0	ND 5.0	ND 5.0	ND 5.0	0.0%	0.0%
Hexachlorobutadiene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Isopropylbenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
m,p-Xylene	µg/L	ND 1.0	ND 1.0	ND 1.0	ND 1.0	0.0%	0.0%
m-Dichlorobenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Methyl tert-butyl ether (MTBE)	µg/L	ND 3.0	ND 3.0	ND 3.0	ND 3.0	0.0%	0.0%
Methylene chloride	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
n-Butylbenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
n-Propylbenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Naphthalene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
o-Dichlorobenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
o-Xylene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
p-Dichlorobenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
p-Isopropyltoluene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
sec-Butylbenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Styrene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Tert-amyl methyl ether	µg/L	ND 3.0	ND 3.0	ND 3.0	ND 3.0	0.0%	0.0%
tert-Butylbenzene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Tetrachloroethene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Toluene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
trans-1,2-Dichloroethene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
trans-1,3-Dichloropropene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Trichloroethene	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Trichlorofluoromethane	µg/L	ND 5.0	ND 5.0	ND 5.0	ND 5.0	0.0%	0.0%
Vinyl chloride	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%
Xylenes (total)	µg/L	ND 0.50	ND 0.50	ND 0.50	ND 0.50	0.0%	0.0%

TABLE II-3-11: DI-C (coarse-grained)
BENCH TEST: ANALYTICAL DATA
SANTA CLARA VALLEY WATER DISTRICT
RECYCLED WATER STUDY

	Sample ID	DI Source Influent		Soil Core DI-C Effluent		% Rem	% Rem
	Round	1st	2nd	1st	2nd	1st	2nd
Parameter	Units						
Analytical Method: EPA 525.2							
2,4-Dinitrotoluene	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
2,6-Dinitrotoluene	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
4,4'-DDD	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
4,4'-DDE	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
4,4'-DDT	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Acenaphthene	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Acenaphthylene	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Acetochlor	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Alachlor	µg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Aldrin	µg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Alpha-BHC	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
alpha-Chlordane	µg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Anthracene	µg/L	ND 0.02	ND 0.02	ND 0.02	ND 0.02	0.0%	0.0%
Atrazine	µg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Benz(a)Anthracene	µg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Benzo(a)pyrene	µg/L	ND 0.02	ND 0.02	ND 0.02	ND 0.02	0.0%	0.0%
Benzo(b)Fluoranthene	µg/L	ND 0.02	ND 0.02	ND 0.02	ND 0.02	0.0%	0.0%
Benzo(g,h,i)perylene	µg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Benzo(k)Fluoranthene	µg/L	ND 0.02	ND 0.02	ND 0.02	ND 0.02	0.0%	0.0%
Beta-BHC	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Bromacil	µg/L	ND 0.2	ND 0.2	ND 0.2	ND 0.2	0.0%	0.0%
Butachlor	µg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
butylbenzylphthalate	µg/L	ND 0.5	ND 0.5	ND 0.5	ND 0.5	0.0%	0.0%
Caffeine by method 525mod	µg/L	ND 0.02	ND 0.02	ND 0.02	ND 0.02	0.0%	0.0%
Chlorobenzilate	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Chloroneb	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Chlorothalonil(Draconil,Bravo)	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Chlorpyrifos (Dursban)	µg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Chyrsene	µg/L	ND 0.02	ND 0.02	ND 0.02	ND 0.02	0.0%	0.0%
Delta-BHC	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Di(2-Ethylhexyl)phthalate	µg/L	ND 0.6	ND 0.6	ND 0.6	ND 0.6	0.0%	0.0%
Di-(2-Ethylhexyl)adipate	µg/L	ND 0.6	ND 0.6	ND 0.6	ND 0.6	0.0%	0.0%

TABLE II-3-11: DI-C (coarse-grained)
BENCH TEST: ANALYTICAL DATA
SANTA CLARA VALLEY WATER DISTRICT
RECYCLED WATER STUDY

	Sample ID	DI Source Influent		Soil Core DI-C Effluent		% Rem	% Rem
	Round	1st	2nd	1st	2nd	1st	2nd
Parameter	Units						
Analytical Method: EPA 525.2							
Di-n-Butylphthalate	µg/L	ND 1	ND 1	ND 1	ND 1	0.0%	0.0%
Di-N-octylphthalate	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Diazinon (Qualitative)	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Dibenz(a,h)Anthracene	µg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Dichlorvos (DDVP)	µg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Dieldrin	µg/L	ND 0.2	ND 0.2	ND 0.2	ND 0.2	0.0%	0.0%
Diethylphthalate	µg/L	ND 0.5	ND 0.5	ND 0.5	0.60	0.0%	-20.0%
Dimethoate	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Dimethylphthalate	µg/L	ND 0.5	ND 0.5	ND 0.5	ND 0.5	0.0%	0.0%
Endosulfan I (Alpha)	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Endosulfan II (Beta)	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Endosulfan Sulfate	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Endrin Aldehyde	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Endrin	µg/L	ND 0.2	ND 0.2	ND 0.2	ND 0.2	0.0%	0.0%
EPTC	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Fluoranthene	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Fluorene	µg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
gamma-Chlordane	µg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Heptachlor Epoxide (isomer B)	µg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Heptachlor	µg/L	ND 0.03	ND 0.03	ND 0.03	ND 0.03	0.0%	0.0%
Hexachlorobenzene	µg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Hexachlorocyclopentadiene	µg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Indeno(1,2,3,c,d)Pyrene	µg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Isophorone	µg/L	ND 0.5	ND 0.5	ND 0.5	ND 0.5	0.0%	0.0%
Lindane	µg/L	ND 0.04	ND 0.04	ND 0.04	ND 0.04	0.0%	0.0%
Malathion	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Methoxychlor	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Metolachlor	µg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
metribuzin	µg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Molinate	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Naphthalene	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Parathion	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%

TABLE II-3-11: DI-C (coarse-grained)
BENCH TEST: ANALYTICAL DATA
SANTA CLARA VALLEY WATER DISTRICT
RECYCLED WATER STUDY

	Sample ID	DI Source Influent		Soil Core DI-C Effluent		% Rem	% Rem
	Round	1st	2nd	1st	2nd	1st	2nd
Parameter	Units						
Analytical Method: EPA 525.2							
Pendimethalin	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Pentachlorophenol	µg/L	ND 1 (L3)	ND 1	ND 1	ND 1	0.0%	0.0%
Permethrin (mixed isomers)	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Phenanthrene	µg/L	ND 0.04	ND 0.04	ND 0.04	ND 0.04	0.0%	0.0%
Propachlor	µg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Pyrene	µg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Simazine	µg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Terbacil	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Terbuthylazine	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Thiobencarb	µg/L	ND 0.2	ND 0.2	ND 0.2	ND 0.2	0.0%	0.0%
trans-Nonachlor	µg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.0%	0.0%
Trifluralin	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.0%	0.0%
Analytical Method: EPA 552.2							
Bromochloroacetic acid (bcaa)	µg/L	ND 1.0	ND 1.0	ND 1.0	ND 1.0	0.0%	0.0%
Dibromoacetic acid (dbaa)	µg/L	ND 1.0	ND 1.0	ND 1.0	ND 1.0	0.0%	0.0%
Dichloroacetic acid (dcaa)	µg/L	ND 1.0	ND 1.0	ND 1.0	ND 1.0	0.0%	0.0%
Monobromoacetic acid (mbaa)	µg/L	ND 1.0	ND 1.0	ND 1.0	ND 1.0	0.0%	0.0%
Monochloroacetic acid (mcaa)	µg/L	ND 2.0	ND 2.0	ND 2.0	ND 2.0	0.0%	0.0%
Total HAA5	µg/L	ND 5.0	ND 5.0	ND 5.0	ND 5.0	0.0%	0.0%
Trichloroacetic acid (tcaa)	µg/L	ND 1.0	ND 1.0	ND 1.0	ND 1.0	0.0%	0.0%
Analytical Method: handheld instrument							
Dissolved Oxygen (DO)	mg/L	8.3	8.6	8.7	4.2	-4.8%	51.2%
ORP	mV	245	297	156	195	36.3%	34.3%
pH		6.5	7.0	7.4	7.3	-13.8%	-4.3%
Residual Chlorine	mg/L	0.0	0.0	1.9	1.3	NA	NA
Analytical Method: MWH PFC							
Perfluoro butanoic acid (PFBA)	ng/L	NT	ND 50	ND 50	ND 50	NA	0.0%
Perfluoro octanesulfonate (PFOS)	ng/L	NT	ND 50	ND 50	ND 50	NA	0.0%
Perfluoro octanoic acid (PFOA)	ng/L	NT	88	ND 20	ND 20	NA	77.3%
Analytical Method: SM 2320B							
Alkalinity as CaCO3	mg/l	ND 2.0	ND 2.0	32	9.5	-1500.0%	-375.0%
Bicarbonate Alkalinity as HCO3	mg/l	ND 2.0	ND 2.0	39	12	-1850.0%	-500.0%

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TABLE II-3-11: DI-C (coarse-grained)
BENCH TEST: ANALYTICAL DATA
SANTA CLARA VALLEY WATER DISTRICT
RECYCLED WATER STUDY

	Sample ID	DI Source Influent		Soil Core DI-C Effluent		% Rem	% Rem
	Round	1st	2nd	1st	2nd	1st	2nd
Parameter	Units						
Analytical Method: SM 2320B							
Carbonate Alkalinity as CaCO3	mg/l	ND 2.0	ND 2.0	ND 2.0	ND 2.0	0.0%	0.0%
Hydroxide Alkalinity as CaCO3	mg/l	ND 2.0	ND 2.0	ND 2.0	ND 2.0	0.0%	0.0%
Analytical Method: SM 5310C							
Dissolved Organic Carbon	mg/l	ND 0.30	ND 0.30	13	0.53	-4233.3%	-76.7%
Total Organic Carbon (TOC)	mg/l	ND 0.30	ND 0.30	44	0.68	-14566.7%	-126.7%
Analytical Method: SM 9215B							
Heterotrophic Plate Count (HPC)	CFU/mL	16495	935	Too High	30200	NA	-3129.9%
Analytical Method: SM 9221							
Fecal Coliform	MPN/100mL	ND 2	ND 2	ND 2	ND 2	0.0%	0.0%
Total Coliform	MPN/100mL	ND 2	ND 2	ND 2	4.0	0.0%	-100.0%
Analytical Method: SM 9223							
E. coli	MPN/100mL	Absent	Absent	Absent	Absent	NA	NA
Total Coliform	MPN/100mL	Absent	Absent	238	2419	NA	NA

Notes:

ND - denotes result was below the detection limit

NT - dentoes sample was not tested

NA - denotes not available. For effluent results, this indicates there was inadequate volume to collect a sample. For % Rem, this indicates the value could not be calculated.

% Rem - is the percent concentration removal from influent to effluent of the given round and can be expresed as [(influent - effluent) / inluent]. Non detected values are treated at the reporting limit. A positive value is indicative of removal.

Nitrate and Nitrite not tested in the core effluent secound round because hold time of sample would have been significantly exceeded

PFCs not tested in the DI influent sample in the first round because sample was lost in transit to laboratory

All constituents that could be analayzed are listed in Table II-3-1. In some cases, there was not enough volume to analyze for all the constituents in Table II-3-1.

Flags:

C - The sample was analyzed beyond holding time

O-09 - This sample was received with the EPA recommended holding time expired.

L3 - The associated blank spike recovered was above method acceptance limits

TABLE II-3-12
SODIUM ADSORPTION RATIO

		Influent				Effluent				
		Calcium	Sodium	Magnesium		Calcium	Sodium	Magnesium		
Location	Event	mg/L	mg/L	mg/L	SAR	mg/L	mg/L	mg/L	SAR	% Change SAR
SJSC-C	First	54	130	30	3.5	57	130	26	3.6	1.8
SJSC-C	Second	50	140	27	4.0	57	120	26	3.3	-16.6
SJSC-D	First	54	130	30	3.5	30	130	41	3.6	3.0
SJSC-D	Second	50	130	27	3.7	27	128	32	3.9	7.2
SCRWA-B	First	46	140	27	4.1	110	24	71	0.4	-89.2
SCRWA-B	Second	54	160	32	4.3	51	140	32	3.8	-11.2
SCRWA-C	First	46	140	27	4.1	75	91	52	2.0	-51.2
SCRWA-C	Second	54	160	32	4.3	52	140	35	3.7	-13.7
SCRWA-D	First	46	140	27	4.1	62	140	34	3.5	-12.4
SCRWA-D	Second	54	160	32	4.3	55	140	31	3.7	-12.2
DI-C	First	ND 0.10	ND 0.50	ND 0.10	N/A	64	140	34	3.5	N/A
DI-C	Second	ND 0.10	ND 0.50	ND 0.10	N/A	150	14	40	0.3	N/A

Notes:

A positive change in SAR indicates an exchange of sodium ions for calcium and magnesium ions in the soil matrix which results in clay shrinkage (increased hydraulic conductivity).

A negative change in SAR indicates an exchange of calcium and magnesium ions for sodium ions in the soil matrix which results in clay expansion (reduced hydraulic conductivity).

Volume III
San Jose Pilot Study

Recycled Water Irrigation and Groundwater Study
Santa Clara and Llagas Groundwater Subbasins
Santa Clara County, California

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LIST OF ACRONYMS AND ABBREVIATIONS

ACRONYM	DESCRIPTION
BCAA	bromochloroacetic acid
bgs	below ground surface
ccf	Hundred cubic feet
CDPH	California Department of Public Health
CFU	colony forming units
cm/sec	centimeter per second
COC	chains of custody
CT	contact time
DO	dissolved oxygen
DOC	dissolved organic carbon
DBAA	dibromoacetic acid
DCAA	dichloroacetic acid
EDTA	Ethylenediaminetetraacetic acid
HAA6	group of six haloacetic acids (DBAA, DCAA, MBAA, MCAA, TCAA, BCAA)
HPC	heterotrophic plate count
IDT	Integrated Device Technology
Locus	Locus Technologies
MBAA	monobromoacetic acid
MBAS	methylene blue active substances, also known as surfactants
MCAA	monochloroacetic acid
mg/L	milligrams per liter
mL	Milliliter
MPN	most propable number
MRL	method reporting limit
MS	matrix spike
MSD	matrix spike duplicate

LIST OF ACRONYMS AND ABBREVIATIONS

mV	millivolts
NDMA	N-nitrosodimethylamine
NTA	nitrilotriacetic acid
ng/L	nanograms per liter
ORP	oxidation reduction potential
PARWQCP	Palo Alto Regional Water Quality Control Plant
PFBA	perfluoro butanoic acid
PFCs	Perfluorochemicals
PFOA	perfluoro octanoic acid
PFOS	perfluoro octanesulfonate
QA/QC	Quality assurance and quality control
RPD	relative percent difference
S	Mann-Kendall Statistic
SAR	Sodium Adsorption Ratio
SCRWA	South County Regional Wastewater Authority
SCVWD	Santa Clara Valley Water District
SJ/SC WPCP	San Jose/Santa Clara Water Pollution Control Plant
SWPCP	Sunnyvale Water Pollution Control Plant
TCAA	trichloroacetic acid
TDS	total dissolved solids
THMs	Trihalomethanes
TOC	total organic carbon
TDS	total dissolved solids
µg/L	micrograms per liter
USCS	Unified soil classification system
VOC	Volatile organic carbon

EXECUTIVE SUMMARY

Volume III covers the third phase of the Recycled Water Irrigation and Groundwater Study. The overall goal of the study is to evaluate the potential impact to groundwater from expanded use of recycled water for irrigation in the Santa Clara and Llagas Subbasins. The scope of this volume is a pilot study of the potential impacts from irrigating with recycled water on vadose zone pore water and groundwater at a commercial facility in San Jose.

Description of Site and Monitoring Program

The pilot study was a full-scale test for observing the subsurface fate and transport of recycled water under real conditions for irrigation. The pilot study was conducted at the Integrated Device Technology (IDT) site located at 6024 Silver Creek Valley Road, San Jose, California (Figure III-2-1). The focus of the study is to determine if any constituents found in recycled water could potentially have a negative impact on groundwater when recycled water is used as a water source for irrigation.

The monitoring program for the pilot study included eight lysimeters and four exisitng monitoring wells. The four monitoring wells were used to monitor groundwater constituent concentrations in the shallowest saturated zone, a depth of approximately 30 feet below ground surface (bgs). The eight lysimeters consisted of four installed at five feet depth and four installed at ten feet depth. These lysimeters monitor the pore water in the vadose zone. Due to the high volume requirement for sampling and limited volume capacity in each lysimeter, samples from the four 5-foot depth lysimeters were composited as L5-COMP and the samples from the four 10-foot depth lysimeters were composited as L10-COMP. Recycled water at the irrigation point was also monitored. The irrigated recycled water for this site was derived from the San Jose/Santa Clara Water Pollution Control Plant (SJ/SC WPCP). Recycled water use at the site was first implemented on September 4, 2008. Additives to the landscape included only fertilizer and grub control.

The monitoring program for the pilot study included baseline sampling of the water source and the monitoring wells and 8 subsequent sampling events of the irrigation water, lysimeters and monitoring wells. The frequency of sampling events was initially set at 50 days apart and later adjusted to 75 days to account for slower-than-expected percolation rates and to obtain additional long-term monitoring data. Due to limited sample volume capacity in the lysimeters, interim sampling events were conducted to complete analyses that could not be completed within the regularly scheduled sampling event. The analytes monitored were based on findings from Volumes I and II of this report. A list of these constituents is shown in Table III-3-1.

Pilot Study Implementation

Irrigation of recycled water at the pilot study began on September 4, 2008. Sampling for the pilot study was performed between October 27, 2008 and March 15, 2010. An additional monitoring event occurred on May 19, 2008 prior to recycled water irrigation, which served as the baseline. Results from the data analysis presented in Volume I and previous monitoring by SCVWD on December 12, August 16, and May 16-17 of 2007 were used as supplemental baseline data for comparative purposes. Chemical results for all sampling events are found in Table III-4-1. In addition, charts graphically displaying the chemical results are provided in Figures III-4-1 through III-4-48.

Pilot Study Results

Irrigation of recycled water was implemented on a seasonal basis during periods when there was insufficient natural rainfall to irrigate the landscaping (Figure III-2-2). Over the study period, L5-COMP, which is nearest to the surface, did not exhibit patterns strongly reflective of seasonal changes with irrigation use.

Based on the results obtained from the pilot study, the constituents that showed the highest potential to impact groundwater were NDMA, HAA6, and PFCs, due to their appearance in groundwater during the pilot study. NDMA, HAA6, and PFCs were not detected in the groundwater at the IDT site in the baseline sampling events prior to use of recycled water. For the first two sampling events after recycled water use began at the site, NDMA concentrations were found in the pore water at or above the California Department of Public Health's drinking water notification level of 10 ng/L (CDPH, 2007). NDMA concentrations in the pore water in the third and subsequent events were below 10 ng/L.

PFCs have shown removal in recycled water through the vadose zone in the pilot study but have also appeared in the groundwater at the IDT site. PFBA in particular was not found in the recycled water but was found in pore water sample locations suggesting the transformation to PFBA from other products. HAA6 is also a concern because of its presence in the pore water and potential to reach groundwater.

Sodium, magnesium, and calcium are constituents in recycled water that may limit soil drainage through clay swelling. Findings in the pilot study suggest that clays were already expanded to some degree in the first five feet through the pilot study period. The change in permeability due to the clay swelling could not be quantitatively measured, but was observed to be significant in the bench test portion of the study as reported in Volume II. Soil drainage can be restricted when switching to a water source with a greater sodium adsorption ratio (SAR). In this case the SAR of the recycled water would have to be greater than that of the water source previously used for expansion to occur.

Constituents that indicated moderate potential to impact groundwater include TDS, boron, sulfate, chloride and pathogens. Rising concentrations of chloride in the pore water and groundwater at the IDT site during the pilot study present a concern for potential long-term impact. Overall, chloride removal in the bench test was not well observed. Some biological constituents, specifically heterotrophic bacteria and total coliforms, were found to be present in the recycled water and to some extent in the pore water and groundwater. Overall there is some evidence from the pilot study suggesting that pathogens in recycled water could potentially impact groundwater. TDS results in groundwater, pore water, and recycled water from the pilot study including baseline data exceeded secondary drinking water standards. Moderately high levels of TDS found in groundwater at the IDT site, as seen in the baseline and pilot study, leave less capacity for further increases in TDS due to incoming recycled water used in irrigation. Boron and sulfate data from the pilot study and bench test suggested that attenuation was low. The soil and fertilizer were suspected to contribute more sulfate in the pore water than recycled water alone.

Most constituents indicated only minimal potential to impact groundwater, including phosphate, nitrate, nitrite, potassium, TOC, DOC, and THMs. Major nutrients such as phosphate and nitrate/nitrite appear to be greatly reduced from irrigation when vegetation is present and fertilizer is not overused. The plant uptake process is believed to be the major pathway for nutrient removal. TOC and DOC were not observed to reach groundwater in the pilot study.

Potassium and THMs were relatively stable in the groundwater through the pilot study. THMs were not detected in groundwater. Potassium was detected in groundwater but at concentrations similar to baseline levels. In addition, bench test data of potassium and THMs generally exhibited removal in the soil.

Alkalinity, pH, ORP, DO, and total chlorine showed negligible potential to impact groundwater through recycled water use. The stability of general parameters (pH, ORP and DO) as seen in the pilot study and bench test indicates that there were no major shifts in conditions in the vadose zone. Chlorine measurements in the pilot study in groundwater were generally higher than in recycled water.

VOCs (excluding THMs) were not detected consistently in recycled water in either the bench test or the pilot study and did not pose a potential threat to groundwater at the IDT site. In addition, Volume I of this study found that xylenes and carbon tetrachloride were regarded as having D) minimal potential impact. The data analysis of Volume I also did not find detections of any other VOCs in recycled water.

Cyanide, terbuthylazine, NTA, and perchlorate were not detected consistently in recycled water in either the bench test or the pilot study. Detections that did occur were near or at the reporting limit. In groundwater, only perchlorate was detected once. Because these parameters were not frequently present in the recycled water source at IDT, they did not have impacts to the groundwater at the IDT site. However, the attenuation behavior of these constituents could not be well examined.

EDTA and surfactants were not consistently detected in the recycled water in the pilot study, thus conclusions from the pilot study could not be made. However, EDTA and surfactants were detected in the recycled water during the bench test and were found to not attenuate well in the bench test.

With respect to permeability and the SAR, sodium, calcium, and magnesium do have an impact on groundwater. The water composition, as indicated by the SAR, from the recycled water and the pore water five feet bgs is more sodium-concentrated than the pore water from ten feet bgs and the groundwater. SAR data suggest the presence of clay swelling in the first five feet. However, the impact of the clay swelling on soil permeability could not be quantitatively measured. The sodium, calcium, and magnesium in the pore water at five feet bgs indicates the soil near the surface was already saturated with these three constituents, likely as a result of previous irrigation. Based on these findings, permeability changes due to recycled water as an irrigation source in clay type soils could present a concern for soil drainage when the SAR in recycled water is greater than the previous irrigation source.

Trends for the pilot study were determined in several ways including a piper diagram analysis and Mann-Kendall analysis. The piper diagram analysis used the cation and anion data to evaluate the trends in the groundwater and in the lysimeters. This approach evaluated the cations (calcium, magnesium, sodium, and potassium), and anions (chloride, sulfate, and bicarbonate) on the percent composition based on equivalence per volume concentrations. Results of the piper diagram analysis indicate a shift in the pore water and groundwater towards an ionic composition similar to that of recycled water. This is most evident in L5-COMP which is at the shallowest depth; however this trend is also discerned in the groundwater. The Mann-Kendall analysis was another approach used to evaluate trends. The Mann-Kendall analysis is a nonparametric statistical test used to to assess trends over time. The Mann-Kendall trends were evaluated for each constituent and location over time.

Below is a table summarizing the potential threat to groundwater with respect to each constituent based on findings from the pilot study and bench test. Each constituent is given a rating between 1 and 5, with 5 representing the highest potential threat. The criteria for assigning each threat are the observed attenuation of the constituent in the pilot study and bench test and the type of constituent. In general, the greater the overall attenuation behavior displayed from the bench test and pilot study the lower the potential threat is. Also considered is whether the constituent is naturally occurring or has known health impacts. The type of constituent can range from general water quality parameters like alkalinity and DO, to emerging contaminants like NDMA and PFCs. The potential threat assigned for each constituent below is a culmination of these factors. Some monitored constituents were not consistently detected in the recycled water source during the study. Since the attenuation of those constituents could not be evaluated, they are assigned as inconclusive. Further monitoring of recycled water sources is needed to determine whether those constituents are sufficiently present to pose a potential threat to groundwater.

In addition to the potential threat value, the table includes a recommendation on whether further monitoring of each constituent is warranted. Constituents that are recommended for further monitoring are those with a threat value of three or higher. The evaluation of potential threats presented below is based on the 18-month pilot study conducted at the IDT site. Due to the fairly limited monitoring period for this study, it is possible that the arrival of some constituents did not occur within the pilot study duration. As part of an agreement with the SCVWD, IDT is conducting ongoing groundwater monitoring at the site, and those results should be considered along with the findings of this study to guide future efforts.

Constituent	**Potential Threat**	**Recommend for Further Monitoring?**	**Findings**
ORP	1	N	ORP is a general water quality parameter. Measurements of ORP suggest no major shifts in redox conditions.
pH	1	N	The pH is a general water quality parameter. The pH was near neutral in the pilot study and bench test. Similarity of pH across depth indicates conditions are stable.
Chlorine, Total	1	N	Concentrations of chlorine were higher in groundwater than in recycled water and pore water in the pilot study.
Dissolved Oxygen	1	N	DO is a general water quality parameter. DO was 0.01 mg/L or above across depth in the pilot study indicating that anoxic conditions are unlikely. Samples from the bench test indicated oxic conditions.
Alkalinity, Total	1	N	Alkalinity is a general water quality parameter. A greater alkalinity in the pore water equates to more stability in pH conditions.
Bicarbonate Alkalinity	1	N	
Boron	3	Y	Boron removal was not well observed in the bench test or pilot study.

Calcium	2	Y (See SAR)	Calcium concentrations are greater in the subsurface than in recycled water.
Magnesium	2	Y (See SAR)	Magnesium concentrations are greater in the subsurface than in recycled water.
Sodium	4	Y	Sodium is directly related to SAR, as well as having a direct potential effect on groundwater.
Sodium Adsorption Ratio (SAR)	4	Y	SAR may indicate impact to soil drainage from clay swelling as a result of recycled water application when the SAR in the recycled water is higher than the SAR of the previous irrigation source.
Potassium	1	N	Potassium data from bench test and pilot study suggest good removal.
Sulfate	3	Y	Sulfate increased in concentration in pore water, likely due to contribution from soil and fertilizer. Sulfate concentration in groundwater was relatively stable in the pilot study. In the bench test, removal was not well observed. The constituent also contributes to the total dissolved solids.
Nitrite	2	N	Nitrate/Nitrite data show removal with depth in the pilot study. Mechanism is suspected to be attenuation by root uptake pathway.
Nitrate	2	N	
Chloride	4	Y	Chloride over time has shown an increasing trend in concentrations in groundwater and pore water. At the end of the pilot study, chloride had not yet reached stable conditions. Attenuation of chloride in the bench test was not well observed. The constituent also contributes to the total dissolved solids.
Total Organic Carbon (TOC)	2	N	TOC was decreased by microbial activity and adsorption to soil; groundwater was relatively stable in pilot study. The bench test findings were consistent with the pilot study.
Total Filterable Residue at 180C (TDS)	3	Y	Although TDS in the pilot study in groundwater appeared relatively stable, levels have been observed above secondary drinking water standards in both the baseline and subsequent events. TDS in recycled water and lysimeters are also above secondary drinking water standards. In the bench test, attenuation was not well observed.
Dissolved Organic Carbon	2	N	DOC was decreased by microbial activity and adsorption to soil; groundwater was relatively stable in pilot study. The bench test findings were consistent with the pilot study.

Bromodichloromethane (THM)	2	N	Bromodichloromethane was removed in the vadose zone. Bromodichloromethane was not detected in groundwater during the pilot study. THM data in the bench test also showed attenuative behavior.
Bromoform (THM)	2	N	Bromoform was removed in the vadose zone. Bromoform was not detected in groundwater during the pilot study. THM data in the bench test also showed attenuative behavior.
Chloroform (THM)	2	N	Chloroform was removed in the vadose zone. Chloroform was not detected in groundwater during the pilot study. THM data in the bench test also showed attenuative behavior.
Dibromochloromethane (THM)	2	N	Dibromochloromethane was removed in the vadose zone. Dibromochloromethane was not detected in groundwater during the pilot study. THM data in the bench test also showed attenuative behavior.
Carbon Tetrachloride (VOC)	1	N	Carbon tetrachloride was not detected in recycled water in pilot study or bench test. The constituent was also categorized as having minimal potential impact in Volume I.
Xylenes, Total (VOC)	1	N	Xylenes were not detected in recycled water in pilot study or bench test. The constituent was also categorized as having minimal potential impact in Volume I.
Additional 8010-list VOCs	1	N	VOCs were not detected in recycled water in the pilot study or bench test. VOCs excluding xylenes and carbon tetrachloride were also not detected in the data analysis of Volume I.
Haloacetic Acids (HAA6): Bromochloroacetic Acid Dibromoacetic Acid Monobromoacetic Acid Monochloroacetic Acid Trichloroacetic Acid	4	Y	HAA6 were not observed in the baseline groundwater samples but were observed in the applied recycled water, pore water, and groundwater during the pilot study. In the bench test, HAA6 attenuation was not well observed. HAA6 are also anthropogenic compounds.
Heterotrophic Plate Count	3	Y	Growth was present in pore water and groundwater. Growth was also observed in the bench test. Attenuation was not observed.
Coliforms, Total	3	Y	Growth was present in pore water and groundwater. Growth was also observed in the bench test. Attenuation was not observed.
Fecal Coliforms	3	Y	Fecal Coliforms were not present in groundwater during the pilot study. In the bench test, fecal coliforms were not frequently detected. Attenuation was not well observed.

E. Coli	Inconclusive	Y	E. Coli was minimally detected in recycled water in the pilot study. In the bench test, E. coli was not frequently detected. Therefore the attenuation behavior could not be examined. The constituent may be present in the other recycled water sources in the study area.
N-Nitroso Dimethylamine (NDMA)	5	Y	NDMA was not observed in the baseline groundwater samples, but was observed in the applied recycled water, pore water, and groundwater during the pilot study. The majority of attenuation of NDMA could potentially be from volatilization in the vadose zone and biotransformation in the soil. In the bench test, NDMA attenuation was not consistently observed. NDMA is an emerging contaminant.
Perfluorochemicals	5	Y	PFCs were not observed in the baseline groundwater samples, but were observed in the applied recycled water, pore water, and groundwater during the pilot study. Similarly, in the bench test, some PFCs were observed in the effluent but not in the influent. There is potential for PFC formation from precursors. PFCs are emerging contaminants.
Phosphate	1	N	Phosphate removal was observed in the pilot study and bench test. Mechanisms that caused removal of phosphates are suspected to be the root uptake pathway and precipitation.
Ethylenediaminetetraacetic acid (EDTA)	3	Y	EDTA was not detected in recycled water in the pilot study. In the bench test attenuation was not consistently observed.
Surfactants (MBAS)	3	Y	Surfactants were minimally detected in recycled water in the pilot study. In the bench test attenuation was not consistently observed.
Bromide	2	Y	Removal of bromide in the vadose zone is low; however the degree of toxicity of bromide is low. Together with chloride, bromide can be a useful tracer for recycled water transport.
Nitrilotriacetic acid (NTA)	Inconclusive	Y	NTA was not detected in the pilot study or bench test. Therefore the attenuation behavior could not be fully examined. This constituent may be present in the other recycled water sources in the study area.
Perchlorate	Inconclusive	Y	Perchlorate was not detected in recycled water during the pilot study or bench test. Therefore the attenuation behavior could not be fully examined. This constituent may be present in the other recycled water sources in the study area.

Cyanide	Inconclusive	Y	Cyanide was minimally detected in pilot study or bench test. Therefore the attenuation behavior could not be fully examined. This constituent may be present in the other recycled water sources in the study area.
Terbuthylazine	Inconclusive	Y	Terbuthylazine was minimally detected in recycled water in pilot study and bench test. Therefore the attenuation behavior could not be fully examined. This constituent may be present in the other recycled water sources in the study area.

VOLUME III
SAN JOSE PILOT STUDY
RECYCLED WATER STUDY

1. INTRODUCTION

This report was prepared by Locus Technologies (Locus) on behalf of the Santa Clara Valley Water District (SCVWD) for the Recycled Water Irrigation and Groundwater Study. Volume III covers the third phase of a study to evaluate the impacts from expanded use of recycled water for irrigation on groundwater resources in the Santa Clara and Llagas Groundwater Subbasins in Santa Clara County. This study uses a combination of approaches, including literature review, data analysis, a fate and transport evaluation, and a full pilot study at a site in the Santa Clara Groundwater Subbasin. The first and second phases of this study are reported in Volumes I and II respectively. This volume focuses on the pilot study portion of the evaluation, but includes support from findings from the first and second phases of this study.

1.1. Purpose

This volume of the report includes the results from the pilot study conducted at the Integrated Device Technology (IDT) site located at 6024 Silver Creek Valley Road, San Jose, California. The pilot study serves as a way to observe the transport of recycled water and the attenuation of its constituents from the surface to the groundwater under real-world conditions. For this report, attenuation is defined as the reduction in concentration of a constituent through the soil, through any process including but not exclusive to sorption, volatilization, transformation, or plant uptake. Constituent migration is operationally defined as the movement of constituents in the vadose zone and in groundwater. The pilot scale test is the final component of the fate and transport evaluation (the other components in the fate and transport evaluation included a literature review, data analysis, soil model, and bench test, presented in Volumes I and II of this report). The pilot study is conducted in a real environment that is irrigated with recycled water. The purpose of the study is to evaluate the recycled water fate and transport through the vadose zone and into the shallow saturated zone. Fate and transport is assessed by looking at depth-discrete chemical data in water as it migrates through the vadose zone and into the saturated zone. The following specific goal was identified for the pilot test:

- Examine the attenuation through soil for a list of constituents present in recycled water that may negatively impact groundwater as determined in Volume I and Volume II.

Recycled water commonly contains a number of constituents introduced through the original use of the water, or through the treatment processes that the water undergoes after use. The focus of the study is chemical constituents, including those of anthropogenic and nonanthropogenic origins. A few constituents of concern are biological. This study focuses on determining whether any of these constituents have the potential to negatively impact groundwater if recycled water is used for irrigation.

2. SITE BACKGROUND

The pilot study was conducted in the Santa Clara Subbasin at the IDT site, located at 6024 Silver Creek Valley Road, San Jose, California. It is bounded by Silver Creek Valley Road and Piercy Road. The IDT property maintains 6.2 acres of landscape: 2.8 acres of irrigated turf and 3.4 acres of irrigated shrub beds (ITAP, 2006). The property contains flat and sloping turf areas and narrow shrub beds which have mature drought tolerant shrubs, large trees, and groundcover. Southwest of the subject property beyond Piercy Road, lies Coyote Creek which runs northwestward toward the San Francisco Bay (USGS, 2011).

2.1. Irrigation

2.1.1. Irrigation System

The current irrigation system uses Hunter gear driven rotors, Toro gear driven rotors, and Toro four-, six-, and twelve-inch plastic pop-up spray heads. There are 127 irrigation control valves that are managed by four Sentar Rain Master Controllers. Between October 2008 and March 2010, about 10,000 hundred cubic feet (ccf) or approximately 23 acre-feet of recycled water for irrigation was applied. Significantly less irrigation was used during the winter months compared to summer months.

The typical root zone for water uptake in lawns and garden is 6 to 12 inches. For shrubs the typical root zone is 12 to 24 inches, and for trees the zone is 18 to 36 inches.

2.1.2. Recycled Source Water

The source of the irrigation water for the pilot study is recycled water supplied from the San Jose/Santa Clara Water Pollution Control Plant (SJ/SC WPCP) which services wastewater treatment to cities in the Santa Clara Subbasin including San Jose, Santa Clara, Milpitas, Campbell, Cupertino, Los Gatos, Saratoga, and Monte Sereno. SJ/SC WPCP wastewater is treated in a three step process (City of San Jose, date unspecified). Primary treatment takes place in large settling tanks removing 40 to 60 percent of the suspended solids and 23 to 35 percent of the biochemical oxygen demand. Secondary treatment includes aeration and secondary clarifiers. The final step is tertiary treatment involving filtration through filter beds and then chlorination for disinfection. Pollutants and solid wastes removed from the three treatment steps are directed to anaerobic digesters. Post tertiary treatment, the portion reserved for reclamation is directed to an effluent diversion facility where the water is dosed with additional chlorine and is directed through a 4310-foot diversion pipeline at the end of which recycled water is distributed (Zadeh, 2010). These additional measures help meet the regulatory chlorine contact time (CT) of 450 mg-min/L (Title 22 §60301.230(a)). CT achieved at the end of the diversion pipeline ranges typically from 1000 to 4000 mg-min/L. SJ/SC WPCP recycled water meets Title 22 regulations.

With the exception of the baseline sampling, the location of the recycled water source sample is at the IDT site on a fixture directly attached to the irrigation line. Initial baseline sampling of the source was collected directly from the SJ/SC WPCP because recycled water use at the IDT site had not yet been implemented. Starting with the first sampling event, the recycled water samples for the study were taken directly from the irrigation system onsite. Recycled water use at the site was implemented on September 4, 2008. The irrigation system is not used as frequently during the winter months when it rains. Figure III-2-2 shows the irrigation use and precipitation data over the study period.

2.2. Vadose Zone

2.2.1. Soil Composition

Previous soil sampling indicated that most of the vadose zone soil at the site is made up of silty clay of medium plasticity. The unified soil classification system (USCS) identifies this soil with the code CL (lean clay). During the installation of the four monitoring wells at the site in 2005, soils were logged to 45 feet bgs by MJO Earthscience Services as part of an environmental baseline report for the IDT site (Pacific Crest Engineering Inc., 2005). The intent of the baseline report was to be used as a reference for when IDT eventually closes the subject site. In all four borings, groundwater was encountered at depths from 30 to 33 feet and well screens were installed between 25 and 45 bgs. However, the upper 30 feet consisted entirely of silty clay. Other shallower soil borings (four to five feet in depth) were also logged at 25 other locations at the site by MJO Earthscience Services, and the shallow soil type was consistently silty clay across the site. In 2008, Locus collected an additional soil core to 30 feet at a fifth location, and logged silty clay for the entire depth. Soil boring logs for all of these locations are included in Appendix III-A. Based on these soil boring logs, the soil appears to be uniform through the vadose zone and across the site. Because the soil characteristics appear to be homogeneous throughout the site, no areas were identified to be more sensitive to recycled water application based on soil type.

2.2.2. Lysimeters

Pore water from the vadose zone is represented by samples from the lysimeters. Four locations were chosen to have lysimeters installed. Since the shallow soil types at the site are not significantly variable, the lysimeter locations were selected based on accessibility and maximum expected infiltration rate. Based on irrigation rates and surface grading, irrigation water can be expected to infiltrate more heavily in some areas. Lysimeters were installed on July 17 and 18, 2008. Sample locations for the IDT site are shown in Figure III-2-1.

Two lysimeters were installed at each location: one at five feet bgs and the second at ten feet bgs. Lysimeters placed at five feet bgs are screened at 4.7 to five feet bgs. Lysimeters placed ten feet bgs are screened at 9.7 to ten feet bgs. According to previous studies discussed in Volume I, the attenuation of constituents is expected to be highest in the first several feet of the soil profile.

The lysimeters consisted of 54-inch long dual-chamber stainless steel lysimeters provided by Soil Measurement Systems. Each lysimeter has an outer diameter of 2 inches and an extractable sample storage capacity of 1,500 milliliters (mL). Lysimeters use a vacuum mechanism to collect pore water from unsaturated soil. The upper chamber of the lysimeter is used for sample storage and is designed to prevent back flow.

2.2.2.1. Lysimeters L1-5 and L1-10

Lysimeters L1-5 and L1-10 are located on the east end of a bed of turf grass which is adjacent to the west side of the second larger IDT building. These lysimeters are located in the lower end of a sloping turf bed. Half of the run-off from the sloping turf bed is directed to the L1 location. The other half is directed to the opposing end of the sloped turf bed where the L2 lysimeters are located. The sloping conditions of the turf bed result in more irrigation water infiltrating at this location. Two lysimeters were installed at the L1 location: one at a depth of five feet (L1-5) and one at a depth of ten feet (L1-10).

2.2.2.2. Lysimeters L2-5 and L2-10

Lysimeter L2-5 and L2-10 are located on the west end of a bed of turf grass which is adjacent to the west side of the larger second IDT building. These lysimeters are located in the lower end of a sloping turf bed. Half of the run off from the sloping turf bed is directed to the L2 location. The other half is directed to the opposing end of the sloped turf bed where the L1 lysimeters are located. The sloping conditions of the turf bed results in more irrigation water infiltrating at this location. Two lysimeters were installed at the L2 location: one at a depth of five feet (L2-5) and one at a depth of ten feet (L2-10).

2.2.2.3. Lysimeters L3-5 and L3-10

Lysimeter L3-5 and L3-10 are located on the north end of the property, in a strip of turf bed near the front driveway entrance. The turf bed is banked along the Silver Creek Valley Road. In addition to turf, the bed is lined with mature trees. The L3 location is located close to groundwater monitoring well MW-3 so that pore water and groundwater can be monitored at approximately the same location. Two lysimeters were installed at the L3 location: one at a depth of five feet (L3-5) and one at a depth of ten feet (L3-10).

2.2.2.4. Lysimeters L4-5 and L4-10

Lysimeter L4-5 and L4-10 are located on turf at the south end of the main field. The main field is located on the west end of the IDT property. These lysimeters are located close to MW-4 so that pore water and groundwater can be monitored at approximately the same location. Two lysimeters were installed at the L4 location: one at a depth of five feet (L4-5) and one at a depth of ten feet (L4-10).

2.2.2.5. Lysimeter Composites

The required sample volume needed to analyze for the full recycled water constituent list was 8000 mL. However, due to the limited water volume capacity of the lysimeters, it was not possible to collect adequate sample volumes from each lysimeter. Therefore, composite samples were collected to provide the sample volume required to accurately analyze for the entire list of constituents of concern. L5-COMP is the composite of L1-5, L2-5, L3-5, and L4-5. L10-COMP is the composite of L1-10, L2-10, L3-10, and L4-10. The composites allow for evaluating results with respect to soil depth. Variation between lysimeter locations could not be evaluated using composite sampling; however this variation is expected to be low due to the homogeneity of soil and surface conditions at the IDT campus.

2.3. Groundwater

Shallow groundwater on site is located at approximately 30 ft bgs. Based on the water levels of the existing monitoring wells, the groundwater flow direction appears to be north-northeast. A previous environmental investigation determined that the groundwater flow was westward (Pacific Crest Engineering Inc., 2005). The hydraulic gradient of the shallow groundwater is estimated to be 0.001 ft/ft. Because of the low hydraulic gradient, the groundwater flow direction is expected to fluctuate considerably, which may explain the differences in the groundwater flow direction over time. Any local pumping may potentially induce changes from the natural flow direction.

2.3.1. Existing Monitoring Wells

Shallow groundwater is represented by water from existing monitoring wells. In 2005, four groundwater monitoring wells were installed by Exploration Geoservices, Inc. as part of an environmental baseline report for the IDT site (Pacific Crest Engineering Inc., 2005). The four existing monitoring wells were installed to provide baseline data for when IDT eventually closes the subject site. The groundwater monitoring wells MW-1, MW-2, MW-3, and MW-4 are shown in Figure III-2-1. Each of these monitoring wells has a casing diameter of 4 inches and is screened from 25 to 45 feet bgs. Appendix III-A includes the boring logs and wells diagrams for these monitoring wells. The monitoring wells are used to monitor groundwater quality constituent concentrations in the shallowest saturated zone. The average screen depth is 35 ft bgs.

2.4. Landscape Additives

IDT regularly applies fertilizer and grub control onto the landscape. One of three fertilizers is utilized depending on the season. The three fertilizers used are Andersons Golf Products Turf Fertilizer 30-3-9 with Poly-S® Nitrogen & 2% Iron (from February to September), Best® Nitra King® 19-4-4 with 2.2% Iron (from October to November), and Best® Ammonium Sulfate 21-0-0 (from December to January). Together, the fertilizers contain nitrogen, phosphate, potassium, sulfur, iron, calcium, and chlorine. Nitrogen, phosphate, and potassium are major nutrients for plant growth. Sulfur, iron, calcium, and chlorine are minor nutrients for plant growth. The grub control (Nemasys® G) contains live nematodes to control the growth of pest larvae. The grub control is used in conjunction with surfactants (AquatrolsSixteen 90) for optimal effectiveness. Product sheets for the landscape additives are found in Appendix III-B. Gypsum (hydrated calcium sulfate), commonly used to promote soil hydraulic conductivity, is not used at the site.

3. METHODOLOGY

To evaluate the effects that recycled water irrigation may have on groundwater, it is necessary to characterize the groundwater conditions before and after recycled water application begins. Groundwater conditions before recycled water application were established by a water quality baseline sampling event for comparison with subsequent sampling events. One baseline sampling event was performed as part of this pilot study. The SCVWD also conducted three additional baseline sampling events prior to the pilot study, which were used to supplement the data. The pilot study subsequent sampling events monitored groundwater and pore water conditions as recycled water was applied, and were designed to observe the effects of recycled water as it migrated through the vadose zone and into the saturated zone. Results from the sampling were used to observe the constituent concentrations over depth and over time.

The constituents monitored in this pilot study were selected based on their presence in recycled water sources and the potential negative impact the constituent may pose to the beneficial uses of groundwater. An evaluation of recycled water constituents and their potential to impact groundwater was presented in Volume I of this report.

For support and comparison, findings from the bench test (originally presented in Volume II of this report) are included in the pilot study evaluation. Conclusions from the bench test, specifically whether or not attenuation was consistently observed for the constituent, were compared with the pilot study findings. The overall conclusions for this volume consider findings from both the bench test and pilot study.

3.1. Analytes

Each location sampled was tested for a set of constituents (shown in Table III-3-1) based on the findings from Volume I. Constituents were selected based on the potential negative impact the constituent may pose to the beneficial uses of groundwater. Specifically, constituents were selected based on the following criteria: 1) potential to degrade groundwater based on significantly higher concentrations in recycled water, 2) fate and transport characteristics (e.g., mobility, persistence), and 3) an established state or federal regulatory, action, or notification level indicating potential human health effects. Aldicarb sulfoxide, PHaCs, NDCs, NBBS, and trisphosphates, which were recommended for further monitoring from Volume I, were not included in the pilot study as a commercial laboratory to test for these constituents could not be identified. While these constituents were not monitored, the constituents that were included in the monitoring plan for the pilot study cover a wide characteristic range that strongly represents recycled water. In addition, bromide was included in the sampling list as a tracer.

VOCs, which were not recommended for further monitoring in Volume I, were included in the pilot study because the VOCs are reported as a part of the analysis (EPA 8260B) that also analyzes THMs.

Constituents including ethylenediaminetetraacetic acid (EDTA), surfactants (MBAS), nitrilotriacetic acid (NTA), perchlorate, cyanide, and terbuthylazine, which were initially analyzed in the pilot study, were later scaled down in monitoring scope because these constituents were not consistently found above detection limits in the recycled water during the pilot study or bench test. Further discussion of the monitoring changes for specific constituents is included in Section 4.1.

3.2. Analytical Laboratories

To cover the necessary analyses needed for this pilot study, three primary analytical laboratories were used: Curtis and Tompkins, Montgomery Watson Harza Laboratories, and EMLab P&K. All three are California state-certified laboratories. Specific analyses assigned to each laboratory are listed on Table III-3-1.

3.3. Data Evaluation

3.3.1. Mann-Kendall Trend Analysis

Data results were evaluated using a Mann-Kendall trend analysis. The Mann-Kendall trend analysis was evaluated over the entire pilot study period, from the baseline event to the last sampling event. Results for the the Mann-Kendall trend analysis are provided in Table III-4-4. The Mann-Kendall is a nonparametric statistical test that is used to assess trends over time. The procedure compares the most recent datum with results of the earlier sampling events. A +1 point is awarded if the most recent concentration is larger, or a

-1 point is awarded if the most recent concentration is smaller. Where the recent concentration is equal to the compared result, no point is awarded and the comparision is regarded as a tie. The total score for the time series data is called the Mann-Kendall statistic (S), which is then compared to a critical value, to test whether the trend in concentration over time is increasing ("up"), decreasing ("down"), or if no trend ("none" or "none - all ties") in concentration can be determined. Conditions set for the trend analysis include treating nondetect values at the reporting limit and using a five percent significance level (i.e. 95% confidence). A probability is also included in Table III-4-4 which indicates the level of uncertainty in the trend. A lower probability indicates high confidence of the resulting trend. The difference between "none" and "none – all ties" is that in the "none – all ties" case, all the values are equal to each other. In this data set, this occurs because all the values are below detection and are treated at the reporting limit which is consistent through the pilot study. A trend of "none" is reported when the concentrations fluctuate, and the trend direction cannot be determined with a confidence of 95%. Results of the Mann-Kendall analysis are discussed with the concentration data in Section 4.1. The Mann-Kendall analysis included the baseline data as part of the evaluation to represent conditions prior to recycled water irrigation. Any concentration changes in subsequent events were compared to the baseline data.

The Mann-Kendall analysis is a more statistically robust analysis compared to the percentage difference approach used for the bench test data in Volume II. Since only two sampling events were collected for the bench test, a Mann-Kendall analysis could not be performed on those data. The pilot study reported a sufficient volume of data for this analysis.

3.3.2. Quality Assurance/Quality Control

Quality assurance/quality control evaluations were performed for all laboratory reports. The following criteria were considered in evaluating data quality:

- Duplicate sample results should be within 25% of each other
- Field blank and method blank samples should not have constituents detected
- Recovery of surrogate analyses should be 80 to 120%
- Matrix and blank spike samples should have 50 to 150% recovery

- Spike and spike duplicate results should be within 35% of each other

These data quality indicators were used when method-specific quality control limits were not specified by the laboratory. Data that did not meet criteria resulted in data being disregarded or qualified, depending on the degree to which quality control was compromised. Qualified and/or disregarded data is flagged in Table III-4-1.

3.4. Sampling Frequency

The pilot study was implemented over a period of 18 months. A summary of events during the pilot study can be found in Table III-3-2.

3.4.1. Baseline Sampling Event

On May 19, 2008, prior to implementation of recycled water irrigation at the IDT site, samples were collected from the four existing monitoring wells and the recycled water source at SJ/SC WPCP to represent conditions prior to application of recycled water at the site. Additional baseline sampling on May 16-17, 2007, August 16, 2007, and December 20, 2007 was conducted by the SCVWD at the four existing monitoring wells. The additional baseline sampling was a subset of constituents monitored in the pilot study. Reporting limits were different from the pilot study for some of the constituents in the additional baseline monitoring. The baseline sampling was used to determine the pre-existing concentrations in the groundwater and the initial conditions of the recycled source water.

Additional analyses were added for the final baseline sampling event in May 2008, based on the results of Volume I of this study. An abbreviated analysis list was used for the prior baseline sampling events. Lysimeters were not part of the baseline sampling event because they were not installed until July 2008. The recycled water source was only sampled in the May 2008 baseline sampling event.

3.4.2. Subsequent Sampling Events

After the baseline sampling, eight sampling events took place over the course of the pilot study between October 27, 2008 and March 1, 2010. For each of these sampling events, thirteen locations were sampled: four existing groundwater monitoring wells (MW-1 to MW-4), eight lysimeters, and one at the selected recycled water source location as discussed in Section 2.1.2. The lysimeter samples were composited into two samples (L5-COMP, L10-COMP) as described in Section 2.2.2.5 to meet sample volume requirements.

Sampling events began approximately 50 days after recycled water irrigation had initiated. Each sampling event was initially scheduled approximately 50 days apart. The initial frequency was estimated using the geometric mean of the hydraulic conductivity of the shallow soil at the site. Two soil samples were collected at the IDT site as part of the bench test as described in Volume II, and analyzed for permeability. From these measured values (4.7×10^{-6} and 3.1×10^{-4} centimeters per second (cm/sec)), a geometric mean hydraulic conductivity of 3.8×10^{-5} cm/sec was calculated. This value is expected to be representative of the vadose zone across the site because of the observed vertical and horizontal homogeneity of soil types as discussed in Section 2.2.1. Based on this value, the irrigation water was expected to migrate downwards through the vadose zone at a maximum rate of 0.1 feet per day. Following the third sampling event, the sampling schedule was adjusted to sample every 75 days because downward migration appeared to be slower than predicted.

3.4.3. Sample Extraction for Lysimeters

In addition to compositing the lysimeters, the lysimeters were sampled in two sample extractions for each sample event due to large sample volume required and limited capacity of the lysimeters. The capacity of the lysimeter is 1500 mL. Therefore the maximum sample volume yielded from compositing four lysimeters is 6000 mL. However, a full set of analyses listed in Table III-3-1 requires approximately 8000 mL. To accommodate for the limited volume, an interim trip was made approximately three weeks following the initial sample extraction as shown in Table III-3-2. The interim extraction provided additional sample volume used to complete the analysis list. Interim samples were collected from all the lysimeters and were not composited with the initial samples. Appendix III-C contains the chain of custody forms indicating what analyses were done in each event. Lysimeters maintained a continuous vacuum to maximize the sample volume as needed by the study. Because water is stored in the chamber once it enters the lysimeter until time of sampling, time between storage and sampling may change the characteristics of the water from that of vadose zone water. Given the constraints of the lysimeter devices, it is assumed that the characteristic differences are minimal.

3.5. Sampling Protocol

3.5.1. Monitoring Well Sampling

Immediately before sampling each well, standing water was purged from the casing and gravel pack using electric submersible pumps. In each well, three casing volumes were purged prior to sampling, except in the case where the well was pumped dry during purging. The casing volume was determined before sampling by measuring the depth to water, subtracting that from the total depth of the well (45 feet for each well), and multiplying the water column height by 1.96 to obtain the casing volume in gallons. The calculation of the 1.96 conversion factor is shown below.

$$\begin{aligned}
3\,\text{casing volumes (gal)} &= 3\left[\text{casing cross-sectional area (ft}^2)\right]\left[\text{water column height (ft)}\right]\left[\frac{7.48\,\text{gal}}{1\,\text{ft}^3}\right] \\
&= 3\pi\left[\text{casing radius (ft)}\right]^2\left[\left[\text{well depth}\right]-\left[\text{water table depth}\right]\right]\left[\frac{7.48\,\text{gal}}{1\,\text{ft}^3}\right] \\
&= 3\pi\left[\frac{2}{12}\,\text{ft}\right]^2\left[\frac{7.48\,\text{gal}}{1\,\text{ft}^3}\right]\left[\left[\text{well depth}\right]-\left[\text{water table depth}\right]\right] \\
&= \left[1.96\,\frac{\text{gal}}{\text{ft}}\right]\left[\left[\text{well depth}\right]-\left[\text{water table depth}\right]\right]
\end{aligned}$$

All four monitoring wells at the site have the same casing radius (2 inches) and well depth (45 feet). During the purging process, pH, temperature, and conductivity were monitored to verify that the readings were steady before sample collection. The final steady-state measurements of these parameters were recorded on the well sampling form, along with other field measurements listed in Table III-3-1 (ORP, dissolved oxygen, total chlorine).

Purge water from the monitoring wells was reapplied on the IDT site landscape in an area not located near the lysimeters or monitoring wells (e.g. along the south border or northernmost corner of the parking lot).

3.5.2. Lysimeter Sampling

Each installed lysimeter has two ¼-inch diameter tube attachments, one to apply vacuum or pressure and one for fluid return. To obtain a sample, the fluid return tube is sealed, and a vacuum is applied to the vacuum/pressure tube. This action moves the water from the lower chamber where water enters the lysimeter to the upper chamber where it can be stored and extracted. To collect the sample, the fluid return tube is opened and inserted into the sample container. A pressure is applied to the vacuum/pressure tube, and the sample water is forced up through the fluid return tube. The vacuum was reapplied immediately after sample extractions, and on a regular basis between sampling events to maintain negative pressure in the lysimeters for the duration of the study.

Lysimeters were purged once, prior to the first sampling event, to remove the residual water left behind during installation of the lysimeter.

3.5.3. Recycled Water Source Sampling

For the May 2008 baseline sampling event, recycled water could not be sampled directly at the pilot study site because the irrigation system was not yet connected to the recycled water source. Therefore, the baseline sample representing the recycled water source was collected from the SJ/SC WPCP, located approximately 15 miles northwest of the pilot study site. Starting with the first monitoring event after recycled water application began, the irrigation source samples were collected by using an attachment on one of the spray heads of the irrigation system. Using this method, the samples represent the irrigation source prior to any volatilization or photodegradation that would occur as a result of the use of spray irrigation.

3.5.4. Quality Control Samples

For quality assurance/quality control (QA/QC) purposes, a duplicate water sample was collected for every 20 field samples to evaluate precision in the laboratory and sampling procedures. Similarly, a blank water sample was collected for every 20 field samples. One rinseate blank was also collected during the pilot study to evaluate cross contamination by sampling equipment. Blank samples were used to evaluate any potential false positives in the samples. All QA/QC samples were analyzed by the laboratory using the same preparation and analytical methods.

3.5.5. Documentation

A water sampling log was completed for each sample collected, except for quality control samples. Water sampling logs and chains of custodies are included in Appendix III-C. All purging information, as well as field measurements and associated quality control samples are recorded on the water sampling log. The samples were also recorded on a chain of custody form sent with the samples to the laboratory. Logs for recharging the lysimeters are included in Appendix III-D.

4. RESULTS

4.1. Chemical Results

This section discusses the analytical results of the constituents of recycled water that were monitored. Chemical results discussed in this section may be found in Table III-4-1. Minimum and maximum range data and Mann-Kendall trend analyses are included in this section with the text. For minimum and maximum range data, the baseline includes four baseline data events: May 19, 2008; December 20, 2007; August 16, 2007; and May 16-17, 2007. Sample event numbers refer to the sequence after recycled water implementation (e.g. 1st event is the first event after recycled water application began).

In addition, charts graphically displaying the chemical results are provided in Figures III-4-1 to III-4-48. Concentrations are plotted in these figures over time at each location, and also over depth for each sampling event (with average concentrations from the monitoring wells used to represent the concentrations at 35 feet). Data results with no detections are treated as zero in the figures. A legend of data qualifiers and results of QA/QC data are provided in Tables III-4-2 and III-4-3 respectively. A table summarizing the Mann-Kendall trend analyses is provided in Table III-4-4. Original lab reports of the constituent analyses are found in Appendix III-E.

For each constituent, the concentrations were evaluated with respect to the following questions:

- Does the constituent concentration consistently change with depth, indicating possible attenuation through the soil?
- Is there a clear increasing trend in the concentrations in pore water or groundwater over time, suggesting a potential impact to groundwater in the short-term or long-term?
- Is the constituent present only in recycled water or are there other sources in the pilot study (e.g. naturally occurring, or derived from fertilizer or soil amendments)?

These questions address the overall goals of this study, and will be used to determine which constituents have the potential to impact groundwater within the Santa Clara and Llagas Groundwater Subbasins.

Chemical results covered in this section discuss water from three categories: irrigation water (recycled water), vadose zone, and groundwater. Irrigation water is represented by samples collected from the irrigation system, pore water from the vadose zone is represented by the lysimeters, and groundwater is represented by monitoring wells MW-1 to MW-4.

In the vadose zone, soil is not fully saturated so that pore water is exposed to air and potential for volatilization is present. Microbial activity in the upper vadose zone region is high. Near the surface of the soil, in the presence of vegetation, root uptake serves as a sink for nutrients found in recycled water. Soil interacts with the pore water through soil sorption/desorption and filtration processes. Evapotranspiration of water may occur, particularly in the upper vadose zone. In addition to irrigation water, rain water is also a source for water found in the vadose zone. Due to water losses and gains from these processes, concentrations of conservative constituents from the irrigation to the vadose zone are expected to concentrate by a factor of two (see section 4.3). Results discussed in Section 4.1 take into account the concentration effect between irrigation water and pore water.

The shallow groundwater is a fully saturated zone. The volatilization pathway is not significantly present at this stage. Groundwater is a mixture of pore water percolating from the vadose zone and groundwater currently present or flowing onsite through the saturated zone, which may include recharge from nearby Coyote Creek. The extent of dilution at this site is not known.

General Water Quality

4.1.1.1. pH and Alkalinity

Measured pH remained in a neutral or near neutral range in the recycled water, pore water, and groundwater. Generally, pH in the irrigation and the pore water were slightly higher than in the groundwater. The pH of recycled water fell within the pH range expected from the previous data analysis in the literature review and agrees with the values obtained from the bench test. The groundwater pH was observed in the lower end of the pH range expected from the data analysis (see Volume I). Because the pH of groundwater is also near neutral, groundwater pH would not likely be affected by the irrigation of recycled water. The near neutral pH across all locations indicates that recycled water did not cause major shifts in pH in either the vadose zone or the groundwater. The pH in the bench test effluent and influent were also found to be near neutral.

Summary of Median [Minimum - Maximum] Data for pH (pH unit)				
	Recycled Water	Pore Water (5ft bgs)	Pore Water (10ft bgs)	Groundwater
Baseline	7.34 [6.75 - 7.94]	-	-	6.75 [6.24 - 7.4]
Sample Events		7.26 [6.43 - 7.76]	7.22 [6.55 - 7.84]	6.77 [6.41 - 6.9]
Mann-Kendall Trend	None	None	None	MW-1: None MW-2: None MW-3: None MW-4: None

Alkalinity was highest in the pore water followed by the groundwater, and lowest in the recycled water. Alkalinity in the recycled water was within the expected range from the Volume I data analysis and agrees with the values obtained from the bench test. Alkalinity in the groundwater was in the higher end of the alkalinity range expected from the data analysis. The primary form of alkalinity was bicarbonate. Contributions to alkalinity from other forms such as phosphate, sulfides, or borates were minimal. Alkalinity increased in concentration from the recycled water to the pore water likely as a result from leaching of naturally occurring carbonate material in the soil. In the bench test, alkalinity was found not to be significantly different in concentration in the influent and effluent samples potentially due to the shorter distance of percolation and shorter monitoring time frame.

Alkalinity is a measure of the buffering capacity of water. The high alkalinity in the pore water suggests that the vadose zone is resistant to pH changes.

Summary of Median [Minimum - Maximum] Data for Alkalinity, Total (as CaCO3) (mg/L)				
	Recycled Water	Pore Water (5ft bgs)	Pore Water (10ft bgs)	Groundwater
Baseline	170 [170 - 210]	-	-	351.5 [299 - 510]
Sample Events		620 [470 - 720]	690 [660 - 730]	368 [240 - 490]
Mann-Kendall Trend	None	None	None	MW-1: None MW-2: None MW-3: None MW-4: None

4.1.1.2. Total Dissolved Solids

Total dissolved solids (TDS) or Total Filterable Residue (at 180 °C) concentrations in recycled water fell within the expected range from the Volume I data analysis. TDS in the recycled water, lysimeters and majority of groundwater wells at IDT were above the national secondary drinking water standard of 500 mg/L. TDS was observed to be highest in L5-COMP followed by L10-COMP, recycled water, and groundwater. TDS in the five-foot lysimeters was initially high relative to the recycled water possibly as a result of the contribution of material leached from the soil. The increase may also be as a result of water loss from evapotranspiration and thus concentrating the constituent. In the bench test, TDS concentrations between the influent and effluent were not significantly different suggesting low attenuation. TDS in L10-COMP was lower than in the L5-COMP. Over time, TDS in the L5-COMP decreased while TDS in recycled water appeared stable relative to the concentration changes in the pore water. TDS in the groundwater remained relatively stable through the study relative to changes in the pore water. While TDS groundwater remained relatively stable, monitoring should be continued to ensure that recycled water does not further impact groundwater relative to secondary drinking water standards.

Summary of Median [Minimum - Maximum] Data for Total Dissolved Solids (TDS) (mg/L)				
	Recycled Water	Pore Water (5ft bgs)	Pore Water (10ft bgs)	Groundwater
Baseline	740 [690 - 880]	-	-	549 [380 - 738]
Sample Events		1650 [1240 - 2180]	1075 [1010 - 1280]	560 [400 - 760]
Mann-Kendall Trend	None	Down	Down	MW-1: None MW-2: None MW-3: None MW-4: None

4.1.1.3. Dissolved and Total Organic Carbon

Dissolved organic carbon (DOC) and total organic carbon (TOC) were observed to be similar in concentrations to each other in most sampling locations. TOC and DOC were observed to be highest in L5-COMP, followed by recycled water, L10-COMP, and groundwater. In only L5-COMP, TOC and DOC were observed to be very high in the first sampling event followed by a reduction to levels similar to that of recycled water. The initial peak in organic carbon observed in L5-COMP suggests an initial desorption of material resulting from the switch to recycled water as an irrigation source, which was similar to the behavior of TDS. TOC and DOC remained stable thereafter. In the bench test, TOC and DOC displayed a similar behavior of initial high effluent concentrations followed by more subsided concentrations in the later event.

The lower concentrations of organic carbon in the L10-COMP relative to L5-COMP suggest removal occurring with depth potentially due to filtering, adsorption to soil, and aerobic respiration.

The only data qualifier flag that was applied to the DOC results in the pilot study was the "B" flag, which was applied to one sample from the L5-COMP location. A discussion of each flag is found in Section 4.2.4. Although there is some reduced confidence in the qualified data, only a few data points were affected and those qualified results are consistent with other samples from the same locations. Therefore, the data are still appropriately useful for comparative purposes and are therefore used for evaluation in this study.

Summary of Median [Minimum - Maximum] Data for Dissolved Organic Carbon (DOC) (mg/L)				
	Recycled Water	Pore Water (5ft bgs)	Pore Water (10ft bgs)	Groundwater
Baseline	6.2 [4.8 - 7.2]	-	-	1.25 [0.44 - 1.6]
Sample Events		7.8 [6.2 - 78]	3.45 [2.7 - 6.4]	ND 1 [ND 1 - 2.1]
Mann-Kendall Trend	Down	None	None	MW-1: None MW-2: None MW-3: None MW-4: None

Summary of Median [Minimum - Maximum] Data for Total Organic Carbon (TOC) (mg/L)				
	Recycled Water	Pore Water (5ft bgs)	Pore Water (10ft bgs)	Groundwater
Baseline	6.4 [5.4 - 8]	-	-	0.69 [0.44 - 0.91]
Sample Events		7.55 [5.8 - 73]	3.35 [2.9 - 6.6]	0.595 [ND 0.5 - 0.88]
Mann-Kendall Trend	None	None	None	MW-1: None MW-2: None MW-3: None MW-4: None

4.1.1.4. Redox Potential and Dissolved Oxygen

Generally, oxidation reduction potential (ORP) at all sample locations was stable, maintaining measurements between 50 and 200 mV. ORP measurements in the lysimeters correlated strongly with measurements in recycled water, beginning with the third sampling event. ORP in the recycled water was high in comparison to groundwater in the baseline event. ORP data suggest that there were no major shifts in redox conditions. ORP measurements in the bench test also suggested that there were no major shifts in redox conditions.

Summary of Median [Minimum - Maximum] Data for ORP (mV)				
	Recycled Water	Pore Water (5ft bgs)	Pore Water (10ft bgs)	Groundwater
Baseline	126 [78 - 417]	-	-	183 [174 - 192]
Sample Events		112 [25 - 182]	100.5 [69 - 179]	114.5 [68 - 915]
Mann-Kendall Trend	None	None	None	MW-1: None MW-2: None MW-3: Down MW-4: None

Dissolved oxygen (DO) concentrations in groundwater water remained at 0.01 mg/L or above throughout the pilot study, indicating oxic conditions. DO measurements in groundwater for the baseline sampling events were also low but were always 0.01 mg/L or higher. DO in the recycled water remained at concentrations above 0.01 mg/L. DO in the L5-COMP and L10-COMP locations were measured but are not considered representative because compositing of samples could not be completed without some exposure to air. Groundwater DO remained above 0.01 mg/L through the pilot study suggesting anoxic conditions are unlikely to occur as a result of recycled water used for irrigation at the site. In the bench test, the system also maintained oxic conditions.

Summary of Median [Minimum - Maximum] Data for Dissolved Oxygen (mg/L)				
	Recycled Water	Pore Water (5ft bgs)	Pore Water (10ft bgs)	Groundwater
Baseline	5.69 [0.04 - 8.1]	-	-	0.045 [0.01 - 0.05]
Sample Events		8.315 [5.84 - 11.3]	8.365 [6.21 - 9.89]	1.315 [0.51 - 4.94]
Mann-Kendall Trend	None	None	None	MW-1: None MW-2: None MW-3: None MW-4: None

4.1.1.5. Total Chlorine

Total chlorine was measured in the pilot study because it is an easily tested field measurement and can provide useful information with regard to bacterial counts. Total chlorine was unexpectedly higher in the groundwater than in the other locations. It is unclear why chlorine results were higher in the groundwater, but the median heterotrophic plate count was found to be lower in the groundwater compared to the recycled water and pore water during the pilot study. Consistency in measurements between sampling events suggests no issues with QA/QC. The baseline total chlorine concentration in recycled water was high because the sample was taken near the treatment plant compared to the total chlorine concentration for the subsequent sample events which were taken at the IDT site. Levels of total chlorine appear to diminish as recycled water travels from the plant to the site. Because of low levels of total chlorine in the recycled water relative to groundwater, total chlorine does not appear to be a concern for groundwater impacts due to recycled water irrigation.

In the bench test, detection of total chlorine in the influent and soil core effluent was overall sporadic.

Summary of Median [Minimum - Maximum] Data for Chlorine, Total (mg/L)				
	Recycled Water	Pore Water (5ft bgs)	Pore Water (10ft bgs)	Groundwater
Baseline	0.13 [0.04 - 8.8]	-	-	-
Sample Events		0.125 [0.07 - 0.42]	0.13 [0.04 - 1.05]	0.89 [0.21 - 2.2]
Mann-Kendall Trend	None	None	None	MW-1: Down MW-2: Down MW-3: None MW-4: None

4.1.2. Anions and Cations

4.1.2.1. Chloride

Generally chloride was highest in recycled water followed by L5-COMP, L10-COMP and groundwater. Chloride concentrations in recycled water were stable over time relative to changes in the pore water. Chloride in L5-COMP and L10-COMP steadily increased over time. Chloride concentrations in the lysimeters do not appear to have reached equilibrium during the pilot study, and may have the potential to increase further. No mechanisms for removal of chloride were identified in the literature review and the mobility of chloride as seen in the data suggests that mechanisms for chloride removal are minimal. Most chloride samples were below the secondary drinking water standard for chloride of 250 mg/L. Chloride was detected above 250 mg/L only once in the recycled water source and once in L5-COMP during the pilot study.

In groundwater, chloride at MW-3 increased toward the end of the study indicating a potential long term effect on groundwater. Chloride in the other groundwater wells remained stable.

In the bench test, chloride did not change significantly between influent and effluent samples, suggesting also that attenuation of chloride was low.

Summary of Mean [Minimum - Maximum] Data for Chloride (mg/L)				
	Recycled Water	Pore Water (5ft bgs)	Pore Water (10ft bgs)	Groundwater
Baseline	200 [190 - 280]	-	-	26 - 72
Sample Events		125 [86 - 270]	81 [71 - 130]	25 - 95
Mann-Kendall Trend	None	Up	Up	MW-1: None MW-2: None MW-3: Up MW-4: None

4.1.2.2. Sulfate

Sulfate was found to be highest in L5-COMP followed by L10-COMP, recycled water, and groundwater. The increase in sulfate concentrations from recycled water to the pore water at five feet bgs was likely caused by sulfate found in the fertilizer. The heaviest sulfate-containing fertilizer was applied in December and January. Sulfate in the fertilizers used in the other months were lower in concentration. The contribution of sulfate from this source to pore water appears to be significantly higher than the contribution from recycled water. Some increase may also be as a result of water loss from evapotranspiration and thus concentrating the constituent. At ten feet bgs, sulfate concentrations were decreased significantly from five feet bgs. At the groundwater depth, sulfate concentrations decreased from the ten foot depth, although the decrease may be due to dilution in groundwater. Decreases of sulfate in the pore water over depth may have occurred from mineralization. The plant uptake pathway is not likely to affect the analysis to a large degree, and absorption of sulfate requires positively charged surfaces which are not common in mediterranean climates such as the study area. Sulfate concentrations in the lysimeters were found above secondary drinking water standard of 250 mg/L.

Sulfate concentrations in recycled water and groundwater were stable over time relative to the changes in the pore water. Sulfate in L5-COMP and L10-COMP steadily decreased over time. The result may be from the use of a more sulfate-heavy fertilizer in January and December than the rest of the year. In the bench test, sulfate generally exhibited no significant differences in concentration between influent and effluent water samples.

Summary of Median [Minimum - Maximum] Data for Sulfate (mg/L)				
	Recycled Water	Pore Water (5ft bgs)	Pore Water (10ft bgs)	Groundwater
Baseline	95 [89 - 110]	-	-	69.45 [40 - 129]
Sample Events		545 [260 - 980]	195 [130 - 320]	60.5 [34 - 80]
Mann-Kendall Trend	None	Down	Down	MW-1: None MW-2: None MW-3: None MW-4: None

4.1.2.3. Bromide

Bromide was highest in concentration toward the surface. Bromide concentrations in recycled water and the lysimeters were similar, and correlated strongly over time starting with the fourth sampling event. Groundwater bromide concentrations were lower than the recycled water and lysimeter concentrations throughout the pilot study. It should be noted that the reporting limit for bromide for the baseline sampling event was 0.5 mg/L, and all bromide concentrations (for groundwater and recycled water) were below detection. Figure III-4-12A shows these points as zero. Subsequent sampling events had a bromide reporting limit of 0.05 to 0.065 mg/L, and most concentrations in all sources were detected between 0.05 and 0.5 mg/L. In the bench test, bromide was below detection in the influent and effluent samples. The laboratory reporting limit in the bench test was 0.5 mg/L.

The only data qualifier flag that was applied to any bromide results was the "J" flag, which was applied to a single concentration from the L10-COMP location in the first sampling event. A discussion of the "J" flag is found in Section 4.2.4. The "J" flag reduces confidence in the quantification of the constituent but does not negate the fact that the constituent was detected. The flagged concentration is consistent with other concentrations from this location, and the qualified data does not affect the other results or affect the bromide findings above.

Summary of Median [Minimum - Maximum] Data for Bromide (mg/L)				
	Recycled Water	Pore Water (5ft bgs)	Pore Water (10ft bgs)	Groundwater
Baseline	0.27 [ND 0.5 - 0.38]	-	-	0.17 [ND 0.5 - 0.32]
Sample Events		0.26 [0.16 - 0.43]	0.235 [0.15 J - 0.3]	0.165 [ND 0.065 - 0.26]
Mann-Kendall Trend	None	None	Up	MW-1: None MW-2: None MW-3: None MW-4: None

4.1.2.4. Cyanide

Cyanide, which was monitored only in the recycled water, was detected infrequently and near the reporting limit. Cyanide was monitored only in the recycled water as recommended from the bench test conclusions to limit the monitoring of constituents that were not frequently detected. In the bench test, cyanide was below detection in both the influent and effluent. The reporting limit for cyanide ranged from 0.005 to 0.01 mg/L in the pilot study and bench test. The range is below the California MCL for cyanide of 0.15 mg/L. Because cyanide is not prominent in the recycled water source, the attenuation behavior was not observed.

Summary of Median [Minimum - Maximum] Data for Cyanide (mg/L)				
	Recycled Water	Pore Water (5ft bgs)	Pore Water (10ft bgs)	Groundwater
Baseline	ND 0.01 [ND 0.005 - 0.02]	-	-	ND 0.005 [ND 0.005 - ND 0.005]
Sample Events		-	-	-
Mann-Kendall Trend	None	-	-	-

4.1.2.5. Boron

Boron was highest in recycled water followed by the lysimeters, and lowest in the groundwater. Boron concentrations across all locations did not appear to change significantly over time. Boron concentrations decreased from recycled water to the pore water at five foot bgs, possibly due to plant uptake. Concentrations of boron at the five foot and ten foot depth did not appear to change significantly. Boron in groundwater was relatively stable through the pilot study. The results suggest that boron in the recycled water may have not yet reached groundwater. In the bench test, boron concentrations in the influent and effluent were not significantly different, suggesting that the soil cores had minimal effect on this constituent.

Summary of Median [Minimum - Maximum] Data for Boron (µg/L)				
	Recycled Water	Pore Water (5ft bgs)	Pore Water (10ft bgs)	Groundwater
Baseline	460 [380 - 480]	-	-	189 [140 - 229]
Sample Events		285 [250 - 400]	285 [230 - 330]	190 [130 - 240]
Mann-Kendall Trend	None	None	None	MW-1: None MW-2: None MW-3: None MW-4: None

4.1.2.6. Potassium

Potassium was highest in recycled water followed by L5-COMP, L10-COMP, and groundwater, indicating a consistent decrease in concentration with depth. Potential mechanisms for the decrease include plant uptake and sorption. In clay soils, potassium is preferentially sorbed due to a high charge to size ratio. Results are similar to the bench test, where potassium exhibited significant removal in the soil cores. In addition to recycled water, minor amounts of potassium from fertilizer contributed to potassium at the soil surface.

The Mann-Kendall trend analysis did not indicate statistically significant upward or downward trends of potassium in recycled water, groundwater, or L5-COMP. In L10-COMP, potassium decreased over time particularly in the early portion of the pilot study. The decreasing trend in the early part of the pilot study may be the result of the fluctuation observed in the recycled water. Data suggest that there is minimal potential for potassium to negatively impact groundwater.

Summary of Median [Minimum - Maximum] Data for Potassium (mg/L)				
	Recycled Water	Pore Water (5ft bgs)	Pore Water (10ft bgs)	Groundwater
Baseline	15 [12 - 19]	-	-	0.83 [ND 0.5 - 2.3]
Sample Events		5.2 [2.5 - 9.3]	1.35 [1.1 - 3.6]	0.605 [ND 0.5 - 1.1]
Mann-Kendall Trend	None	None	Down	MW-1: None MW-2: None MW-3: None MW-4: None

4.1.2.7. Sodium Adsorption Ratio

The sodium adsorption ratio (SAR), which is calculated from calcium, magnesium, and sodium data, describes the concentration of sodium relative to calcium and magnesium. A high level of SAR in the recycled water relative to the soil has the potential to cause clay swelling and reduce hydraulic conductivity. A decrease of SAR in the vadose zone with respect to depth suggests that sodium ions are replacing calcium and magnesium ions in the intra-particle clay surfaces, which causes clays to swell. A further background discussion of SAR may be found in Section 3.1 of Volume I. SAR was observed to be highest in recycled water and L5-COMP, followed by L10-COMP and groundwater. The SAR values in the groundwater and L10-COMP were stable over time, and SAR in L10-COMP remained slightly higher but similar to that of groundwater throughout the pilot study. SAR in the recycled water and L5-COMP were stable to an extent with moderate variability. SAR in recycled water and L5-COMP were similar suggesting that ions in the pore water were in equilibrium with ions in the clay surfaces in the first five feet over the study period. This suggests that clays may have been have swelled to some degree in the first five feet prior to the pilot study. The difference in SAR between L5-COMP and L10-COMP indicates the pore water composition is different. This suggests a clay swelling wave front occurring between the five and ten foot depth during the study period. The presence of clay swelling may present a concern for soil drainage. However, because the effect of clay swelling could not be measured, the level of impact could not be determined.

Summary of Median [Minimum - Maximum] Data for SAR (unitless)				
	Recycled Water	Pore Water (5ft bgs)	Pore Water (10ft bgs)	Groundwater
Baseline	4.13 [3.3 - 5.11]	-	-	0.82 [0.74 - 0.95]
Sample Events		3.58 [2.68 - 4.17]	1.12 [0.98 - 1.22]	0.8 [0.62 - 0.92]
Mann-Kendall Trend	None	None	None	MW-1: None MW-2: None MW-3: None MW-4: None

4.1.2.8. Calcium

Calcium was highest in L5-COMP, followed by L10-COMP, groundwater, and recycled water which had consistently the lowest concentration. Pore water at the five-foot depth had calcium concentrations significantly higher than recycled water. The high levels of calcium found in L5-COMP are potentially caused by displacement in the soil by exchange of calcium for sodium within the uppermost five feet. The increase at the IDT site may also be as a result of water loss from evapotranspiration and thus concentrating the constituent. Calcium in the pore water at the ten-foot depth was lower than at the five-foot depth. The difference in concentrations between the two depths diminished over time. Calcium decreased over time seen in the L5-COMP which is potentially a result of an initial flushing of calcium from the surface soil. A subsequent increase in calcium concentrations in groundwater from flushing was not consistently observed during the pilot study. The removal over time lessened as the system approached equilibrium. In the bench test, calcium behaved in a similar manner in the soil cores, exhibiting an initial concentration increase in the effluent followed by a return to influent levels.

Calcium concentrations in groundwater and recycled water were stable over time. In addition to recycled water, minor amounts of calcium from fertilizer (Best® Nitra King® 19-4-4 with 2.2% Iron) applied regularly in the fall (October and November) contributed to calcium at the soil surface. Calcium contributes to the total dissolved solids of the system.

Summary of Median [Minimum - Maximum] Data for Calcium (mg/L)				
	Recycled Water	Pore Water (5ft bgs)	Pore Water (10ft bgs)	Groundwater
Baseline	54 [44 - 64]	-	-	87.75 [62 - 122]
Sample Events		180 [120 - 270]	150 [120 - 170]	85 [49 - 120]
Mann-Kendall Trend	None	Down	None	MW-1: None MW-2: None MW-3: None MW-4: None

4.1.2.9. Magnesium

Magnesium was highest in L10-COMP followed by L5-COMP, groundwater, and recycled water. Higher magnesium concentrations in the lysimeters compared to the recycled water maybe a result of displacement in the soil by exchange of magnesium for sodium. At the groundwater depth, magnesium concentrations were consistently lower than in L10-COMP. The increase from recycled water to vadose zone water at the IDT site may also be as a result of water loss from evapotranspiration and thus concentrating the constituent. In the bench test, magnesium behaved in a similar manner in the soil cores, exhibiting an initial concentration increase in the effluent followed by a return to levels closer to the influent concentration.

Magnesium concentrations in groundwater and recycled water locations were generally stable over time. Magnesium in L5-COMP and L10-COMP decreased 34% and 25% respectively over the 18-month study period. The gradual decrease over time seen in the lysimeters suggests an initial flushing of the magnesium leached from the soil, followed by a gradual adjustment to equilibrium. A subsequent increase in magnesium concentrations in groundwater from flushing was not consistently observed during the pilot study. Magnesium concentrations in recycled water are consistently lower than those observed in the subsurface samples. Magnesium contributes to the total dissolved solids of the system.

Summary of Median [Minimum - Maximum] Data for Magnesium (mg/L)				
	Recycled Water	Pore Water (5ft bgs)	Pore Water (10ft bgs)	Groundwater
Baseline	30 [25 - 39]	-	-	52.95 [36 - 73.1]
Sample Events		81.5 [53 - 100]	110 [98 - 130]	51.5 [30 - 73]
Mann-Kendall Trend	None	None	None	MW-1: None MW-2: None MW-3: None MW-4: None

4.1.2.10. Sodium

Sodium concentrations were highest in L5-COMP followed by recycled water, L10-COMP, and groundwater. Sodium levels increased from recycled water to L5-COMP potentially due to water loss from evapotranspiration. Sodium levels decreased in the pore water from the five-foot depth to the ten-foot depth. At the groundwater depth, sodium decreased modestly relative to the ten foot depth. Over time, sodium concentrations in all locations were stable. In the bench test, sodium generally exhibited little to no change in concentrations in the influent and core effluent samples. The differences in observations seen between the bench test and pilot study may potentially be due to the bench test being closer to equilibrium with respect to sodium concentrations compared to the pilot study. Sodium also contributes to the total dissolved solids of the system.

Summary of Median [Minimum - Maximum] Data for Sodium (mg/L)				
	Recycled Water	Pore Water (5ft bgs)	Pore Water (10ft bgs)	Groundwater
Baseline	140 [120 - 210]	-	-	40.55 [32 - 47.8]
Sample Events		240 [140 - 290]	72.5 [63 - 87]	37.5 [23 - 48]
Mann-Kendall Trend	None	None	None	MW-1: None MW-2: None MW-3: None MW-4: None

4.1.3. Nutrients

4.1.3.1. Phosphate- Total as P

Phosphate was highest in the recycled water compared to the pore water and groundwater. Phosphate from fertilizer applied onsite may have also contributed to concentrations found in the subsurface in addition to the phosphate from recycled water.

Phosphate concentrations found in the groundwater were similar in magnitude to those found in the lysimeters with the exception of a few isolated high concentrations. Phosphate concentrations in MW-2 (10/2008) and in MW-1 (12/2009 and 3/2010) were higher than in recycled water, and were not consistent with either the other groundwater phosphate concentrations on those dates or with the phosphate concentrations from those wells on other sampling dates. With respect to depth, phosphate decreased between the applied recycled water and the pore water at five-foot depth. A significant cause of this concentration reduction may be attributed to root uptake of this nutrient and precipitation of phosphate. Between five and ten feet, an additional slight removal of phosphate was observed. In the bench, phosphate behaved similarly, exhibiting a significant decrease from the influent samples to the effluent samples. The Mann-Kendall trend analysis did not indicate any statistically significant upward or downward trends over time.

Considering the level of phosphate attenuation within the upper ten feet of soil at the IDT site, phosphate appears to have minimal potential to impact groundwater.

Summary of Median [Minimum - Maximum] Data for Phosphate, Total as P (mg/L)				
	Recycled Water	Pore Water (5ft bgs)	Pore Water (10ft bgs)	Groundwater
Baseline	0.32 [0.21 - 0.62]	-	-	-
Sample Events		0.0485 [0.031 - 0.21]	0.042 [ND 0.03 - 0.062]	0.0625 [ND 0.03 - 0.86]
Mann-Kendall Trend	None	None	None	MW-1: None MW-2: None MW-3: None MW-4: None

4.1.3.2. Nitrate and Nitrite

Nitrate was highest in recycled water followed by groundwater, L10-COMP, and L5-COMP. With respect to depth, nitrate decreased dramatically at the five-foot depth compared to the recycled water, likely as a result of root uptake, even with contributions of nitrate from fertilizer to the soil surface.

Comparing the five and ten foot depth results, nitrate showed a moderate increase with depth in the pilot study. Nitrate concentrations at ten feet and groundwater are similar. The increase in nitrate observed between the five and ten foot depth is suspected to be a result of nitrate returning to equilibrium after depletion near the surface due to root uptake. Nitrate concentrations in the recycled water appeared generally stable with moderate fluctuation.

Over time, nitrate in the pore water increased slightly as seen in L10-COMP. Generally, nitrate in the groundwater did not show any statistically significant upward or downward trend. MW-2 was an exception to this case where nitrate trend was downward.

In the bench test, nitrate concentrations suggested that there was removal of nitrates in the soil even though the root uptake pathway was not present. Those changes may have been caused by nitrate transformation.

Summary of Median [Minimum - Maximum] Data for Nitrate as N (mg/L)				
	Recycled Water	Pore Water (5ft bgs)	Pore Water (10ft bgs)	Groundwater
Baseline	10 [7.7 - 15]	-	-	5.65 [3.3 - 10]
Sample Events		1.34 [ND 0.1 - 2.3]	2.25 [1.7 - 3.4]	2.95 [1.6 - 8.2]
Mann-Kendall Trend	None	None	Up	MW-1: None MW-2: Down MW-3: None MW-4: None

Nitrite concentrations were found to be highest in recycled water. Nitrite was detected only once in the groundwater and was not at all detected in the lysimeters. The behavior suggests transformation of nitrites to nitrates by nitrifying bacteria in the initial depth of soil. At the five foot depth, nitrite concentrations were at levels below detection. Given the decrease in nitrate concentrations in the vadose zone (likely due to root uptake) and the lack of nitrite in the subsurface, neither of these constituents appears to have the potential to impact groundwater as a result of recycled water application for irrigation. Note that there is mobility of nitrate when the root uptake pathway does not capture all the nitrogen. This may occur when fertilizer is over applied and/or when vegetation is absent. In these cases, excess nitrate can travel to groundwater.

Summary of Median [Minimum - Maximum] Data for Nitrite as N (mg/L)				
	Recycled Water	Pore Water (5ft bgs)	Pore Water (10ft bgs)	Groundwater
Baseline	0.13 [ND 0.15 - 0.85]	-	-	ND 0.4 [ND 0.15 - ND 0.4]
Sample Events		ND 0.05 [ND 0.05 - ND 0.1]	ND 0.05 [ND 0.05 - ND 0.1]	ND 0.05 [ND 0.05 - 0.15]
Mann-Kendall Trend	None	Down	None	MW-1: None MW-2: None MW-3: None MW-4: None

4.1.4. Anthropogenic Compounds

4.1.4.1. Trihalomethanes (THMs)

THM concentrations (bromodichloromethane, bromoform, chloroform, and dibromochloromethane) were consistently found to be highest in the recycled water. With respect to depth, the concentrations of all THMs decreased dramatically comparing recycled water to the pore water at five feet bgs suggesting effective removal in the soil. Below five feet, THMs were detected infrequently. THM removal could be partly attributed to volatilization from the irrigation spray process and in the vadose zone. THMs were not detected in the groundwater throughout the pilot study. THMs, specifically bromodichloromethane and chloroform, were only once detected in the lysimeters in September 2009 (sixth sampling event). THMs were not detected in the pore water in the subsequent events.

In the bench test, THMs exhibited a similar behavior. Generally, THMs in the effluent samples were lower in concentration than the influent samples.

Overall, the lack of THMs beyond five feet suggests a significant level of attenuation in the soil and minimal potential to impact groundwater.

Summary of Median [Minimum - Maximum] Data for Bromodichloromethane (µg/L)				
	Recycled Water	Pore Water (5ft bgs)	Pore Water (10ft bgs)	Groundwater
Baseline	10 [7.8 - 27]	-	-	ND 0.5 [ND 0.5 - ND 0.5]
Sample Events		ND 0.5 [ND 0.5 - 0.7]	ND 0.5 [ND 0.5 - 0.7]	ND 0.5 [ND 0.5 - ND 0.5]
Mann-Kendall Trend	None	None	None	MW-1: None - All Ties MW-2: None - All Ties MW-3: None - All Ties MW-4: None - All Ties

Summary of Median [Minimum - Maximum] Data for Bromoform (µg/L)				
	Recycled Water	Pore Water (5ft bgs)	Pore Water (10ft bgs)	Groundwater
Baseline	1.3 [0.6 - 2.9]	-	-	ND 0.5 [ND 0.5 - ND 0.5]
Sample Events		ND 0.5 [ND 0.5 - ND 42]	ND 0.5 [ND 0.5 - ND 0.5]	ND 0.5 [ND 0.5 - ND 0.5]
Mann-Kendall Trend	None	None	None - All Ties	MW-1: None - All Ties MW-2: None - All Ties MW-3: None - All Ties MW-4: None - All Ties

Summary of Median [Minimum - Maximum] Data for Chloroform (µg/L)				
	Recycled Water	Pore Water (5ft bgs)	Pore Water (10ft bgs)	Groundwater
Baseline	12 [7 - 23]	-	-	ND 0.5 [ND 0.5 - ND 0.5]
Sample Events		ND 0.5 [ND 0.5 - 1.1]	ND 0.5 [ND 0.5 - 1.7]	ND 0.5 [ND 0.5 - ND 1]
Mann-Kendall Trend	None	None	None	MW-1: None MW-2: None MW-3: None MW-4: None

Summary of Median [Minimum - Maximum] Data for Dibromochloromethane (µg/L)				
	Recycled Water	Pore Water (5ft bgs)	Pore Water (10ft bgs)	Groundwater
Baseline	5.3 [3.9 - 14]	-	-	ND 0.5 [ND 0.5 - ND 0.5]
Sample Events		ND 0.5 [ND 0.5 - 0.8]	ND 0.5 [ND 0.5 - 0.7]	ND 0.5 [ND 0.5 - ND 0.5]
Mann-Kendall Trend	None	None	None	MW-1: None - All Ties MW-2: None - All Ties MW-3: None - All Ties MW-4: None - All Ties

4.1.4.2. Volatile Organic Carbons (VOCs)

Volatile organic carbons (VOCs), excluding THMs, were not detected in the recycled water. VOCs, including those discussed in Volume I (xylenes and carbon tetrachloride), were not detected in recycled water or the other sample locations. VOCs were not recommended for further monitoring in Volume I, but were included in the pilot study because they are reported as a part of the analysis (EPA 8260B) that also analyzes THMs. Trichloroethylene, cis-1,2-dichloroethene, and Freon 113 were detected in the groundwater.The source of trichloroethylene, cis-1,2-dichloroethene, and Freon 113 in the groundwater is not known, but these VOCs and its parent products were not detected in the recycled water and hence are not are not a result of recycled water application. The lack of detection indicates that VOCs did not pose a concern for groundwater impacts due to recycled water irrigation during the pilot study.

4.1.4.3. Haloacetic Acids (HAA6)

Haloacetic Acids (HAA6) include bromochloroacetic acid (BCAA), dibromoacetic acid (DBAA), dichloroacetic acid (DCAA), monobromoacetic acid (MBAA), monochloroacetic acid (MCAA), and trichloroacetic acid (TCAA). The most prominent HAA6 in recycled water was DCAA followed by TCAA, BCAA, MCAA, and DBAA. MBAA was not detected in any samples (recycled water source, monitoring wells, or lysimeters) during the pilot study.

Throughout the pilot study, TCAA and BCAA were detected only in recycled water, and not in any of the subsurface samples. MCAA, DCAA, and DBAA were detected in the lysimeters from September to December 2009, approximately 12 to 14 months after recycled water implementation. The appearance of these constituents in the lysimeters well into the study period indicates a slow migration through the vadose zone. In groundwater, only one HAA6 was detected throughout the pilot study. MCAA was detected in groundwater at MW-2 in the final sampling event. No other HAA6 constituents were detected in the groundwater. In the bench test, HAA6 were mixed in results exhibiting increases and decreases in the influent and effluent samples. The varying results in the bench test were attributed to fluctuative concentrations of HAA6 in the recycled water influent. Attenuation of HAA6 in the bench test was not well observed. From the pilot study, it appears that concentrations of HAA6 may continue to increase further over time. Overall, HAA6 was detected in the lysimeters toward the end of the pilot study and suggests potential to impact pore water and groundwater over longer time frames.

Data qualifier flags that were encountered in the haloacetic acids results in the pilot study include the "J" and "P" flags. A discussion of the flags is found in Section 4.2.4. Both of these flags reduce confidence in the quantification of the constituent concentrations but do not negate the fact that the constituent was detected in those samples. Since the above findings rely more on the presence of HAA6 rather than the quantified concentrations, these findings are not affected by the qualified data.

Summary of Median [Minimum - Maximum] Data for Bromochloroacetic Acid (µg/L)				
	Recycled Water	Pore Water (5ft bgs)	Pore Water (10ft bgs)	Groundwater
Baseline	0.92 J [ND 0.99 - 9.6]	-	-	ND 1 [ND 1 - ND 1]
Sample Events		ND 1 [ND 1 - ND 1]	ND 1 [ND 1 - ND 1]	ND 1 [ND 0.99 - ND 1]
Mann-Kendall Trend Data	None	None - All Ties	None - All Ties	MW-1: None
				MW-2: None - All Ties
				MW-3: None
				MW-4: None

Summary of Median [Minimum - Maximum] Data for Dibromoacetic Acid (µg/L)				
	Recycled Water	Pore Water (5ft bgs)	Pore Water (10ft bgs)	Groundwater
Baseline	ND 1 [ND 0.99 - 3.4]	-	-	ND 1 [ND 1 - ND 1]
Sample Events		ND 1 [ND 1 - 0.17 J]	ND 1 [ND 1 - 0.51 J]	ND 1 [ND 0.99 - ND 1]
Mann-Kendall Trend Data	Down	None	None	MW-1: None
				MW-2: None - All Ties
				MW-3: None
				MW-4: None

Summary of Median [Minimum - Maximum] Data for Dichloroacetic Acid (µg/L)				
	Recycled Water	Pore Water (5ft bgs)	Pore Water (10ft bgs)	Groundwater
Baseline	1.8 [ND 1 - 14]	-	-	ND 1 [ND 1 - ND 1]
Sample Events		ND 1 [ND 1 - 0.26 J]	ND 1 [ND 1 - 0.42 J,P]	ND 1 [ND 0.99 - ND 1]
Mann-Kendall Trend Data	None	None	None	MW-1: None
				MW-2: None - All Ties
				MW-3: None
				MW-4: None

Summary of Median [Minimum - Maximum] Data for Monobromoacetic Acid (µg/L)				
	Recycled Water	Pore Water (5ft bgs)	Pore Water (10ft bgs)	Groundwater
Baseline	ND 1 [ND 0.99 - ND 1]	-	-	ND 1 [ND 1 - ND 1]
Sample Events		ND 1 [ND 1 - ND 1]	ND 1 [ND 1 - ND 1]	ND 1 [ND 0.99 - ND 1]
Mann-Kendall Trend Data	None	None - All Ties	None - All Ties	MW-1: None
				MW-2: None - All Ties
				MW-3: None
				MW-4: None

Summary of Median [Minimum - Maximum] Data for Monochloroacetic Acid (µg/L)				
	Recycled Water	Pore Water (5ft bgs)	Pore Water (10ft bgs)	Groundwater
Baseline	ND 2 [ND 2 - 4.2]	-	-	ND 2 [ND 2 - ND 2]
Sample Events		ND 2 [ND 2 - 1.5 J]	ND 2 [ND 2 - 0.65 J]	ND 2 [ND 2 - 0.26 J]
Mann-Kendall Trend Data	None	None	None	MW-1: None - All Ties
				MW-2: None
				MW-3: None - All Ties
				MW-4: None - All Ties

Summary of Median [Minimum - Maximum] Data for Trichloroacetic Acid (µg/L)				
	Recycled Water	Pore Water (5ft bgs)	Pore Water (10ft bgs)	Groundwater
Baseline	3.3 [ND 0.99 - 9.7]	-	-	ND 1 [ND 1 - ND 1]
Sample Events		ND 1 [ND 1 - ND 1]	ND 1 [ND 1 - ND 1]	ND 1 [ND 0.99 - ND 1]
Mann-Kendall Trend Data	None	None - All Ties	None - All Ties	MW-1: None MW-2: None - All Ties MW-3: None MW-4: None

4.1.4.4. N-Nitrosodimethylamine (NDMA)

NDMA concentrations were found to be highest in recycled water samples followed by lysimeters and the groundwater. The NDMA concentrations in recycled water measured at the site varied from 240 to 460 ng/L. The concentration in the recycled water sample collected directly from the SJ/SC WPCP plant for the baseline event was 112 ng/L. A previous study reported NDMA levels at the SJ/SC WPCP plant ranging from 50 to 360 ng/L (Sedlak et al., 2005). NDMA concentrations decreased dramatically between the recycled water source and the pore water at five feet bgs. The majority of this removal is suspected to be caused by volatilization during application by spray irrigation, where the water receives the most exposure to the atmosphere. Removal can also occur from degradation, plant uptake from the soil, and gas phase diffusion in the soil (Gan et al., 2006, Arienzo et al. 2006). However, volatilization in the vadose zone is reduced in soils that have high water content because of less exposure to air in the pore spaces. The clayey soils at the pilot study site appear to be moist, however this was not measured. Installation of soil moisture probes in future studies may provide information for correlation to NDMA volatilization.

NDMA concentrations at five feet and ten feet were similar. NDMA was detected in the pore water starting with the first sampling event, but the pore water concentrations gradually declined over time as seen in L10-COMP. NDMA in MW-1 showed a statistically significant upward trend over time. On three occasions, NDMA was found in the pore water samples above the California notification level for NDMA of 10 ng/L.

NDMA was detected in the groundwater starting with the fourth sampling event at concentrations near the laboratory reporting limit of 2 ng/L. By the seventh and eighth sampling events, NDMA was detected at low concentrations in three of the four monitoring wells. The NDMA concentrations in groundwater remained below the notification level throughout the pilot study.

Data qualifier flags that were encountered in the NDMA results in the pilot study include the "D," "BB," "BD," "L3," "S7," and "R4" flags. A discussion of the flags is found in Section 4.2.4. Some of these qualifiers ("BB", "BD", "L3") only affected certain samples from the second sampling event. Of the affected samples, all were below detection except one (IDT source), and the qualified concentration was similar to the other concentrations in the IDT source. The "D" flag only affected one sample from the IDT source in the fifth sampling event, and that result was also consistent with other concentrations in the IDT source. The "S7" and "R4" flags raise concerns regarding the accuracy of concentrations. However, both of these flags were only applied to samples where NDMA was not detected. Therefore, the accuracy does not impact the findings.

In the bench test, attenuation of NDMA was not consistently observed. NDMA exhibited both increases and decreases in the effluent samples in the bench test. The difference in observations could be that exposure to the atmosphere was minimized in the bench test hence limiting removal by volatilization. In the pilot study, conditions allowed for exposure to the atmosphere.

Although it is suspected that there is some attenuation of NDMA caused by volatilization, NDMA could still present a potential threat to groundwater.

Summary of Median [Minimum - Maximum] Data for N-Nitroso Dimethylamine (NDMA) (ng/L)				
	Recycled Water	Pore Water (5ft bgs)	Pore Water (10ft bgs)	Groundwater
Baseline	380 BB,BD,L3 [112 - 460]	-	-	ND 1001 [ND 1.9 - ND 4800]
Sample Events		ND 2 [ND 2 - 10]	4.15 [ND 2 - 23]	ND 2 [ND 2 - 4.1]
Mann-Kendall Trend	None	None	Down	MW-1: Up MW-2: None MW-3: None - All Ties MW-4: None

4.1.4.5. Terbuthylazine

Terbuthylazine was detected only once in the recycled water during the course of the pilot study, at the reporting limit of 0.1 µg/L. After the baseline sampling event, terbuthylazine was monitored only in the recycled water source because continued monitoring in the subsurface would not yield useful data for a constituent that is detected infrequently. In the bench test, terbuthylazine was not detected in the influent or effluent samples. Because terbuthylazine is not prominent in the recycled water source, the attenuation behavior was not observed.

Summary of Median [Minimum - Maximum] Data for Terbuthylazine (µg/L)				
	Recycled Water	Pore Water (5ft bgs)	Pore Water (10ft bgs)	Groundwater
Baseline	ND 0.1 [ND 0.1 - 0.1]	-	-	ND 0.1 [ND 0.1 - ND 0.1]
Sample Events		-	-	-
Mann-Kendall Trend	None	-	-	-

4.1.4.6. Perfluorochemicals (PFCs)

The three PFCs monitored in the pilot study were perfluorobutanoic acid (PFBA), perfluorooctanesulfonate (PFOS), and perfluorooctonoic acid (PFOA). PFOS and PFOA were consistently observed to be highest in the recycled water compared to the subsurface samples. One sample collected directly from SJ/SC WPCP did not detect PFCs. PFCs were consistently detected in the recycled water at the pilot study site. In the subsurface samples for the pilot study, PFOS was detected sporadically in the lysimeters and the groundwater at low concentrations. PFOA appeared more consistently in L5-COMP and sporadically in the L10-COMP and the groundwater. With respect to depth, PFOS and PFOA concentrations were significantly lower at the five foot depth compared to the recycled water. Concentrations of PFOS and PFOA were not significantly different between the lysimeters and groundwater. Although no clear trend over time was observed for PFOS or PFOA in the subsurface samples, their presence in the subsurface suggests the potential to migrate to groundwater. In the bench test, PFBA and PFOS were consistently below detection in the SJ/SC WPCP source sample, but were observed in the effluent of one of the soil cores. PFOA was detected in the SJ/SC source samples, but was observed at higher concentrations in the effluent of all of the soil cores irrigated with recycled water. These concentration increases during the bench test were attributed to PFC formation from chemical precursors.

In the pilot study, PFBA was detected only once in the recycled water source, but was detected frequently in the pore water at five feet and once in the pore water at ten feet. PFBA was not detected in groundwater throughout the pilot study. PFBA showed a statistically significant downward trend over time in L5-COMP. The appearance of PFBA in the pore water may be the result of transformation from chemical precursors, which include various fluorinated alcohols and other fluorochemicals. Overall, detections of PFCs in subsurface samples suggest that there is some potential for PFCs in recycled water to impact groundwater.

The baseline event for this study did not detect PFCs in the groundwater at the site. The PFCs in the shallow pore water could not have originated from Coyote Creek, because there is no lateral movement through the vadose zone, and the elevation of the pore water samples (5 feet and 10 feet below ground surface) is above the water level in Coyote Creek.

The only data qualifier flag that was applied to the PFC results in the pilot study was the "D" flag, which affected only results from the IDT source samples in the second and fifth sampling event. A discussion of the "D" flag is found in Section 4.2.4. Although there is some reduced confidence in the quantification of those concentrations, the data appear to be consistent with other samples from the same source, and are still appropriately useful for comparative purposes. Therefore, they are still used for evaluation in this study.

Summary of Median [Minimum - Maximum] Data for Perfluorochemicals (PFBA) (ng/L)				
	Recycled Water	Pore Water (5ft bgs)	Pore Water (10ft bgs)	Groundwater
Baseline	ND 20 [ND 20 - 12]	-	-	ND 50 [ND 50 - ND 50]
Sample Events		12 [ND 10 - 71]	ND 20 [ND 10 - 28]	ND 20 [ND 10 - ND 20]
Mann-Kendall Trend	None	Down	None	MW-1: None MW-2: None MW-3: None MW-4: None

Summary of Median [Minimum - Maximum] Data for Perfluorochemicals (PFOS) (ng/L)				
	Recycled Water	Pore Water (5ft bgs)	Pore Water (10ft bgs)	Groundwater
Baseline	46 D [ND 50 - 87]	-	-	ND 50 [ND 50 - ND 50]
Sample Events		ND 5 [ND 5 - 9]	ND 5 [ND 5 - 6]	ND 5 [ND 5 - 13]
Mann-Kendall Trend	None	None	None	MW-1: None MW-2: None MW-3: None MW-4: None

Summary of Median [Minimum - Maximum] Data for Perfluorochemicals (PFOA) (ng/L)				
	Recycled Water	Pore Water (5ft bgs)	Pore Water (10ft bgs)	Groundwater
Baseline	61 [ND 20 - 100]	-	-	ND 20 [ND 20 - ND 20]
Sample Events		3.2 [ND 5 - 17]	ND 5 [ND 5 - 13]	ND 5 [ND 5 - 15]
Mann-Kendall Trend	None	None	None	MW-1: None MW-2: None MW-3: None MW-4: None

4.1.4.7. NTA and EDTA

Nitrilotriacetic acid (NTA) and ethylenediaminetetraacetic acid (EDTA) were not detected in any samples during the pilot study. The reporting limit for each constituent was 100 µg/L. After the second sampling event, NTA monitoring was discontinued, and EDTA monitoring was conducted only for the recycled water source. In the bench test, NTA was also consistently below detection in both influent and effluent samples. In the bench test, EDTA exhibited increases and decreases in concentration in the effluent compared to the influent. Due to the lack of detection of NTA in the recycled water in the pilot study, the attenuation behavior could not be observed. For EDTA, detections were not observed in the pilot study and attenuation was not consistently observed in the bench test.

Summary of Median [Minimum - Maximum] Data for Nitrilotriacetic acid (NTA) (µg/L)				
	Recycled Water	Pore Water (5ft bgs)	Pore Water (10ft bgs)	Groundwater
Baseline	ND 100 [ND 100 - ND 100]	-	-	ND 100 [ND 100 - ND 100]
Sample Events		-	-	-
Mann-Kendall Trend	-	-	-	-

Summary of Median [Minimum - Maximum] Data for Ethylenediaminetetraacetic acid (EDTA) (µg/L)				
	Recycled Water	Pore Water (5ft bgs)	Pore Water (10ft bgs)	Groundwater
Baseline	ND 100 [ND 100 - ND 100]	-	-	ND 100 [ND 100 - ND 100]
Sample Events		ND 100 [ND 100 - ND 100]	ND 100 [ND 100 - ND 100]	ND 100 [ND 100 - ND 100]
Mann-Kendall Trend	None - All Ties	-	-	-

4.1.4.8. Surfactants

During the pilot study, surfactants were detected only once in the recycled water source, during the baseline sampling event. After the second sampling event, monitoring of surfactants was conducted only for the recycled water source. The reporting limit was 0.2 µg/L for surfactants. Additional surfactants from the AquatrolsSisteen 90 additive contributed to surfactants on the surface. However, there were no detections in L5-COMP in the two events that it was monitored. Attenuation behavior in the pilot study could not be observed, since detection of this constituent was infrequent.

In the bench test, surfactants exhibited increases and decreases in the effluent samples compared to the influent samples. From the results in the bench test, the attenuation of surfactants was not consistently observed.

Summary of Median [Minimum - Maximum] Data for Surfactants (MBAS) (mg/L)				
	Recycled Water	Pore Water (5ft bgs)	Pore Water (10ft bgs)	Groundwater
Baseline	ND 0.2 [ND 0.2 - 0.21]	-	-	ND 0.1 [ND 0.1 - ND 0.1]
Sample Events		ND 0.2 [ND 0.2 - ND 0.2]	ND 0.2 [ND 0.2 - ND 0.2]	ND 0.2 [ND 0.2 - ND 0.2]
Mann-Kendall Trend	None - All Ties	-	-	-

4.1.4.9. Perchlorate

Perchlorate was not detected in two samples of recycled water collected for the baseline and first sampling events. After the first sampling event, perchlorate was removed from the monitoring program due to the lack of detection in the recycled water source. Perchlorate was detected in one of the monitoring wells during the baseline sampling event, but since that concentration was observed prior to recycled water application, it is not considered relevant to this study. Similarly, perchlorate was not detected in the influent or effluent samples in the bench test. The reporting limit was 4 µg/L for perchlorate. Because perchlorate is not prominent in the recycled water source, the attenuation behavior was not observed, however the lack of detection suggests that perchlorate does not pose a concern for groundwater impacts due to recycled water irrigation.

Summary of Median [Minimum - Maximum] Data for Perchlorate (µg/L)				
	Recycled Water	Pore Water (5ft bgs)	Pore Water (10ft bgs)	Groundwater
Baseline	ND 4 [ND 4 - ND 4]	-	-	ND 4 [ND 4 - 4.3]
Sample Events		-	-	-
Mann-Kendall Trend	-	-	-	-

4.1.5. Pathogens

Pathogens were evaluated by observing bacteria and indicator organisms. Specific parameters observed were heterotrophic bacteria by heterotrophic plate count (HPC), fecal coliforms, total coliform, and E. coli. All of these parameters were observed in recycled water at some point during the pilot study.

Bacteria by HPC, total coliforms, and fecal coliforms were also detected in pore water samples. In groundwater, only HPC and total coliforms were observed. Overall, attenuation of bacteria and indicator organisms were not well observed in the pilot study.

Detectable levels of HPC were consistently observed across the soil depth. Generally, HPC levels did not exhibit a clear trend with respect to depth. On some occasions, bacterial growth in recycled water measured by HPC was shown to be several orders of magnitude higher than the reporting limit. These changes in HPC in the recycled water source did not appear to correlate to any changes in the subsurface samples. In pore water and groundwater, HPC showed some fluctuation over time, but did not show any trend over time. In the bench test, major bacterial growth, as indicated by HPC, was observed in the influent and effluent samples.

Data qualifier flags that were encountered in the HPC results in the pilot study include the "D" and "T" flags, both of which were applied only to samples from the eighth sampling event. A discussion of the flags is found in Section 4.2.4. Although there is some reduced confidence in the quantification of those HPC results, the data are still appropriately useful for comparative purposes and are therefore used for evaluation in this study. None of the above findings for HPC are dependent on observed concentrations in the eighth sampling event.

Summary of Median [Minimum - Maximum] Data for Heterotrophic Plate Count (CFU/ 1mL)

	Recycled Water	Pore Water (5ft bgs)	Pore Water (10ft bgs)	Groundwater
Baseline	6300 [<1 D - >57000]	-	-	646 [65 - 2000]
Sample Events		3650 [560 - 10000]	2150 [300 - 3400]	1550 [220 - 11000]
Mann-Kendall Trend	None	None	None	MW-1: None MW-2: None MW-3: None MW-4: None

Total coliform detection was most prominent at L5-COMP although detection was inconsistent. Total coliforms were found sporadically at all locations. The frequency of relatively high levels of total coliforms in the subsurface samples appears to correlate to the winter season when rainwater becomes the primary irrigation source. Because rainwater is not a chlorinated source, bacteria is allowed to grow. During winter 2009/2010, there appears to be an increased frequency of elevated total coliform values compared to winter 2008/2009. Continued monitoring through additional seasons would be needed to determine whether the increasing total coliform values are related to the application of recycled water. Daily samples of total coliform taken at the SJ/SC plant in 2009 ranged from less then 1 to 5 CFU/100mL.

Summary of Median [Minimum - Maximum] Data for Coliforms, Total (MPN/ 100 mL)				
	Recycled Water	Pore Water (5ft bgs)	Pore Water (10ft bgs)	Groundwater
Baseline	18 [ND 2 - 24]	-	-	1 [ND 2 - 11]
Sample Events		2 [ND 2 - 240]	1 [ND 2 - 81]	ND 2 [ND 2 - 140]
Mann-Kendall Trend	None	None	None	MW-1: None MW-2: None MW-3: None MW-4: None

Fecal coliforms were found at highest levels in the recycled water, however detection was not consistent. Lower detections of fecal coliforms appeared in the pore water during two monitoring events. However, there is no clear trend in these concentrations over time. Fecal coliforms were not observed in the groundwater. E. coli was detected only once in the recycled water. E. coli was not detected in the pore water or groundwater during the pilot study. Overall, there is some evidence suggesting that pathogens in recycled water (particularly as indicated by total coliforms) could have the potential to impact groundwater. However, contributions of coliforms and other indicator bacteria from rain water and from the nearby creek were not evaluated.

Summary of Median [Minimum - Maximum] Data for Fecal Coliforms (MPN/ 100 mL)				
	Recycled Water	Pore Water (5ft bgs)	Pore Water (10ft bgs)	Groundwater
Baseline	ND 2 [ND 2 - 24]	-	-	ND 2 [ND 2 - ND 2]
Sample Events		ND 2 [ND 2 - 2]	ND 2 [ND 2 - 2]	ND 2 [ND 2 - ND 2]
Mann-Kendall Trend	None	None	None - All Ties	MW-1: None - All Ties MW-2: None - All Ties MW-3: None - All Ties MW-4: None - All Ties

Summary of Median [Minimum - Maximum] Data for E. Coli (MPN/ 100 mL)				
	Recycled Water	Pore Water (5ft bgs)	Pore Water (10ft bgs)	Groundwater
Baseline	ND 2 [ND 2 - 8]	-	-	ND 2 [ND 2 - ND 2]
Sample Events		ND 2 [ND 2 - ND 2]	ND 2 [ND 2 - ND 2]	ND 2 [ND 2 - ND 2]
Mann-Kendall Trend	None	None - All Ties	None - All Ties	MW-1: None - All Ties MW-2: None - All Ties MW-3: None - All Ties MW-4: None - All Ties

4.2. Quality Assurance/Quality Control

Field QA/QC samples were collected to assess the potential for contamination associated with field sampling equipment, containers, and procedures. The field QC samples that were collected are discussed in the following subsections. Although some data collected for this pilot study were qualified as discussed below, after evaluation with respect to the specific conclusions drawn, it was determined that these qualifications do not substantially affect the interpretation or conclusions derived from the data.

4.2.1. Field Duplicates

Duplicate samples were submitted "blind" to the laboratory using a numeric identification and were analyzed for the same parameters as those specified for the primary sample. Results of duplicate samples are presented in Table III-4-3. Primary sample results associated with the field duplicate are also included in the Table III-4-3 for comparison. One field duplicate was collected for every 20 samples. Field duplicates are marked with an "FD". Duplicate samples of the recycled water source (IDT source) were collected in four sampling events throughout the pilot study and in the baseline event. The majority of the duplicate samples were found to be within reasonable range of the project sample, indicating reliability in the laboratory analysis methods for the pilot study. Issues with field duplicates occurred with HPC (one sample in the eighth sampling event), NDMA (one sample in the fifth sampling event) and PFCs (one sample each in the second and fifth sampling event). In cases where the duplicate sample was out of range (relative percent difference (RPD) > 25% to the primary sample), a "D" flag was associated with the project sample result in Table III-4-1.

The RPD exceedance for HPC was 102 percent for the sample from the IDT source in the eighth sampling event. Because of the biological nature of the HPC analysis, results for HPC can vary significantly compared to other analyses. Although there is a reduced confidence in the quantification of this result, the data are still appropriately useful for comparative purposes because HPC variability within this range is not generally considered significant.

The RPD exceedance for NDMA was 37 percent for the sample from the IDT source in the fifth sampling event. This exceedance occurred only once out of the four sampling events that included field duplicates. Although there is some reduced confidence in the quantification of this result, the qualified value is consistent with other concentrations from the IDT source. Additionally, the findings for NDMA are based on concentration differences exceeding 37 percent (see Section 4.1.4.4). Therefore the uncertainty associated with this data qualification does not impact the NDMA findings.

For PFCs, the RPD exceedance for PFOS was 41 percent in the second sampling event and 26 percent in the fifth sampling event. The RPD exceedance for PFOA was 41 percent in the second sampling event. These RPD exceedances applied only to the IDT source samples. There were no RPD exceedances for PFBA. This type of exceedance occurred in two out of the four sampling events with field duplicates. Although there is a reduced confidence in the quantification of these concentrations, the findings of the study regarding PFCs rely primarily on the frequency and locations of detection rather than the quantified concentrations (see Section 4.1.4.6). Therefore the potential for inaccurate quantification of these concentrations does not substantially impact the findings.

4.2.2. Trip Blanks

Trip blanks are used to assess potential cross-contamination of constituents among samples. One trip blank accompanied every 20 samples. The trip blanks consisted of containers filled with deionized water. Results of trip blanks are also presented in Table III-4-3. Trip blanks were collected in four sampling events throughout the pilot study. The majority of the trip blank samples were found below detection, indicating reliability in the sample delivery. Trip blanks with detections occurred with HPC, sodium, alkalinity, and DOC. A detection in the trip blank does not necessarily indicate an issue of quality. If the associated sample results are greater than the concentration detected in the trip blank, the detection in the trip blank would have no effect on the sample results. In instances where the trip blank sample caused an issue of quality, a "T" flag was placed with the associated sample results in Table III-4-1.

For both sodium and alkalinity the concentrations in the trip blanks were much lower than concentrations of the primary samples, such that the primary samples would not be affected. Hence, "T" flags were not assigned to any samples from these constituents.

For DOC, a "T" flag was not assigned to any DOC results from that event because there were no quantifiable results that were below were that had a lower concentration than the trip blank result. For HPC, a "T" flag was assigned to only the HPC result from MW-4 from the eighth sampling event. Although there is some reduced confidence in the quantification of these concentrations, the data are still relevant and used in the study for evaluation purposes.

4.2.3. Rinseate Blanks

A rinseate blank was collected to assess the quality of field decontamination procedures particularly with respect to volatile organic carbons (VOCs). This sample was submitted "blind". No detection was reported for this sample, indicating proper field decontamination procedures.

4.2.4. Flags

Below is a discussion of the different data qualifier flags that have appeared in the pilot study analytical data and any implications for the qualified data. Implications of these flags on the findings are discussed with the analytical results in Section 4.1.

4.2.4.1. "B"

The "B" flag is defined as a low recovery in the matrix spike (MS) and matrix spike duplicate (MSD). The associated relative percent difference (RPD) is out of laboratory limits. The purpose of the MS and MSD is to identify method performance and precision. This flag was applied once for the dissolved organic carbon analysis of L5-COMP in the sixth sampling event.

4.2.4.2. "BB"

The "BB" flag is defined as detection in the associated method blank at or above the laboratory minimum reporting limit (MRL). There is no impact on the reported result due to the "BB" flag because the target analyte is ten times above the concentration level of the detection found in the method blank.

This flag was applied once for the NDMA result in the IDT source sample in the second sampling event which is also qualified with "BD" and "L3" flags.

4.2.4.3. "BD" and "L3"

The "BD" flag is defined as detection in the associated method blank that is above the California Department of Public Health (CDPH) recommended value of 0.5 and does not meet the internal blank limit of one third the MRL. One third of the MRL for NDMA is 0.7 ng/L.

The "L3" flag indicates that the associated blank spike recovery was above the method acceptance limits. A blank spike identifies the performance of the preparation method on a clean matrix that is void of interferences.

Flags "BD" and "L3" were applied to the NDMA result in the IDT source and monitoring well samples in the second sampling event. The monitoring well results are not affected by these qualifiers because

NDMA was not detected in those samples. These flags may indicate potential uncertainty in the quantification of NDMA in the IDT source sample. However, the result is consistent with the other samples collected from that source and is therefore still considered representative.

4.2.4.4. "D"

The "D" flag indicates that the associated field duplicate sample was out of RPD limits with respect to the primary sample. See Section 4.2.1 for discussion of the field duplicates.

4.2.4.5. "J"

The "J" flag indicates that the constituent is detected but the quantitation is an estimate between the method detection limit and the laboratory reporting limit. Estimated values in this range are at a lower confidence than quantitations at or above the reporting limit.

"J" flags were applied to the haloacetic acids results in the IDT source, L5-COMP, and L10-COMP in the sixth through eighth sampling events, and MW-2 in only the eighth sampling event. A "J" flag was also applied to the bromide result from the L10-COMP location in the first sampling event.

4.2.4.6. "P"

The "P" flag indicates that confirmation criteria were exceeded for the gas chromatography or high-performance liquid chromatography. The RPD was greater than 40% between the two analytical results. All data qualified with the "P" flag were also qualifed with a "J" flag.

The "P" flag was applied to the haloacetic acid results from the IDT source, L5-COMP, and L10-COMP locations in the last two sampling events.

4.2.4.7. "R4"

The "R4" flag indicates that the RPD associated with the MS/MSD exceeded method limits, which is similar to the "B" flag. The purpose of the MS and MSD is to identify method performance and precision.

The "R4" flag was applied to the NDMA result for MW-2 in the sixth sampling event. Since this result was below detection, the quantification of this result is not critical to the findings of the study.

4.2.4.8. "S7"

The "S7" flag indicates that the surrogate recovery was below laboratory and method acceptance limits. The effect to the matrix could not be confirmed. The purpose of surrogate recovery is to demonstrate correct sample preparation and absence of matrix effects in the test method.

The "S7" flag was applied to the NDMA result from the L10-COMP location in the seventh sampling event. Since this result was below detection, the quantification of this result is not critical to the findings of the study.

4.2.4.9. "T"

The "T" flag indicates that there is a detection found in the associated trip blank at a concentration greater than the associated sample. See Section 4.2.2 for discussion on the trip blanks.

4.3. Water Budget of Recycled Water to Vadose Zone

A water budget is included in the pilot study evaluation to estimate the amount of water that may infiltrate the soil. The major finding was that for conservative constituents, concentrations of recycled water were estimated to increase by a factor of two in the vadose zone based on the gains and losses of water alone. This estimate is obtained by using a basic hydrologic budget to estimate of the dilution or concentration of recycled water in the vadose zone. An equation for the hydrologic budget is given by:

$F = Bi - Bo + P - ET - S - R$ Brutsaert, 2005

Where
F = Infiltration rate.
Bi = Boundary in condition. For this case, the irrigation rate is used here.
Bo = Boundary out condition, assumed zero.
P = Precipitation.
ET = Evapotranspiration.
S = Storage, assumed negligible.
R = Surface runoff, assumed negligible.

Storage and surface runoff are taken to be negligible. Precipitation, P, in the central San Jose region was reported at 10.04 inches/year for the 2008/2009 winter season (SCVWD, 2009) and 15.12 inches/year for the 2009/2010 winter season (SCVWD, 2010). The average precipitation from the two seasons is 12.58 inches/year. Irrigation application, Bi, at the IDT site was estimated to be 8,717 ccf / year, or 38.7 inches / year (Pacific Crest Engineering Inc., 2005). ET is calculated using

$ET = Kc \times ETo$ University of California Cooperative Extension, 2000

Where
ET = Crop evapotranspiration.
Kc = Crop coefficient.
ETo = Reference evapotranspiration

Kc of warm season turfgrass is 0.6 (University of California Cooperative Extension, 2000). Warm season turfgrass was assumed for the entire irrigated IDT landscape including shrub beds. ETo in the San Jose region is 49.4 inch / year (CIMIS, 1999). Therefore, ET is calculated to be 29.6 inch / year.

Infiltration rate, F, is calculated from the hydrologic budget to be 21.7 inch / year (or 11.2 acre-ft/year). The concentration of recycled water in the vadose zone is estimated to be roughly a factor of 2. This estimate is obtained by using the ratio of the irrigation application rate (38.7 inches/year) to the infiltration rate (21.7 inches/year). TDS data which is taken to be a relatively conservative parameter, supports this estimate. The TDS concentrations in the pore water at five feet bgs is approximately twice that of the recycled water source concentration.

4.4. Piper Diagram Analysis

Piper diagrams graphically summarize cation and anion data in a composite diamond to visually distinguish differences in ionic water quality. In Figure III-4-49, anions including chloride, sulfate, bicarbonate, and cations including calcium, magnesium, sodium, potassium, are plotted as a percent composition of the anions or cations. Compositions are in terms of percentages of equivalence per volume concentrations.

Points for the baseline and sampling events are plotted out. Groundwater data points are an average of the four monitoring wells. L5-COMP and L10-COMP are plotted individually. Recycled water is plotted as one data point, an average of the water quality of the baseline and sampling events through the pilot study since this source is not expected to vary significantly over time.

Of the cations used in the piper diagram, calcium and magnesium appear to be more dominant in groundwater while sodium and/or potassium appear to be more dominant in the recycled water. For the anions, bicarbonate is the dominant anion in groundwater while recycled water is more dominated by chloride.

Comparing the water composition in the recycled water, groundwater, and the pore water, the diagram shows at shallower depths, the water quality is closer to that of recycled water. Visually, L5-COMP data points are more closely plotted to the recycled water while groundwater tends to be plotted furthest away from recycled water.

Over time, trends of the ionic composition in the pore water and the groundwater tend to show a shift towards the ionic composition of recycled water. This is most evident in L5-COMP which is the shallowest depth; however some shift towards an ion composition in recycled water can be discerned in the groundwater data as well.

Trends identified from the piper diagram analysis indicate that recycled water has contributed to the changes in groundwater within the pilot study period. This agrees with other findings of this study, such as NDMA detections observed in the groundwater.

4.5. Conclusions

4.5.1. Constituent Attenuation

Below is a table summarizing the potential threat to groundwater with respect to each constituent based on findings from the pilot study and bench test. Each constituent is given a rating between 1 and 5, with 5 representing the highest potential threat. The criteria for assigning each threat are the observed attenuation of the constituent in the pilot study and bench test and the type of constituent. In general, the greater the overall attenuation behavior displayed from the bench test and pilot study the lower the potential threat. Also considered is whether the constituent is naturally occurring or has known health impacts. The type of constituent can range from general water quality parameters like alkalinity and DO, to emerging contaminants like NDMA and PFCs. The potential threat assigned for each constituent below includes consideration of these factors. Some monitored constituents were not consistently detected in the recycled water source during the study. Since the attenuation of those constituents could not be evaluated, they are assigned as inconclusive. Further monitoring of recycled water sources is needed to determine whether those constituents are sufficiently present to pose a potential threat to groundwater.

In addition to the potential threat value, the table includes a recommendation on whether further monitoring of each constituent is warranted. Constituents that are recommended for further monitoring are those with a threat value of three or higher or if the constituent has been assigned as inconclusive.

Constituent	**Potential Threat**	**Recommend for Further Monitoring?**	**Findings**
ORP	1	N	ORP is a general water quality parameter. Measurements of ORP suggest no major shifts in redox conditions.
pH	1	N	The pH is a general water quality parameter. The pH was near neutral in the pilot study and bench test. Similarity of pH across depth indicates conditions are stable.
Chlorine, Total	1	N	Concentrations of chlorine were higher in groundwater than in recycled water and pore water in the pilot study.
Dissolved Oxygen	1	N	DO is a general water quality parameter. DO was 0.01 mg/L or above across depth in the pilot study indicating that anoxic conditions are unlikely. Samples from the bench test indicated oxic conditions.
Alkalinity, Total	1	N	Alkalinity is a general water quality parameter. A greater alkalinity in the pore water equates to more stability in pH conditions.
Bicarbonate Alkalinity	1	N	
Boron	3	Y	Boron removal was not well observed in the bench test or pilot study.

Calcium	2	Y (See SAR)	Calcium concentrations are greater in the subsurface than in recycled water.
Magnesium	2	Y (See SAR)	Magnesium concentrations are greater in the subsurface than in recycled water.
Sodium	4	Y	Sodium is directly related to SAR, as well as having a direct potential effect on groundwater.
Sodium Adsorption Ratio (SAR)	4	Y	SAR may indicate impact to soil drainage from clay swelling as a result of recycled water application when the SAR in the recycled water is higher than the SAR of the previous irrigation source.
Potassium	1	N	Potassium data from bench test and pilot study suggest good removal.
Sulfate	3	Y	Sulfate increased in concentration in pore water, likely due to contribution from soil and fertilizer. Sulfate concentration in groundwater was relatively stable in the pilot study. In the bench test, removal was not well observed. The constituent also contributes to the total dissolved solids.
Nitrite	2	N	Nitrate/Nitrite data show removal with depth in the pilot study. Mechanism is suspected to be attenuation by root uptake pathway.
Nitrate	2	N	
Chloride	4	Y	Chloride over time has shown an increasing trend in concentrations in groundwater and pore water. At the end of the pilot study, chloride had not yet reached stable conditions. Attenuation of chloride in the bench test was not well observed. The constituent also contributes to the total dissolved solids.
Total Organic Carbon (TOC)	2	N	TOC was decreased by microbial activity and adsorption to soil; groundwater was relatively stable in pilot study. The bench test findings were consistent with the pilot study.
Total Filterable Residue at 180C (TDS)	3	Y	Although TDS in the pilot study in groundwater appeared relatively stable, levels have been observed above secondary drinking water standards in both the baseline and subsequent events. TDS in recycled water and lysimeters are also above secondary drinking water standards. In the bench test, attenuation was not well observed.
Dissolved Organic Carbon	2	N	DOC was decreased by microbial activity and adsorption to soil; groundwater was relatively stable in pilot study. The bench test findings were consistent with the pilot study.

Bromodichloromethane (THM)	2	N	Bromodichloromethane was removed in the vadose zone. Bromodichloromethane was not detected in groundwater during the pilot study. THM data in the bench test also showed attenuative behavior.
Bromoform (THM)	2	N	Bromoform was removed in the vadose zone. Bromoform was not detected in groundwater during the pilot study. THM data in the bench test also showed attenuative behavior.
Chloroform (THM)	2	N	Chloroform was removed in the vadose zone. Chloroform was not detected in groundwater during the pilot study. THM data in the bench test also showed attenuative behavior.
Dibromochloromethane (THM)	2	N	Dibromochloromethane was removed in the vadose zone. Dibromochloromethane was not detected in groundwater during the pilot study. THM data in the bench test also showed attenuative behavior.
Carbon Tetrachloride (VOC)	1	N	Carbon tetrachloride was not detected in recycled water in pilot study or bench test. The constituent was also categorized as having minimal potential impact in Volume I.
Xylenes, Total (VOC)	1	N	Xylenes were not detected in recycled water in pilot study or bench test. The constituent was also categorized as having minimal potential impact in Volume I.
Additional 8010-list VOCs	1	N	VOCs were not detected in recycled water in the pilot study or bench test. VOCs excluding xylenes and carbon tetrachloride were also not detected in the data analysis of Volume I.
Haloacetic Acids (HAA6): Bromochloroacetic Acid Dibromoacetic Acid Monobromoacetic Acid Monochloroacetic Acid Trichloroacetic Acid	4	Y	HAA6 were not observed in the baseline groundwater samples but were observed in the applied recycled water, pore water, and groundwater during the pilot study. In the bench test, HAA6 attenuation was not well observed. HAA6 are also anthropogenic compounds.
Heterotrophic Plate Count	3	Y	Growth was present in pore water and groundwater. Growth was also observed in the bench test. Attenuation was not observed.
Coliforms, Total	3	Y	Growth was present in pore water and groundwater. Growth was also observed in the bench test. Attenuation was not observed.
Fecal Coliforms	3	Y	Fecal Coliforms were not present in groundwater during the pilot study. In the bench test, fecal coliforms were not frequently detected. Attenuation was not well observed.

E. Coli	Inconclusive	Y	E. Coli was minimally detected in recycled water in the pilot study. In the bench test, E. coli was not frequently detected. Therefore the attenuation behavior could not be examined. The constituent may be present in the other recycled water sources in the study area.
N-Nitroso Dimethylamine (NDMA)	5	Y	NDMA was not observed in the baseline groundwater samples, but was observed in the applied recycled water, pore water, and groundwater during the pilot study. The majority of attenuation of NDMA could potentially be from volatilization in the vadose zone and biotransformation in the soil. In the bench test, NDMA attenuation was not consistently observed. NDMA is an emerging contaminant.
Perfluorochemicals	5	Y	PFCs were not observed in the baseline groundwater samples, but were observed in the applied recycled water, pore water, and groundwater during the pilot study. Similarly, in the bench test, some PFCs were observed in the effluent but not in the influent. There is potential for PFC formation from precursors. PFCs are emerging contaminants.
Phosphate	1	N	Phosphate removal was observed in the pilot study and bench test. Mechanisms that caused removal of phosphates are suspected to be the root uptake pathway and precipitation.
Ethylenediaminetetraacetic acid (EDTA)	3	Y	EDTA was not detected in recycled water in the pilot study. In the bench test attenuation was not consistently observed.
Surfactants (MBAS)	3	Y	Surfactants were minimally detected in recycled water in the pilot study. In the bench test attenuation was not consistently observed.
Bromide	2	Y	Removal of bromide in the vadose zone is low; however the degree of toxicity of bromide is low. Together with chloride, bromide can be a useful tracer for recycled water transport.
Nitrilotriacetic acid (NTA)	Inconclusive	Y	NTA was not detected in the pilot study or bench test. Therefore the attenuation behavior could not be fully examined. This constituent may be present in the other recycled water sources in the study area.
Perchlorate	Inconclusive	Y	Perchlorate was not detected in recycled water during the pilot study or bench test. Therefore the attenuation behavior could not be fully examined. This constituent may be present in the other recycled water sources in the study area.

Cyanide	Inconclusive	Y	Cyanide was minimally detected in pilot study or bench test. Therefore the attenuation behavior could not be fully examined. This constituent may be present in the other recycled water sources in the study area.
Terbuthylazine	Inconclusive	Y	Terbuthylazine was minimally detected in recycled water in pilot study and bench test. Therefore the attenuation behavior could not be fully examined. This constituent may be present in the other recycled water sources in the study area.

4.5.2. Potential for Reduction in Soil Drainage Caused by Soil Aquifer Plugging

The pilot study has shown based on SAR data that the potential for soil aquifer plugging from recycled water use exists. SAR data suggest clay swelling to some degree in the first five feet. This was indicated by the difference in compositions of sodium, magnesium, and calcium at different soil depths. SAR in the pore water at five feet bgs was much higher than SAR at ten feet bgs and below. Values of SAR found in L5-COMP in the first event were similar to the SAR values of recycled water. Because recycled water was implemented between the baseline and first sampling event, it is possible that clays at the IDT site expanded during this time although baseline data of the pore water was not available to prove this conclusively. The change in permeability due to the clay swelling could not be quantitatively measured. Comparatively, a switch to recycled water can only contribute to clay swelling when the water source previously used has a lower SAR than recycled water. Typically, groundwater will have a lower SAR value than recycled water, as was the observed condition for the pilot study.

In the bench test, clay swelling occurred in the fine-grained soil cores. This was determined by comparing the core effluent volumes of the fine-grained soil cores with and without gypsum applied. The fine-grained soil cores which had gypsum applied achieved greater percolation than the fine-grained soil cores. The use of gypsum, which was not implemented at the pilot study site, promotes permeability by introducing calcium to the system, hence lowering SAR. However, constituent transport downward is also promoted.

5. CONCLUSIONS

5.1. Limitations of the Pilot Study

This pilot study was designed to directly monitor the effect of recycled water irrigation on groundwater at the IDT site in the southern part of the Santa Clara Subbasin. For the purpose of the entire recycled water study, the data and conclusions from this pilot study will be extrapolated for application to the entire project study area, which includes all of Santa Clara and Llagas Groundwater Subbasins. To use this information appropriately, it is important to note the factors that limit the applicability of this data set. These factors are described below.

5.1.1. Duration and Scale

The pilot study monitoring program covered a period of approximately 18 months from September 2008 to March 2010. It was observed that some recycled water constituents have the potential to impact groundwater within this time frame. However, other constituents that migrate more slowly may still have the potential to impact groundwater, but on a longer time frame. Examination of the pore water concentrations at five feet and ten feet can be used to extrapolate potential impacts to groundwater over a longer time period. For example, constituents that affected pore water at five feet after 18 months could affect groundwater at 30 feet after 108 months. Similar extrapolations could be used to approximate conditions for differing groundwater depths.

5.1.2. Site Characteristics

The selected pilot study site has surface and subsurface characteristics that are similar to many other areas with the project study area. However, there are many other sites within the project study area with substantially different characteristics. At the pilot study site, only one type of soil was represented (silty clay). As observed in previous phases of this study, the soil type has significant influence on the migration of recycled water constituents. Extrapolation of the pilot study conclusions to other soil types can serve as a guideline or framework for specific sites but will require careful consideration of the differences in infiltration rate and sorption characteristics.

Recycled water irrigation and infiltration at the pilot study were in areas of turf grass and trees/shrubs. The effect of the specific type of landscaping on recycled water constituent migration could not be evaluated in the pilot study. Application of recycled water for irrigation of other landscape types may require consideration of varying evapotranspiration and nutrient intake rates. However, it is not expected that the landscaping for proposed recycled water applications in the project study area would be significantly different from the IDT site. Pilot study data would be most applicable to a similar mix of landscape.

As described previously, some soil additives in use at the pilot study site may have affected the assessment of certain constituents (e.g. sulfate, potassium, phosphate). This information was factored into the pilot study findings for those affected constituents. Changes in the application of fertilizer or other soil additives should be considered when trying to use the pilot study conclusions for other sites. This is especially the case if gypsum is being used. Gypsum was not applied at the pilot study site, but has been shown in previous phases of this study to have a significant impact on recycled water constituent migration (see Volume II).

5.1.3. Recycled Water Source

Since the pilot study was conducted at a single location, only one source of recycled water (SJ/SC WPCP) was evaluated. Previous phases of this study have shown significant variability between the four sources of recycled water within the project study area (see Volume I). Differences in the recycled water constituent concentrations should be evaluated when using the pilot study data for other recycled water sources.

5.2. Comparison to Previous Phases of the Study

5.2.1. Soil Attenuation Model

In Volume II of this report, transport of four constituents (m-Xylene, chloroform, NDMA, and bromodichloromethane) was simulated using a one-dimensional vadose zone transport model. These constituents were chosen for the soil attenuation model based on the presence of these constituents in recycled water and the availability of information regarding their chemical transport properties. Results from the pilot study of chloroform, NDMA, and bromodichloromethane agreed well with the model results in clayey soils. Xylenes were not detected in the recycled water in the pilot study, and therefore could not be compared. For the four constituents, the pilot study and the model showed a dramatic decrease to near zero in concentration in the pore water at five feet bgs as compared to the recycled water. At five feet in the pilot study, detection of these constituents was very low. The model at five feet (~1.5 meters) showed concentrations to be near zero.

One noted difference between these methods is that the top boundary conditions of the model begin at the soil surface. Processes that occur before infiltration such as the volatilization from spray irrigation are not captured in the model. In the pilot study, the irrigation system exposed the water to ambient air before reaching the soil. In addition, the model did not capture degradation and/or transformation of constituents.

5.2.2. Bench Test

In the bench test, soil core SJSC-A was derived from the IDT site where the pilot study took place. SJSC-D was also derived from the IDT site and this sample was tested with gypsum applied at the surface. However gypsum was not used during the pilot study. Due to the low infiltration rate of recycled water of SJSC-A, very little effluent water was derived from this sample during the bench test. Therefore, there was insufficient sample volume to complete most of the analyses. The length of SJSC-A was 12 inches and the duration of the test for this sample was 121 days. The initial hydraulic conductivity (which was not exposed to recycled water) of this core was measured to be 4.7 x 10^{-6} cm/sec. Observed hydraulic conductivity (exposed to recycled water) of the soil core at the end of the bench test was less than 1.06 x 10^{-6} cm/sec.

In general, the pilot study data fluctuated less than the data from the bench test. In the bench test there was a high variation in the data which was attributed to the shorter time frame and shorter soil length evaluated. These variations were minimized in the pilot study. In contrast to the bench test, the pilot study was evaluated over 35 foot soil depth and over a study period of 18 months.

For the bench test, a 20% difference was used as a general guideline to define a significant change between influent and effluent concentrations. In the pilot study, a percentage difference was not used in evaluating the data. Instead, trend data were evaluated using Mann-Kendall analysis. The Mann-Kendall analysis is a more statistically robust analysis, and the pilot study provided a sufficient volume of data for this analysis. The bench test used the percentage difference approach because it included only two sampling events, which is not enough to complete a Mann-Kendall analysis.

5.3. Summary of Potential Threat to Groundwater

Based on the results obtained from the pilot study and bench test, the constituents that showed the highest potential to impact groundwater were NDMA, HAA6, and PFCs, due to their appearance in groundwater during the pilot study and lack of presence in the groundwater baseline data. Some results of NDMA found in the pore water were above the California notification level NDMA of 10 ng/L. In the bench test, NDMA removal was not consistently observed. PFCs have appeared in the groundwater and were not present in the baseline sampling event. PFBA in particular was not found in the recycled water but was found in the other sample locations suggesting transformation to PFBA from other products. HAA6 is also a concern because of its presence in the pore water and potential to impact groundwater. Removal of HAA6 was also not observed in the bench test.

Sodium, magnesium, and calcium are other constituents in recycled water that may adversely affect groundwater. Sodium, magnesium, and calcium can limit soil drainage through clay swelling and the pilot study has suggested based on SAR data that the clays in the shallow soil were already expanded. Swelling is likely to occur due to recycled water because other water sources, such as drinking water and groundwater typically have lower SAR values. The change in permeability due to the clay expansion at the site could not be quantitatively measured. Although not used at IDT during the pilot study, the use of gypsum promotes permeability by introducing calcium to the system, hence lowering SAR. However, constituent transport downward is also promoted. In the bench test, it was observed that the application of gypsum greatly improved permeability of the soil.

Constituents that indicated some potential to impact groundwater include TDS, boron, sulfate, chloride, and pathogens. Rising concentrations of chloride in the pore water and groundwater over time during the pilot study present a concern for potential long-term impact and chloride removal in the bench test was not well observed. Some biological constituents, specifically heterotrophic bacteria and total coliforms, were found to be present in the recycled water and to some extent in the pore water and groundwater. Overall there is some evidence from the pilot study suggesting that pathogens in recycled water could potentially impact groundwater. TDS results in groundwater, pore water, and recycled water from the pilot study and effluent in the bench test were found to be above the secondary drinking water standard. Moderately high levels of TDS found in groundwater at the IDT site, as seen in the baseline and pilot study, leave less capacity for further increases in TDS due to incoming recycled water used in irrigation. Boron and sulfate data from the pilot study and bench test suggested that attenuation was low. The soil and fertilizer was likely to contribute to sulfate in the pore water than recycled water alone.

Most constituents indicated only minimal potential to impact groundwater, including phosphate, nitrate, nitrite, potassium, TOC, DOC, and THMs. Major nutrients such as phosphate and nitrate/nitrite appear to be greatly reduced from irrigation when vegetation is present and fertilizer is appropriately used. The plant uptake process is a potential pathway for nutrient removal. TOC and DOC were not observed to reach groundwater in the pilot study.

Potassium and THMs in groundwater appeared stable in the pilot study. THMs were not detected in groundwater. Potassium was detected in groundwater but at concentrations similar to baseline levels. In addition bench test data of potassium and THMs exhibited removal in the soil.

Alkalinity, pH, ORP, DO, and chlorine showed recycled water had negligible potential to impact groundwater through recycled water use. The stability of general parameters (pH, ORP and DO) as seen in the pilot study and bench test indicate that there were no major shifts in conditions. Chlorine measurements in groundwater in the pilot study were generally higher than in recycled water.

VOCs (excluding THMs) were not detected consistently in recycled water in either the bench test or the pilot study and did not pose a potential threat to groundwater at the IDT site. In addition, Volume I of this study found that xylenes and carbon tetrachloride were regarded as having D) minimal potential impact. The data analysis of Volume I also did not find detections of any other VOCs in recycled water.

Cyanide, terbuthylazine, NTA, and perchlorate were not detected consistently in recycled water in either the bench test or the pilot study. Detections that did occur were near or at the reporting limit. In groundwater, only perchlorate was detected once. Because these parameters were not frequently present in the recycled water source at IDT, they did not have impacts to the groundwater at the IDT site. However, the attenuation behavior of these constituents could not be well examined.

EDTA and surfactants were detected in recycled water during the bench test, but were found to not attenuate well. EDTA and surfactants were not consistently detected in the recycled water in the pilot study, thus conclusions from the pilot study could not be made.

The evaluation of potential threats presented in this section is based on the 18-month pilot study conducted at the IDT site. Due to the fairly limited monitoring period for this study, it is possible that the arrival of some constituents did not occur within the pilot study duration. As part of an agreement with the SCVWD, IDT is conducting ongoing groundwater monitoring at the site, and those results should be considered along with the findings of this study to guide future efforts.

REFERENCES

Anders, R. and Schroeder, R.A., United States Geological Survey, 2003, Use of Water-Quality Indicators and Environmental Tracers to Determine the Fate and Transport of Recycled Water in Los Angeles County, California, Water Resources Investigations Report 03-4279, prepared in cooperation with the Water Replenishment District of Southern California.

Arienzo M., Gan J., Ernest F., Qin S., Bondarenko S., Sedlak D.L., 2006, Loss Pathways of N-Nitrosodimethylamine (NDMA) in Turfgrass Soils, Journal of Environmental Quality, 35(1):285-292.

Aspeitia, Miguel A. ITAP Landscape Consultant, 2006, Integrated Device Technology Inc., Landscape Irrigation Evaluation Report, Landscape Meter Account #017545B, prepared for Santa Clara Valley Water District, 15 February.

Brady, N.C., Wiel, R.R., 2008, The Nature and Properties of Soils, Revised 14th Edition, pp 415-430.

Brutsaert, W., 2005, Hydrology an Introduction, Cambridge University Press, pp 142-148.

California Department of Public Health (CDPH), 2007, Drinking Water Notification Levels and Response Levels: An Overview, Drinking Water Program, Last update: December 14, 2007, URL: http://www.cdph.ca.gov/certlic/drinkingwater/Pages/default.aspx.

California Irrigation Management Information System (CIMIS), 1999, Reference Evapotranspiration, Developed as a cooperative project between the Department of Land, Air and Water Resources University of California Davis and Water Use Efficiency Office California Department of Water Resources, Map prepared by David W. Jones.

City of San Jose, date unspecified, Treatment Processes for San Jose/Santa Clara Water Pollution Control Plant, Environmental Services, URL: http://www.sanjoseca.gov/sbwr/treatmentprocess.htm

Gan J., Bondarenko s., Ernst F., Yang W., Ries S.B., Sedlak D.L., 2006, Leaching of N-nitrosodimethylamine (NDMA) in Turfgrass Soils During Wastewater Irrigation, Journal of Environmental Quality, 35(1):277-284.

Pacific Crest Engineering Inc., 2005, Site Soil and Groundwater Sampling Report, prepared for Integrated Device Technology Inc., 1 August.

Santa Clara Valley Water District, 2009, Rainfall and Reservoir Status Report for period 05/28/2009 to 06/30/2009, Automated Local Evaluation in Real Time (ALERT) Hydrologic Data Collection System, June 30.

Santa Clara Valley Water District, 2010, Rainfall and Reservoir Status Report for period 05/31/2010 to 06/28/2010, Automated Local Evaluation in Real Time (ALERT) Hydrologic Data Collection System, June 28.

Sedlak D.L., Deeb R.A., Hawley E.L., Mitch W.A., Durbin T.D., Mowbray S., Carr S., 2005, Sources and Fate of Nitrosodimethylamine and its precursors in municipal wastewater treatment plants, Water Environmental Resources, 77, 32-39.

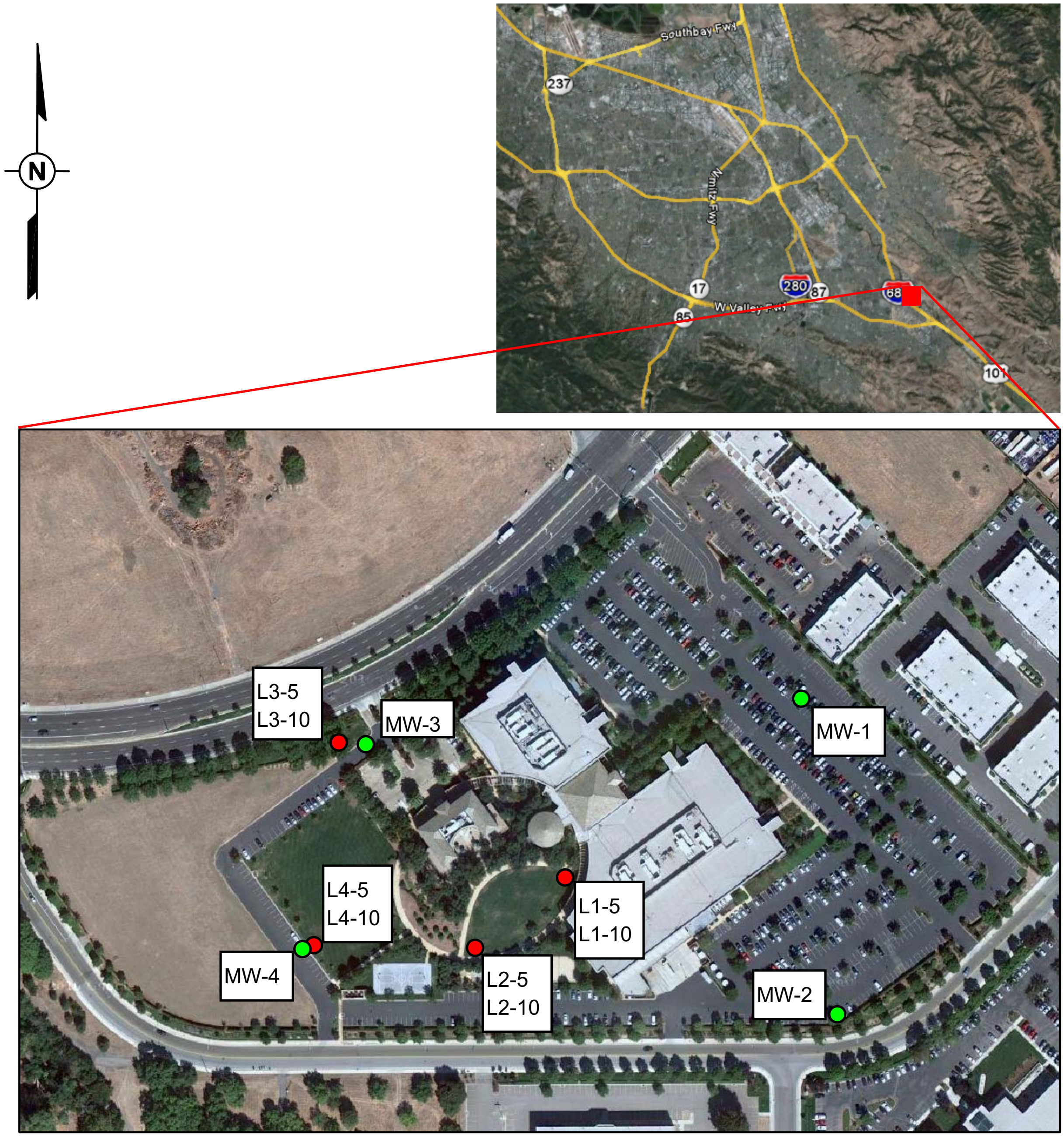
University of California Cooperative Extension, 2000, A Guide to Estimating Irrigation Water needs of Landscape Plantings in California, The Landscape Coefficient Method and WUCOLS III, California Department of Water Resources, August.

US Geological Survey (USGS), 2011, Feature Detail Report for: Coyote Creek, Geographic Names Information System (GNIS), Form Updated: July 19th, 2011, URL: http://geonames.usgs.gov/pls/gnispublic/f?p=gnispq:3:4498371849670995::NO::P3_FID:255083

World Health Organization, 2009, Bromide in Drinking-water, Background document for development of WHO Guidelines for Drinking-water Quality.

Zadeh, J., 2010, Locus Email Correspondence with Jessica Zadeh of South Bay Water Recycling City of San Jose, June 24th 2010.

FIGURES



🟢 Groundwater Monitoring Well
🔴 Lysimeter

SAMPLE LOCATIONS MAP
INTEGRATED DEVICE TECHNOLOGY
6024 SILVER CREEK VALLEY ROAD
SAN JOSE, CA 95138

PREPARED FOR

SANTA CLARA VALLEY WATER DISTRICT

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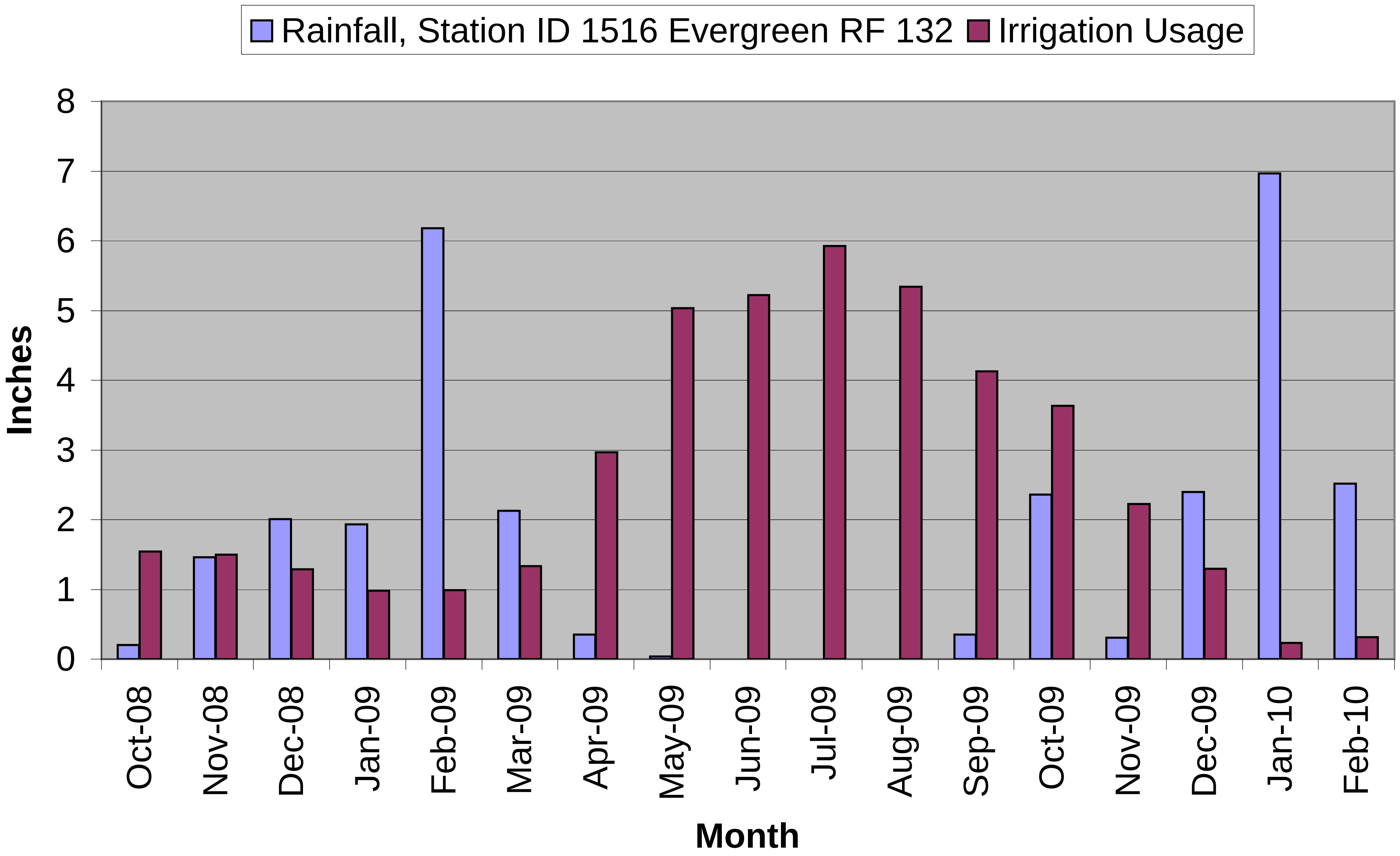
FIGURE III-2-1

Figure III-2-2 IDT Irrigation



Note: Irrigation usage is based on the monthly volumetric irrigation water usage divided by the total area of irrigated areas on the property.

Figure III-4-1A pH

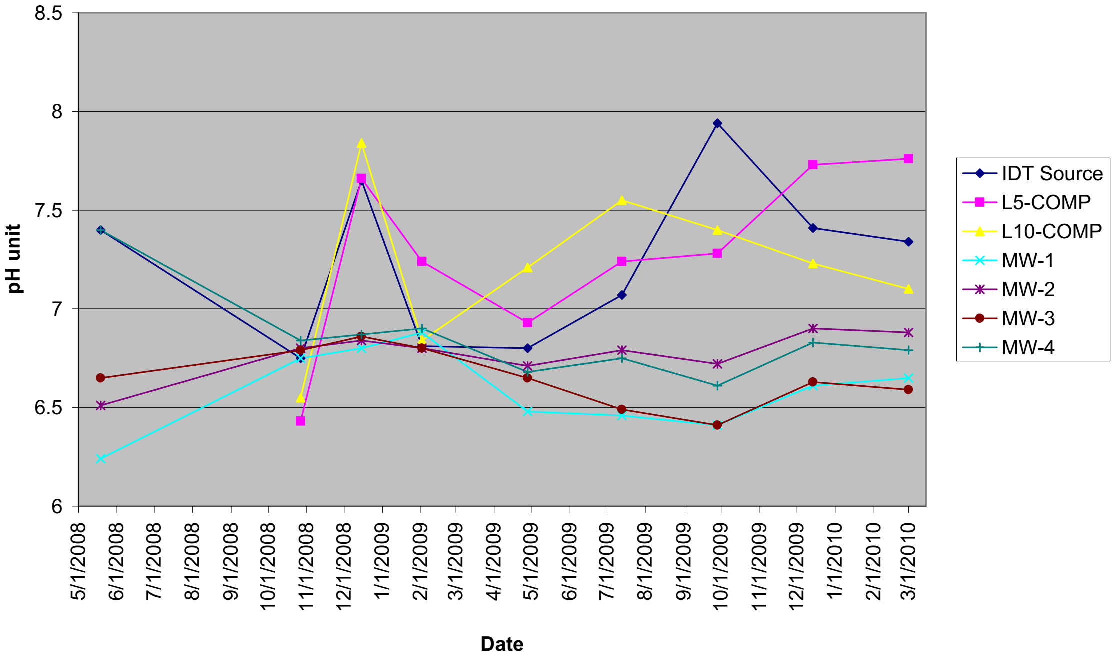


Figure III-4-1B pH

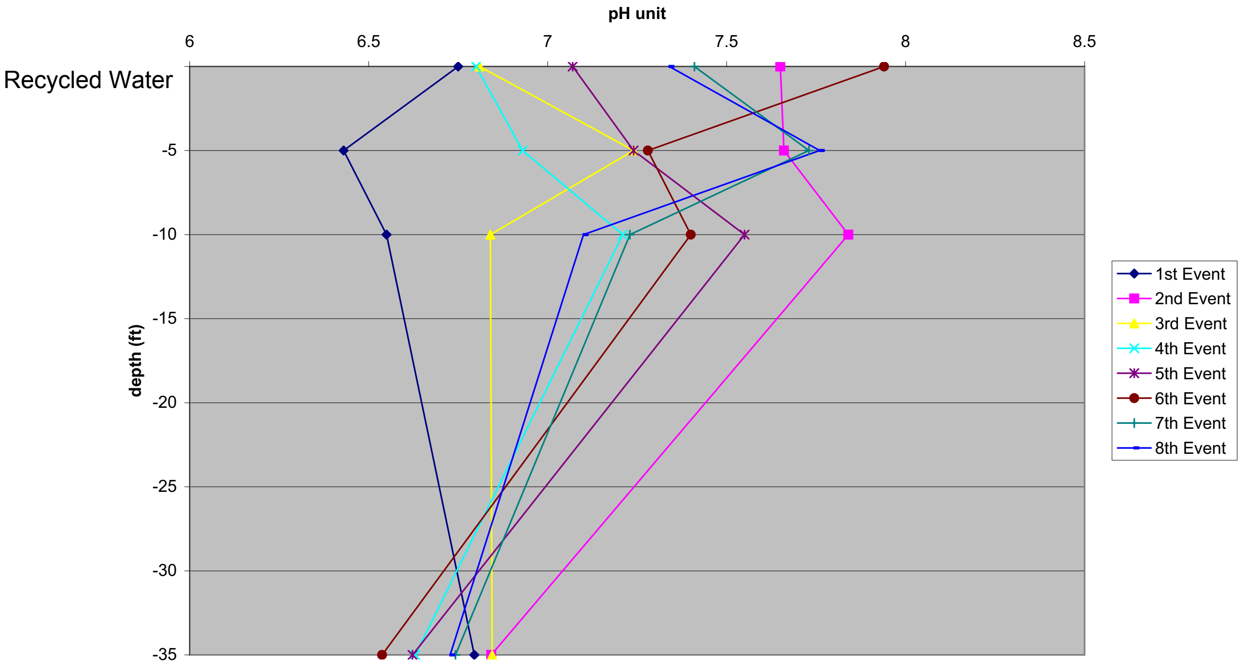


Figure III-4-2A Alkalinity, Total (as CaCO3)

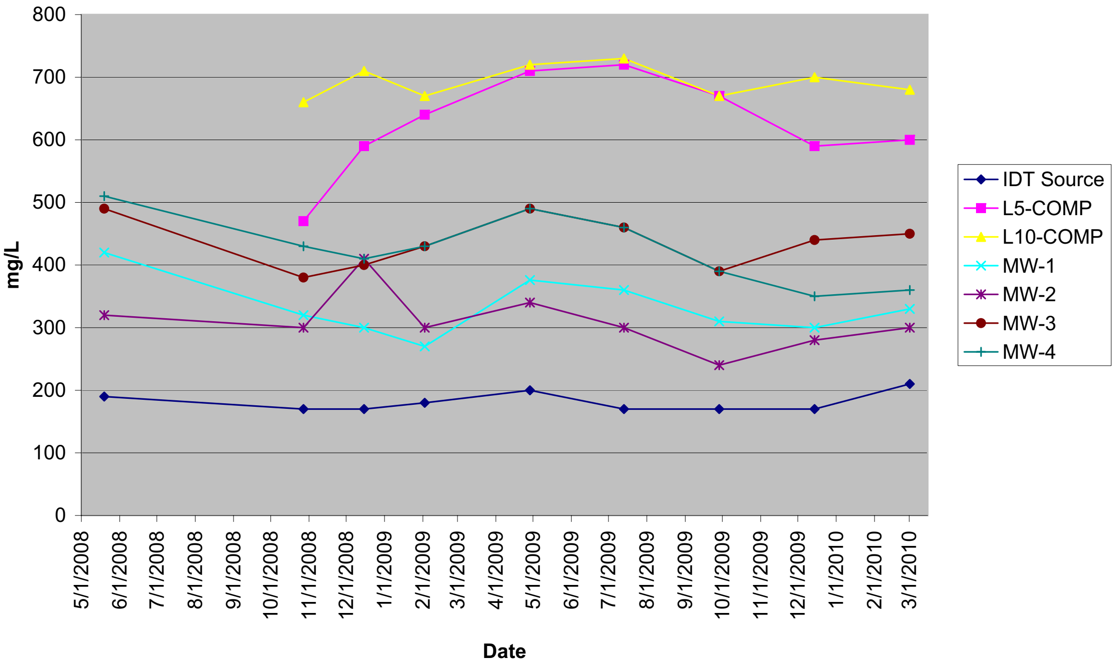


Figure III-4-2B Alkalinity, Total (as CaCO3)

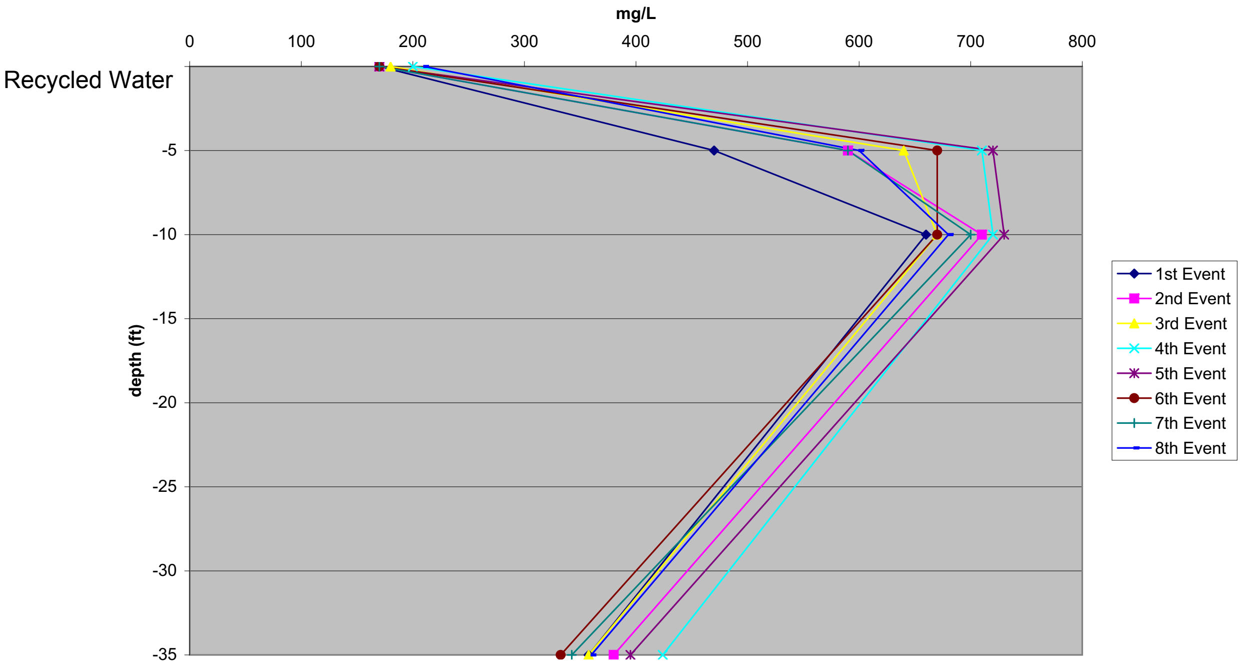


Figure III-4-3A Bicarbonate Alkalinity (as CaCO3)

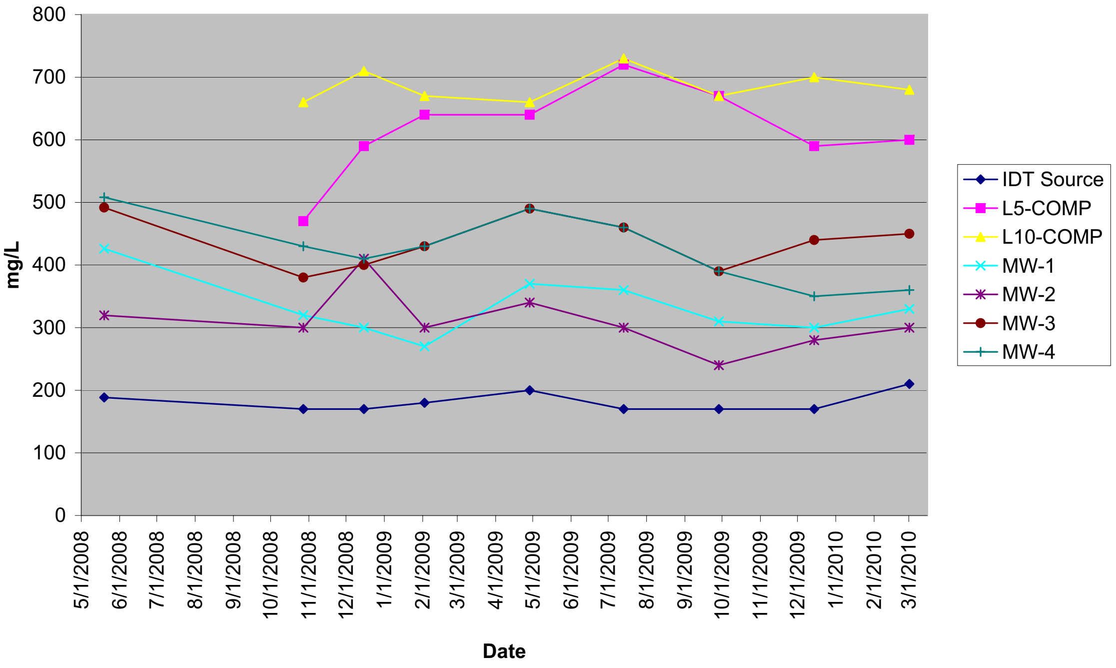


Figure III-4-3B Bicarbonate Alkalinity (as CaCO3)

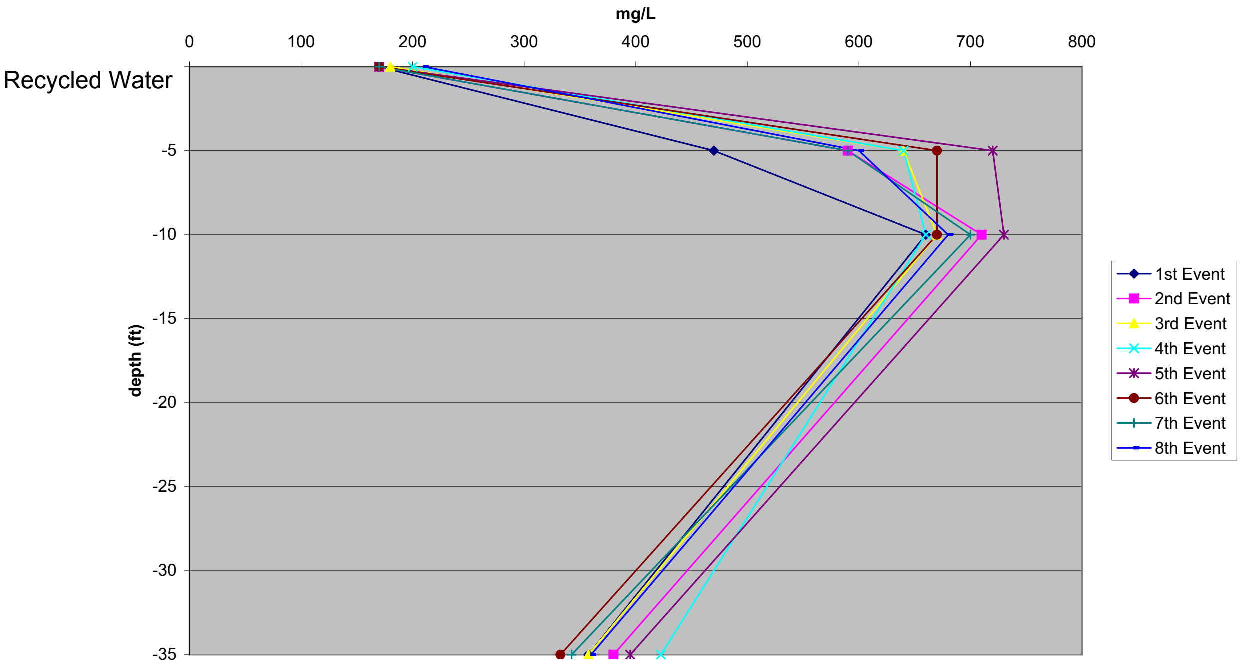


Figure III-4-4A Total Filterable Residue at 180C (TDS)

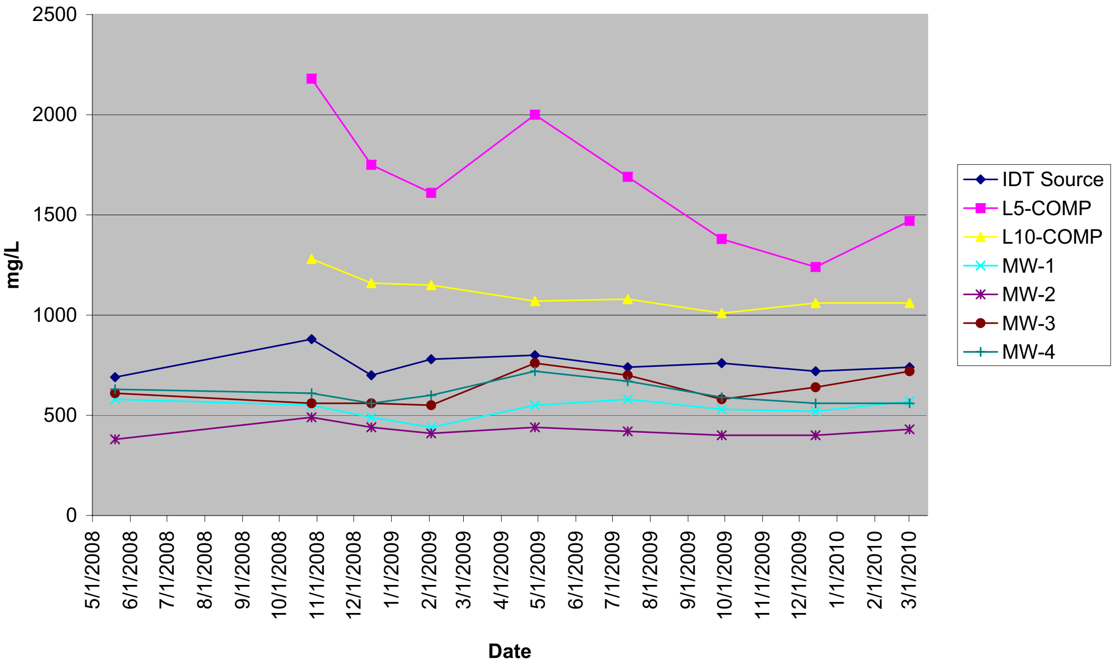


Figure III-4-4B Total Filterable Residue at 180C (TDS)

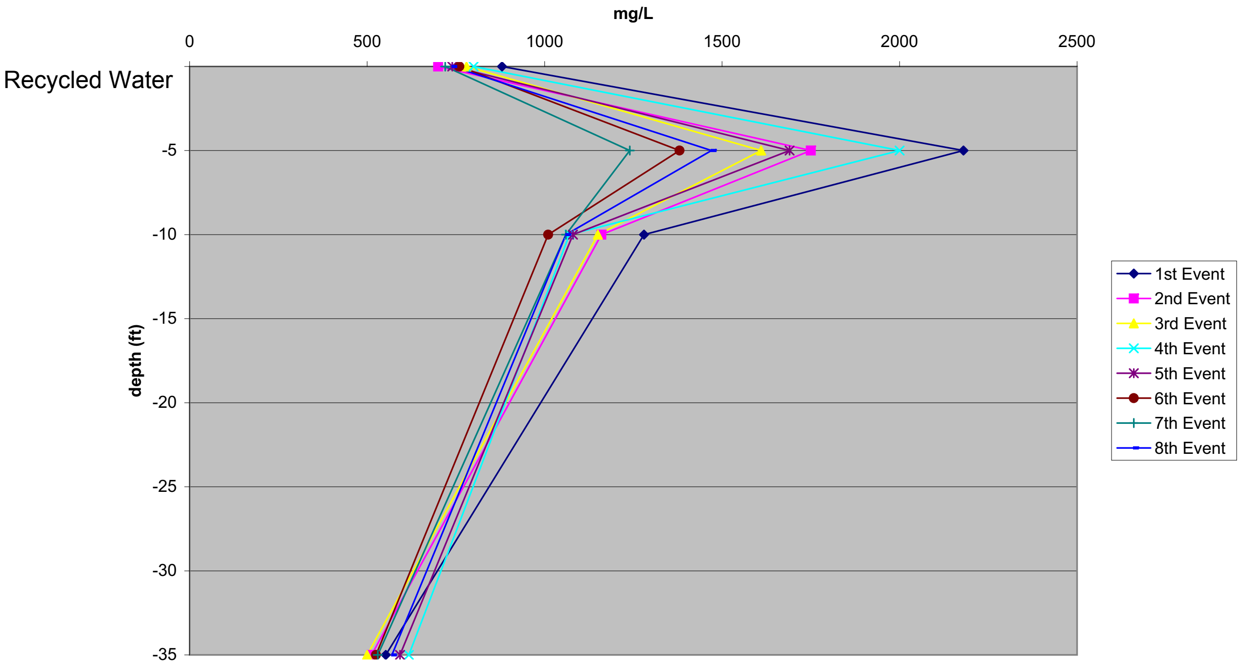
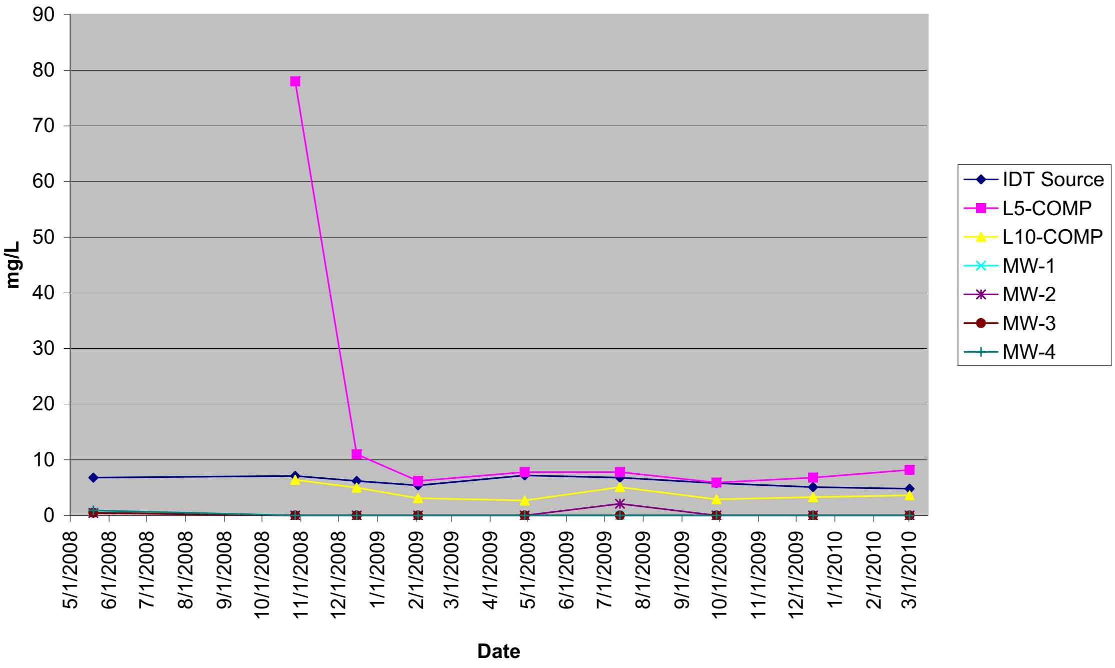
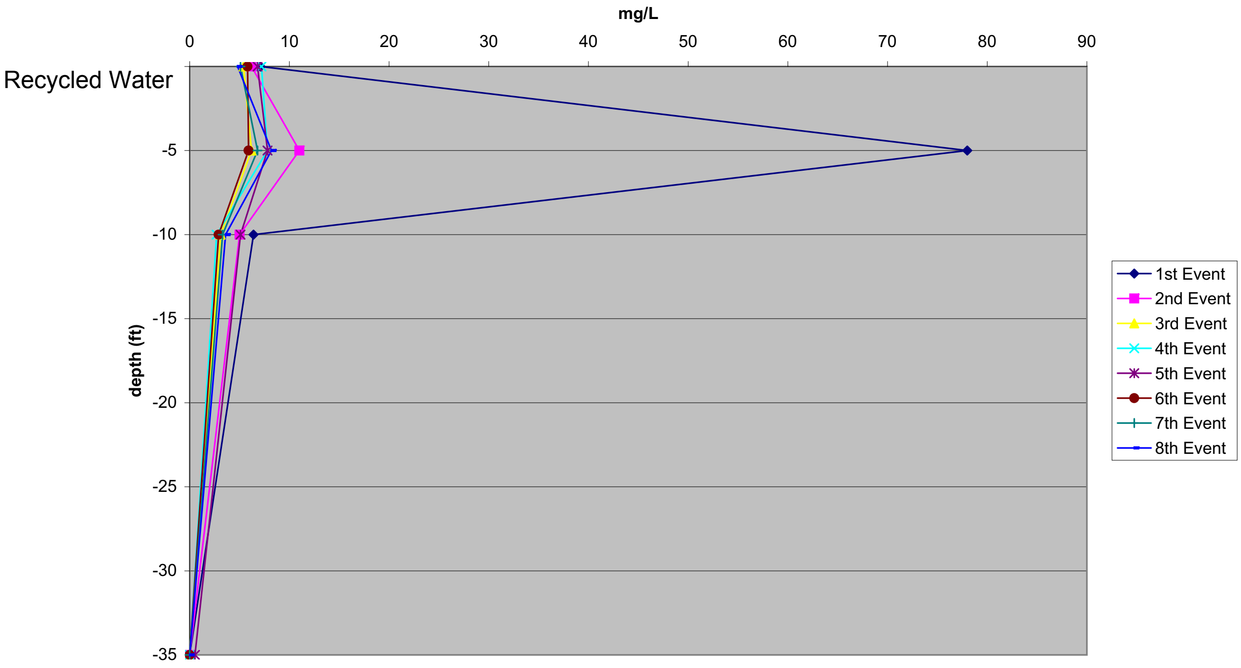


Figure III-4-5A Dissolved Organic Carbon



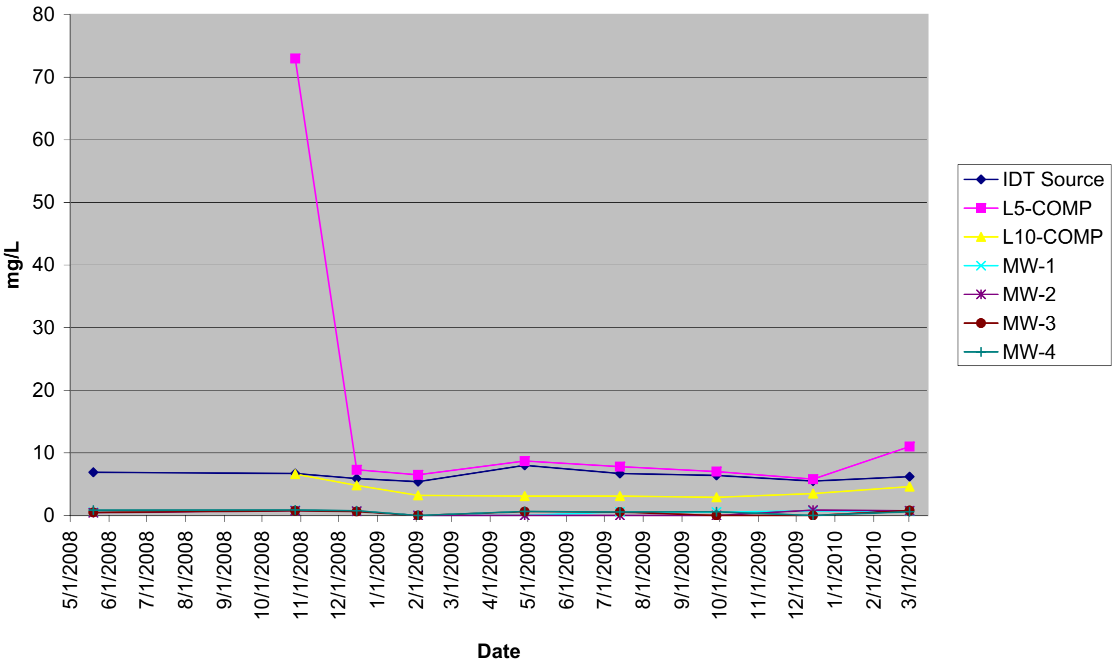
Note: non-detects are treated in the figure as zero.

Figure III-4-5B Dissolved Organic Carbon



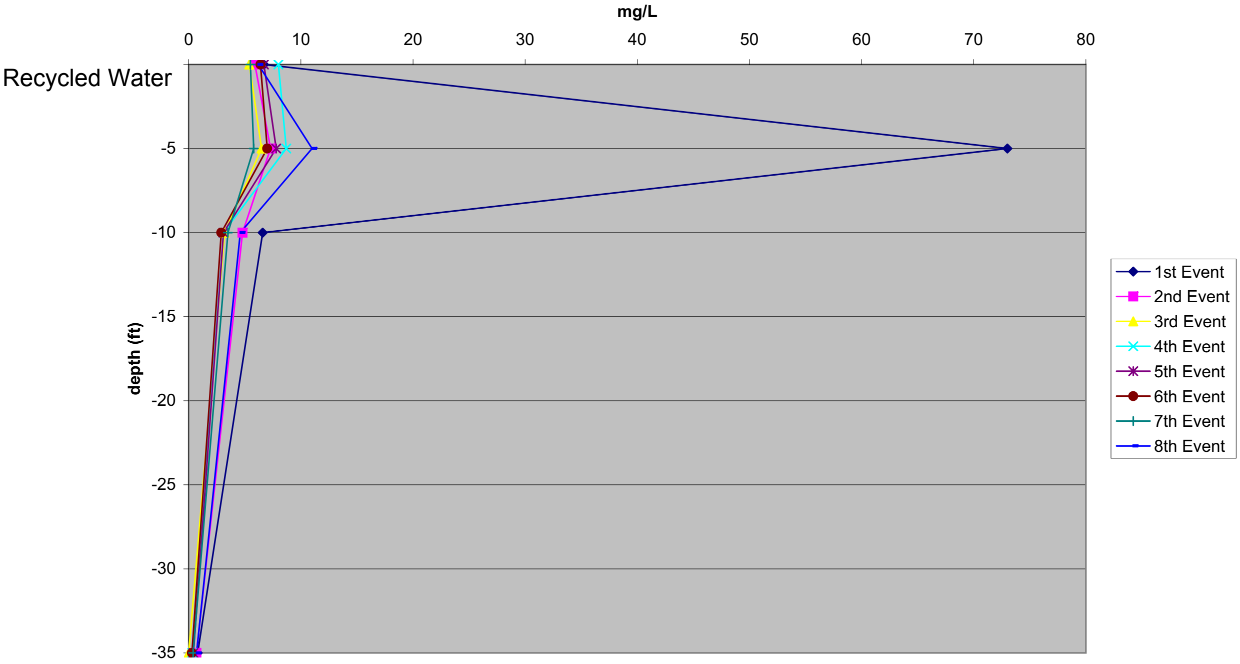
Note: non-detects are treated in the figure as zero.

Figure III-4-6A Total Organic Carbon (TOC)



Note: non-detects are treated in the figure as zero.

Figure III-4-6B Total Organic Carbon (TOC)



Note: non-detects are treated in the figure as zero.

Figure III-4-7A ORP

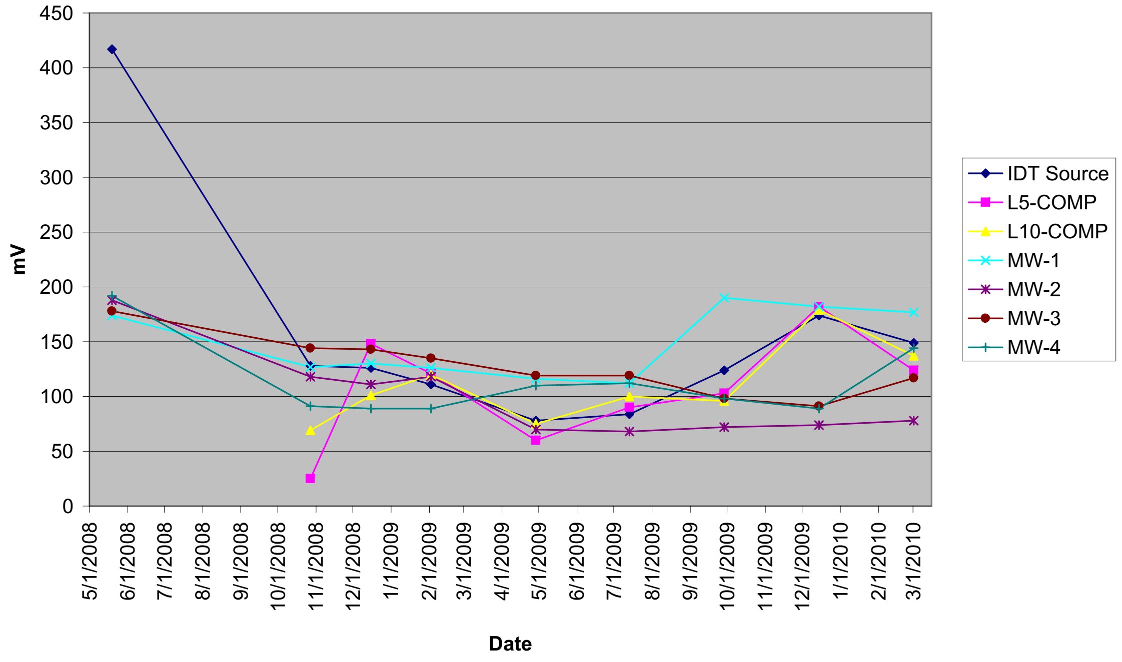


Figure III-4-7B ORP

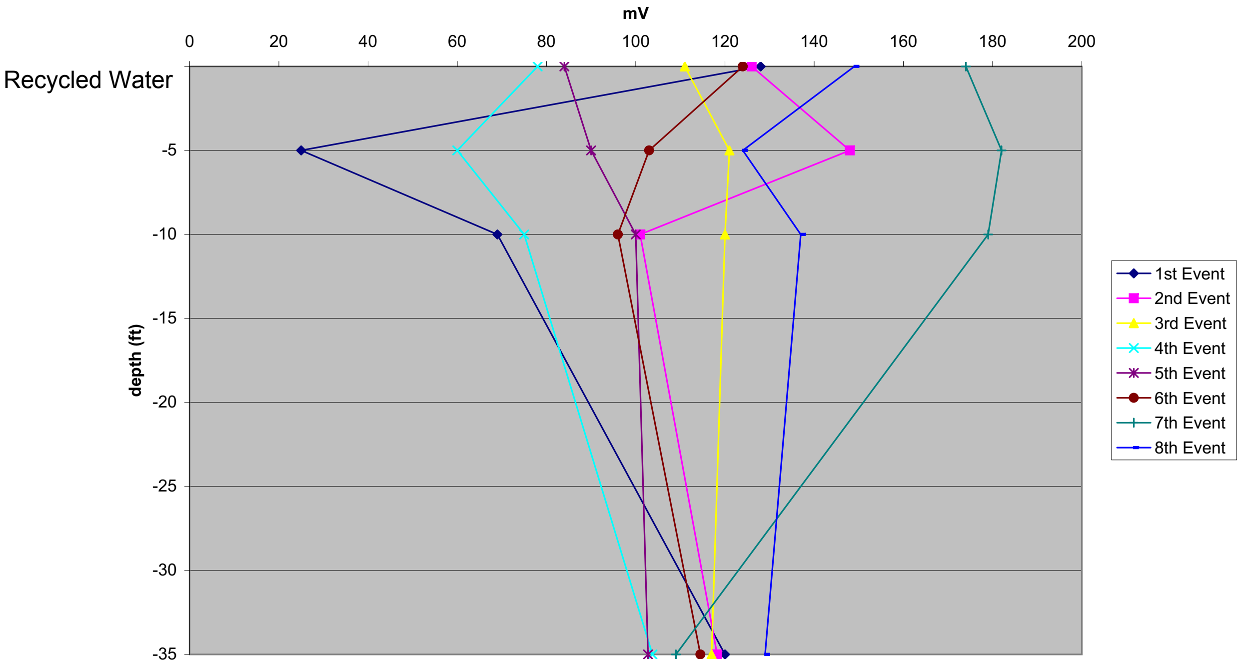
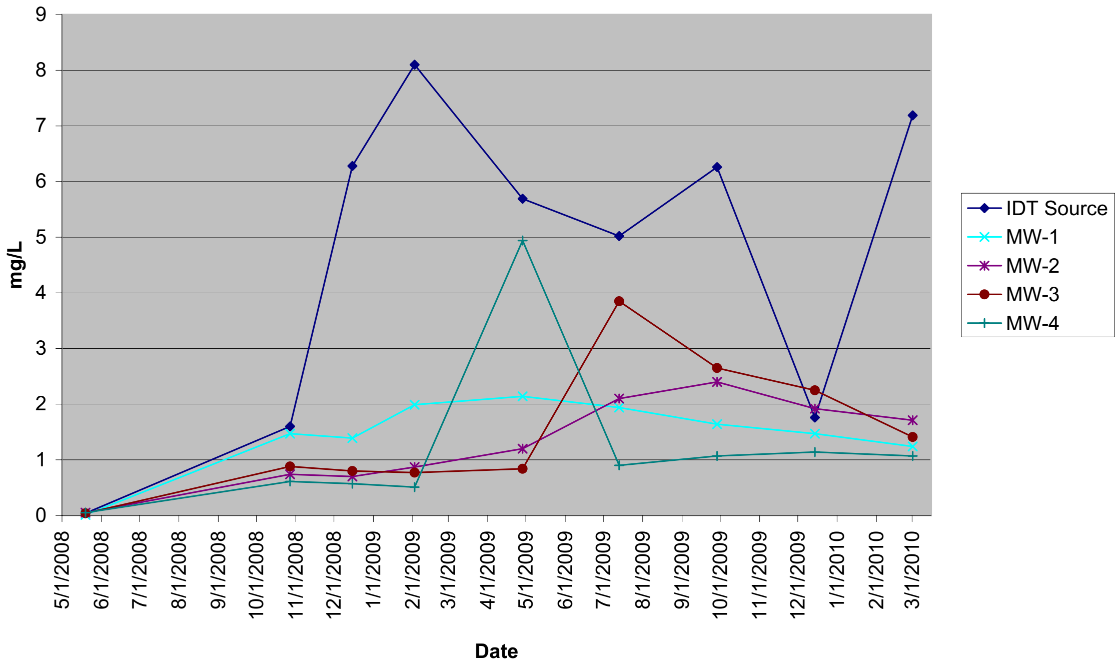


Figure III-4-8A Dissolved Oxygen



Note: non-detects are treated in the figure as zero.

Figure III-4-8B Dissolved Oxygen

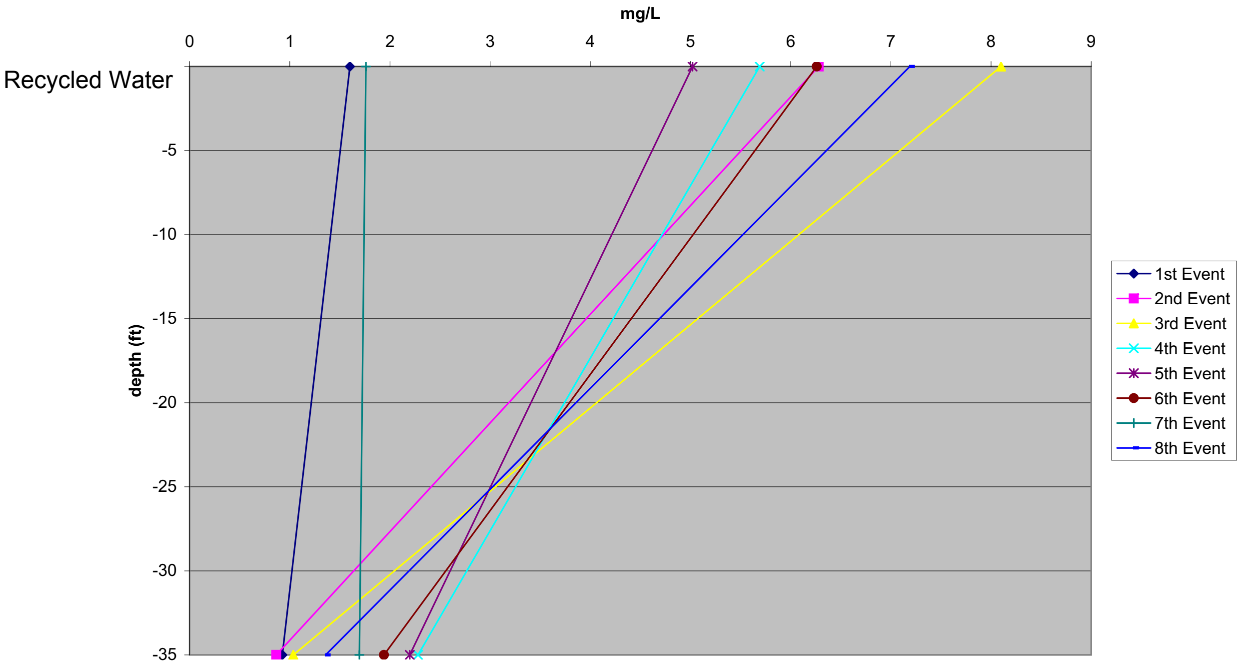


Figure III-4-9A Chlorine, Total

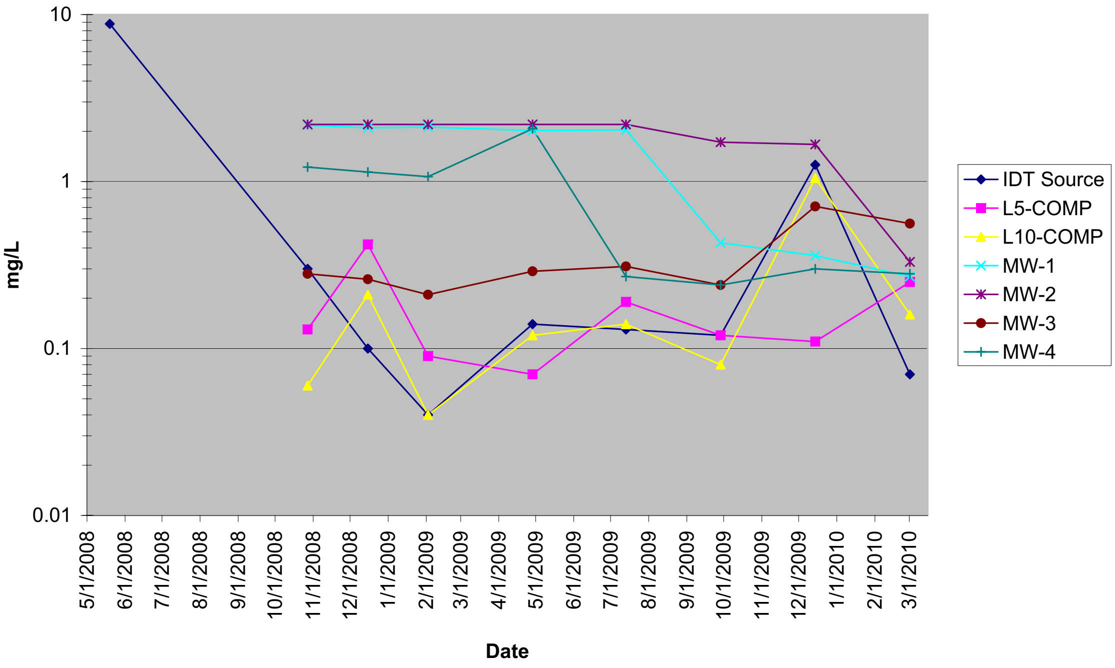


Figure III-4-9B Chlorine, Total

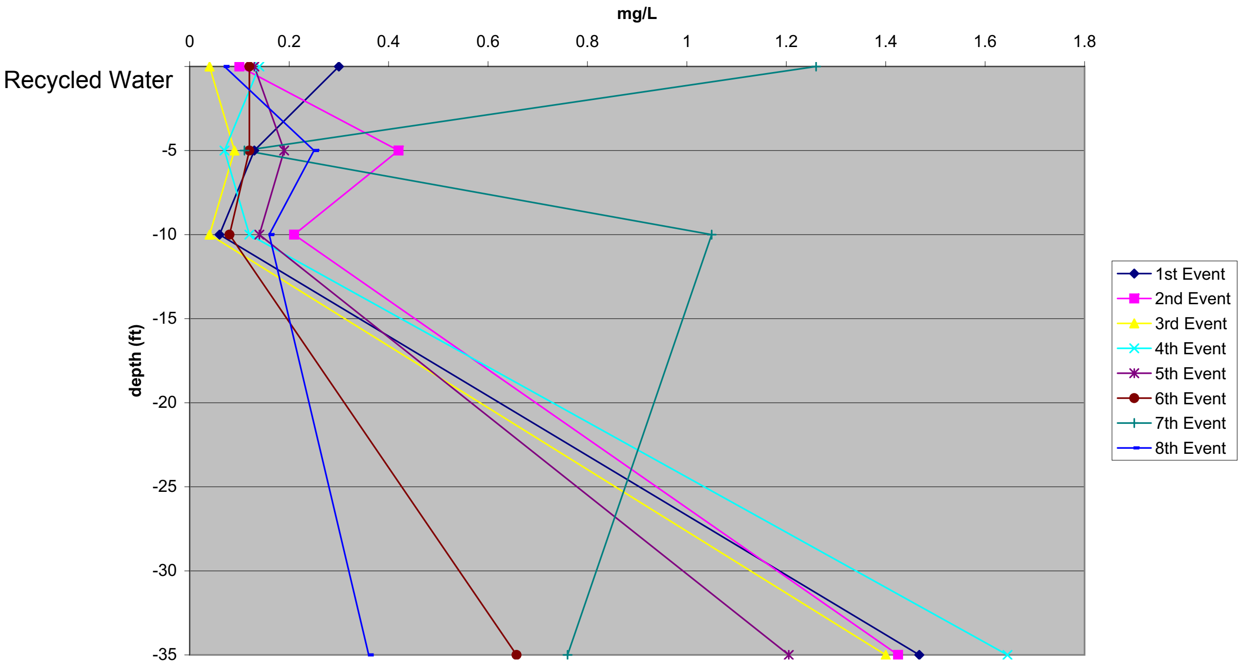


Figure III-4-10A Chloride

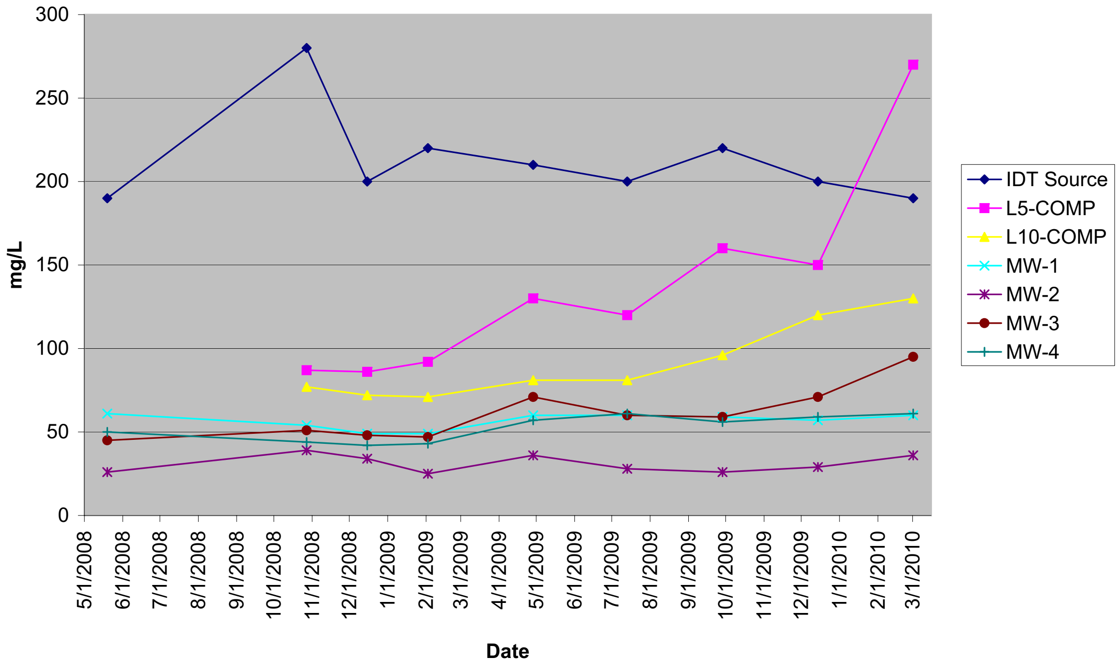


Figure III-4-10B Chloride

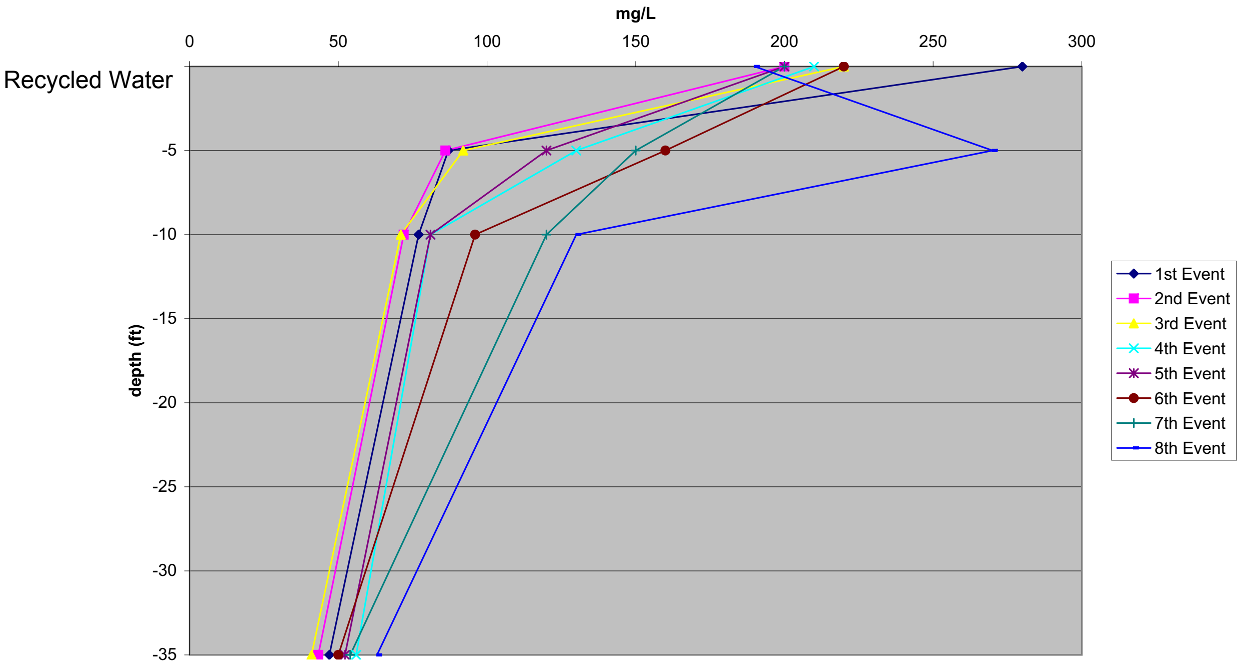


Figure III-4-11A Sulfate

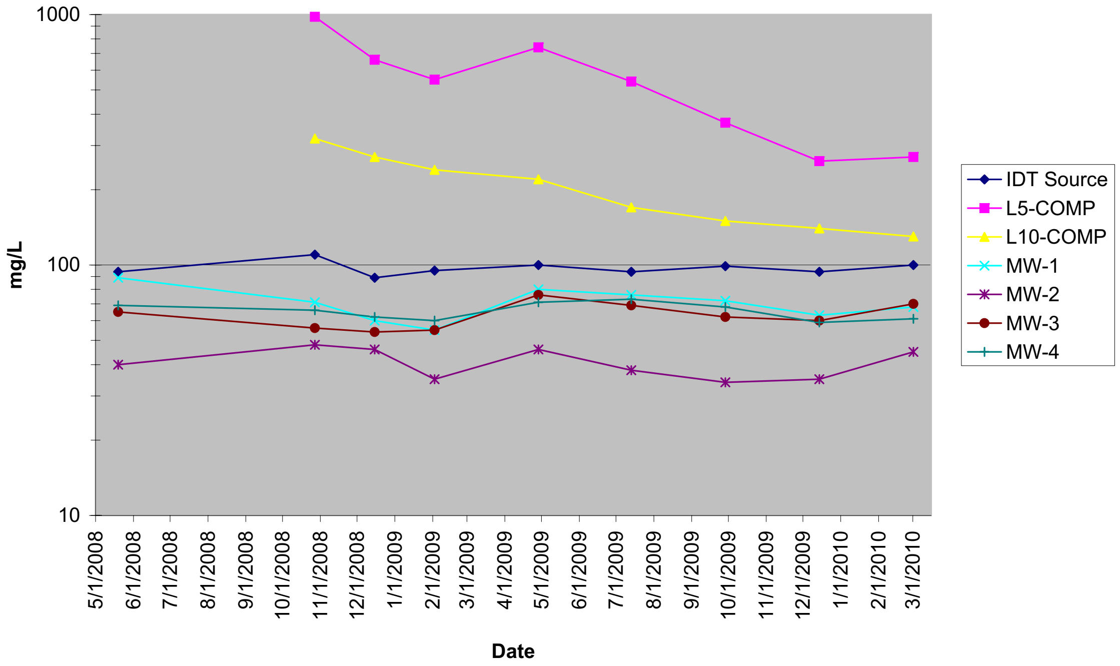


Figure III-4-11B Sulfate

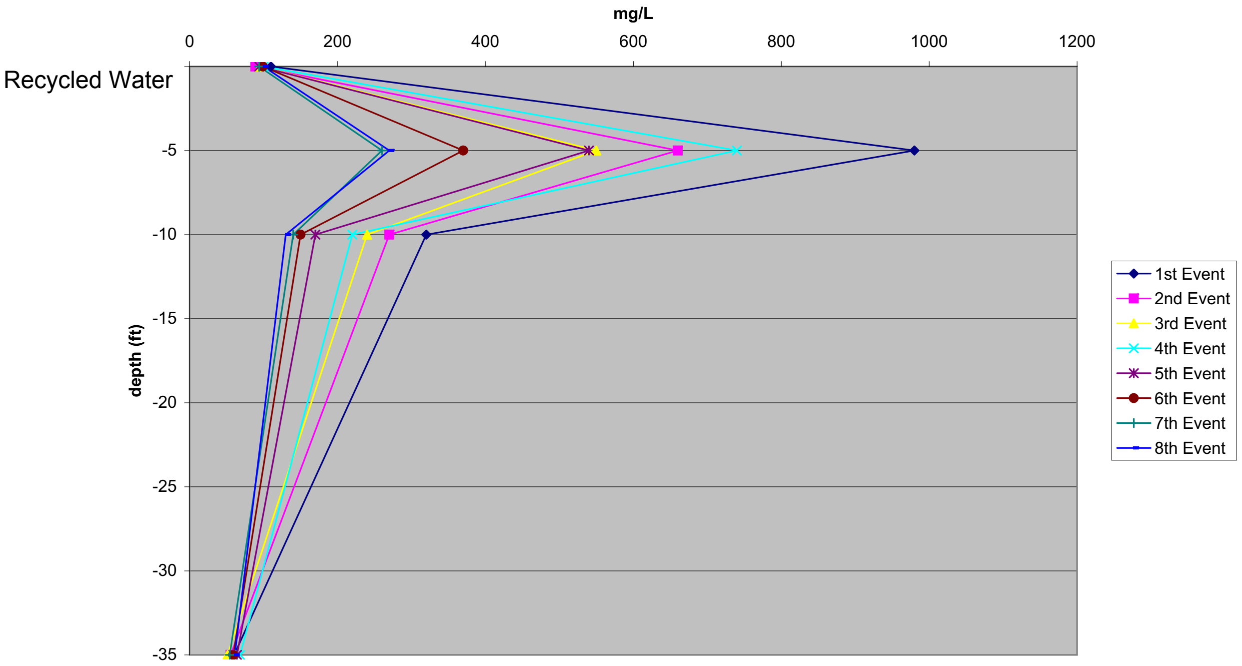
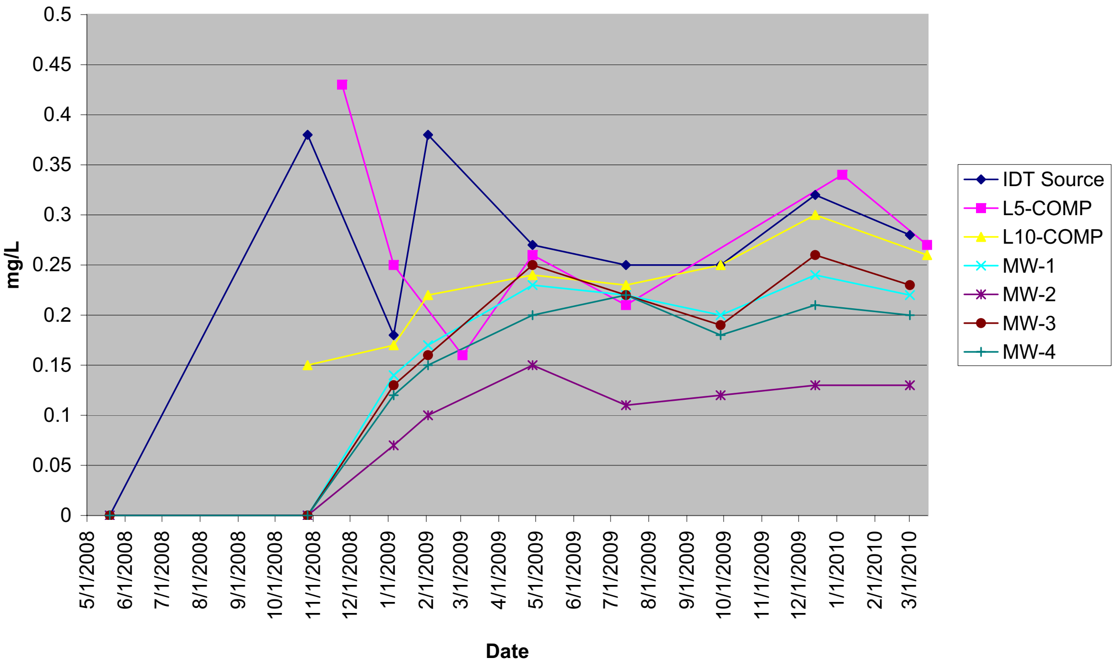
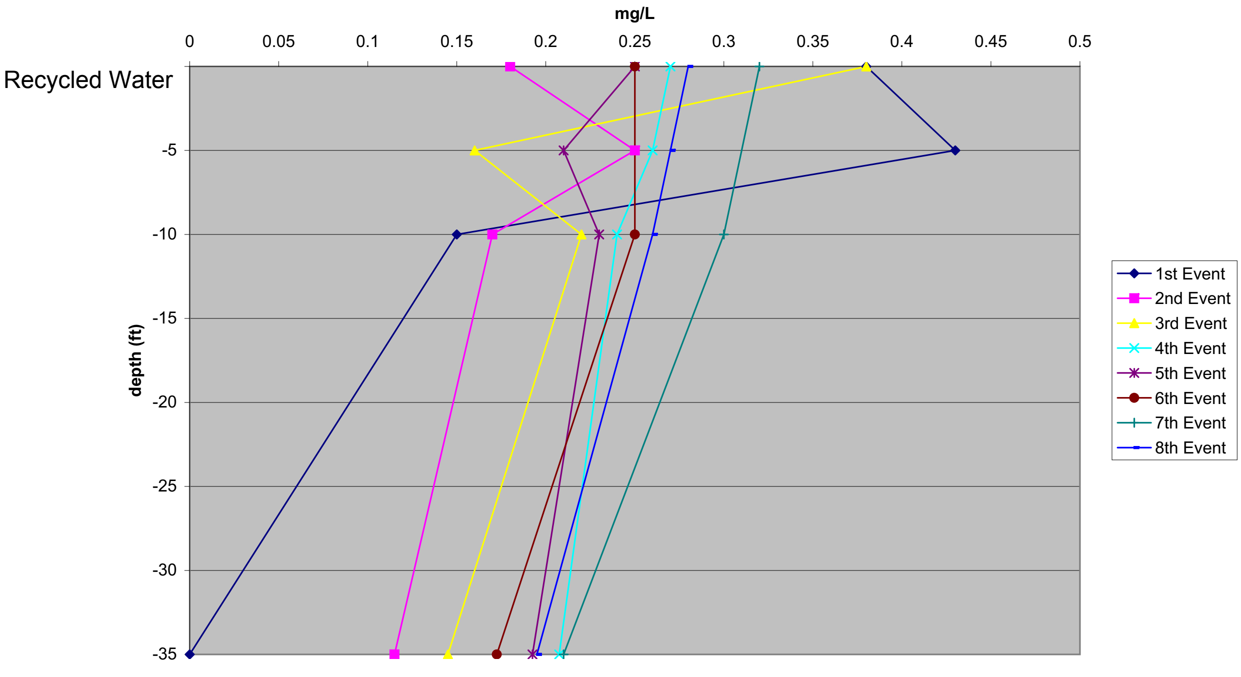


Figure III-4-12A Bromide



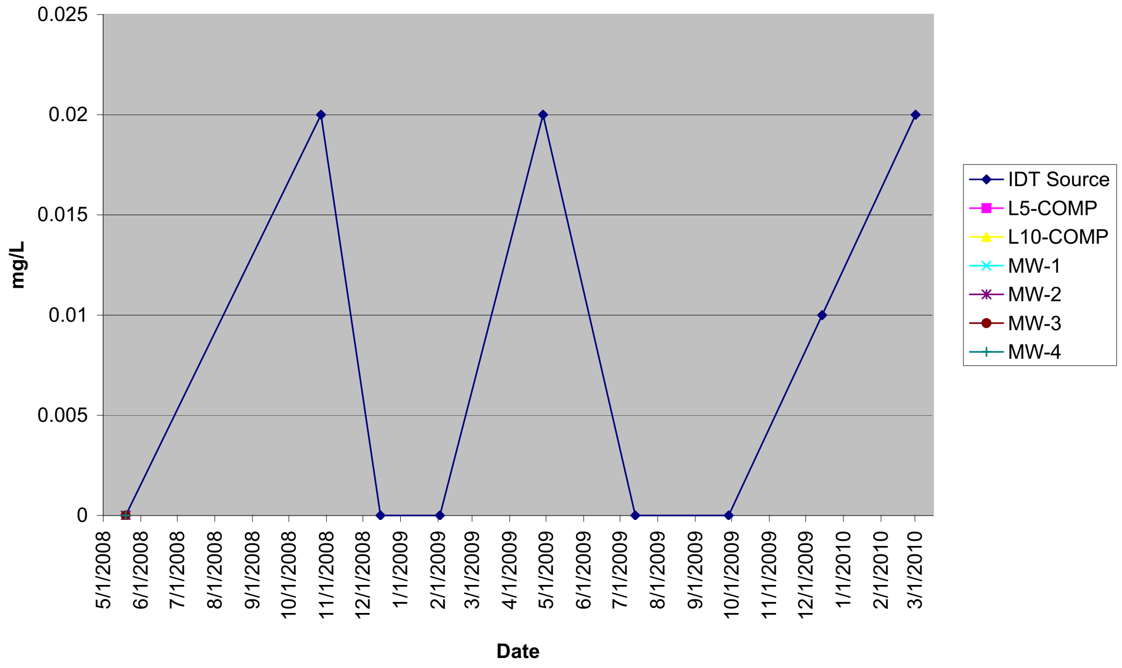
Note: non-detects are treated in the figure as zero.

Figure III-4-12B Bromide



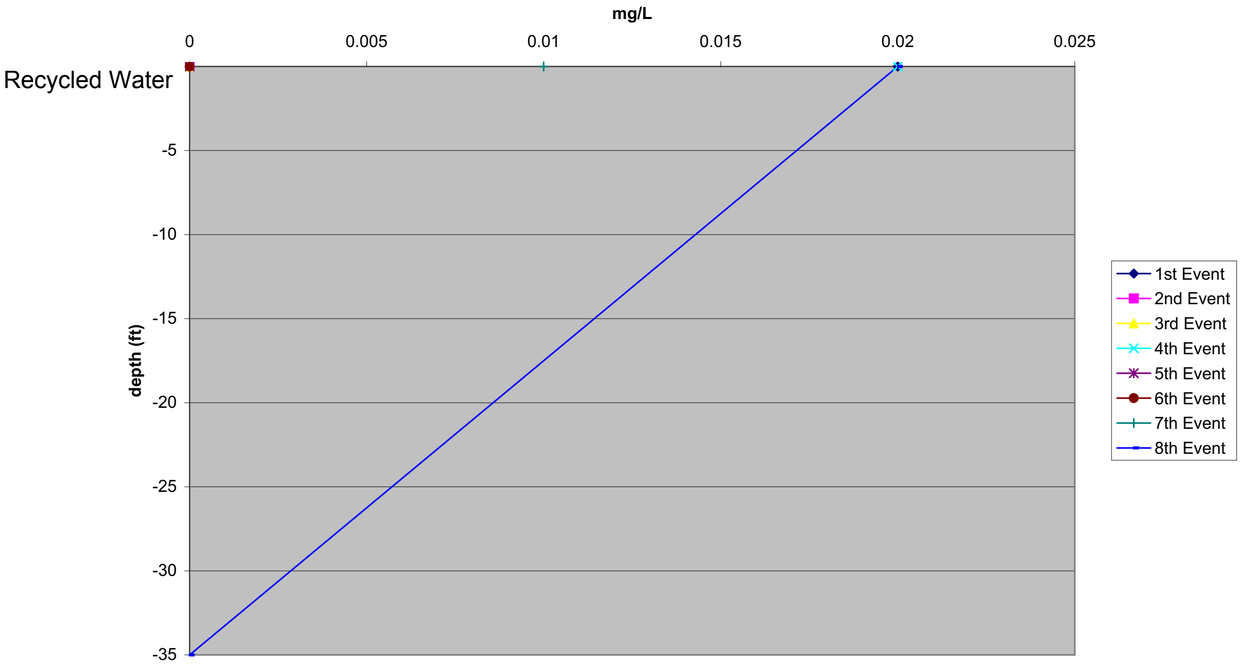
Note: non-detects are treated in the figure as zero.

Figure III-4-13A Cyanide



Note: non-detects are treated in the figure as zero.

Figure III-4-13B Cyanide



Note: non-detects are treated in the figure as zero.

Figure III-4-14A Boron

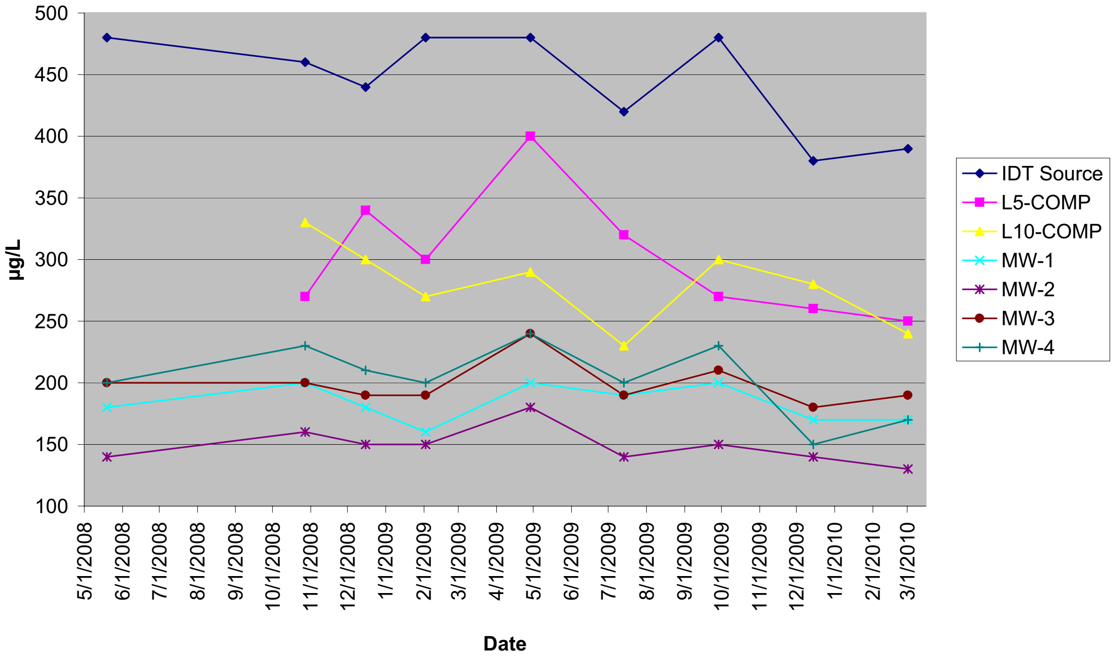


Figure III-4-14B Boron

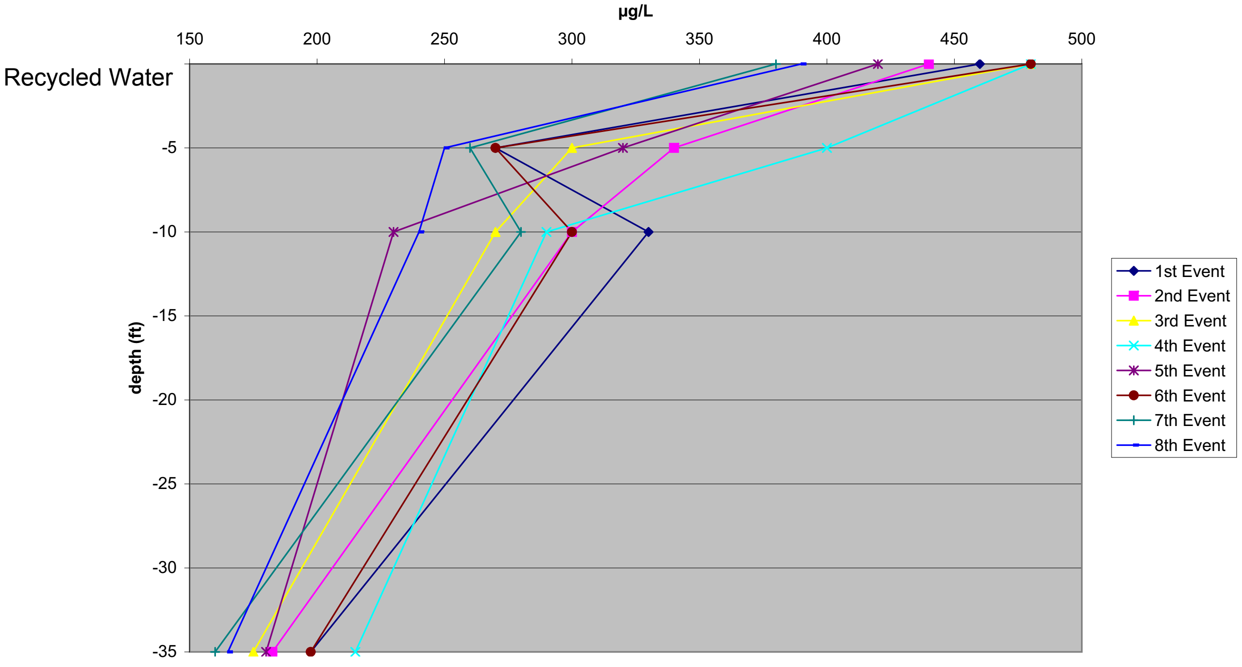
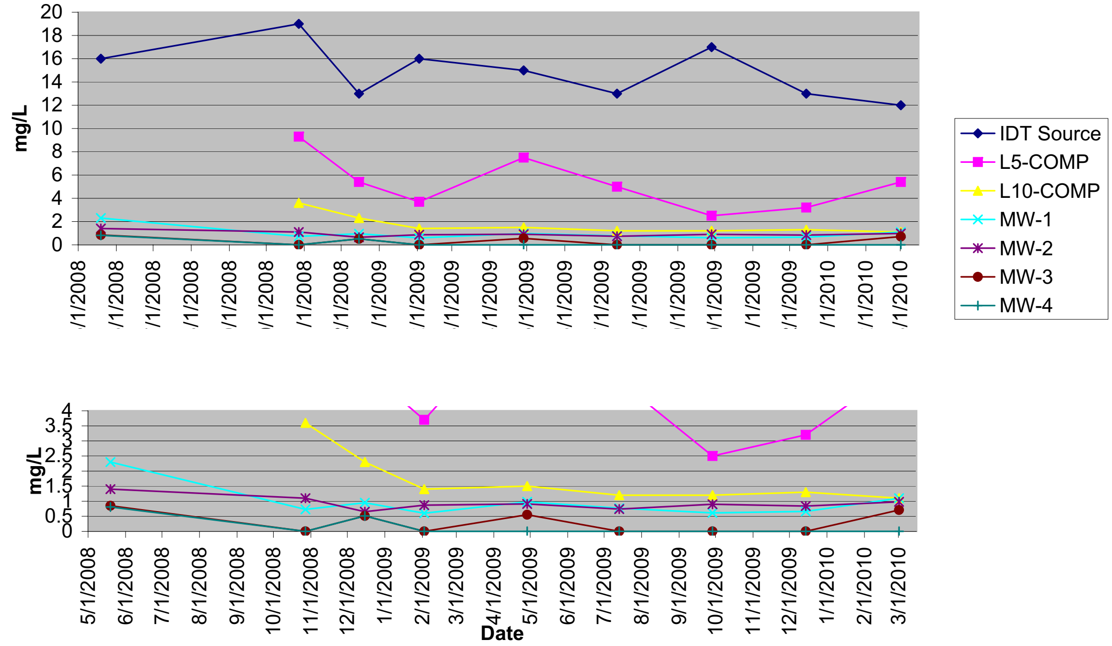
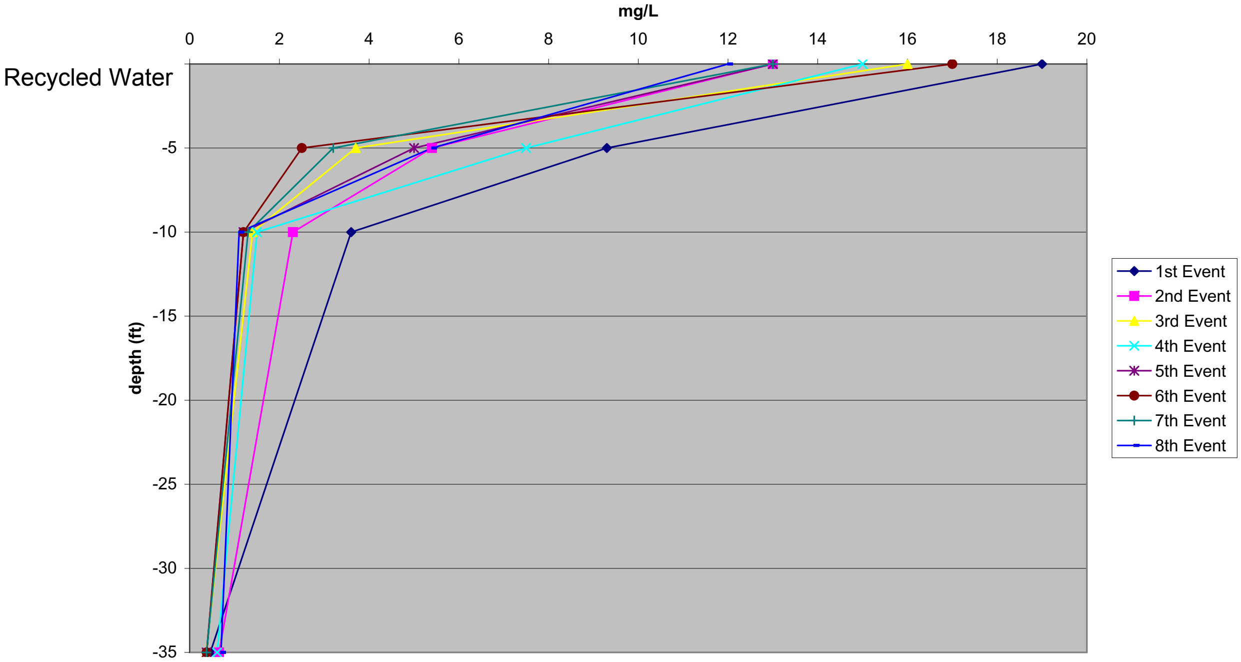


Figure III-4-15A Potassium



Note: non-detects are treated in the figure as zero.

Figure III-4-15B Potassium



Note: non-detects are treated in the figure as zero.

Figure III-4-16A Calcium

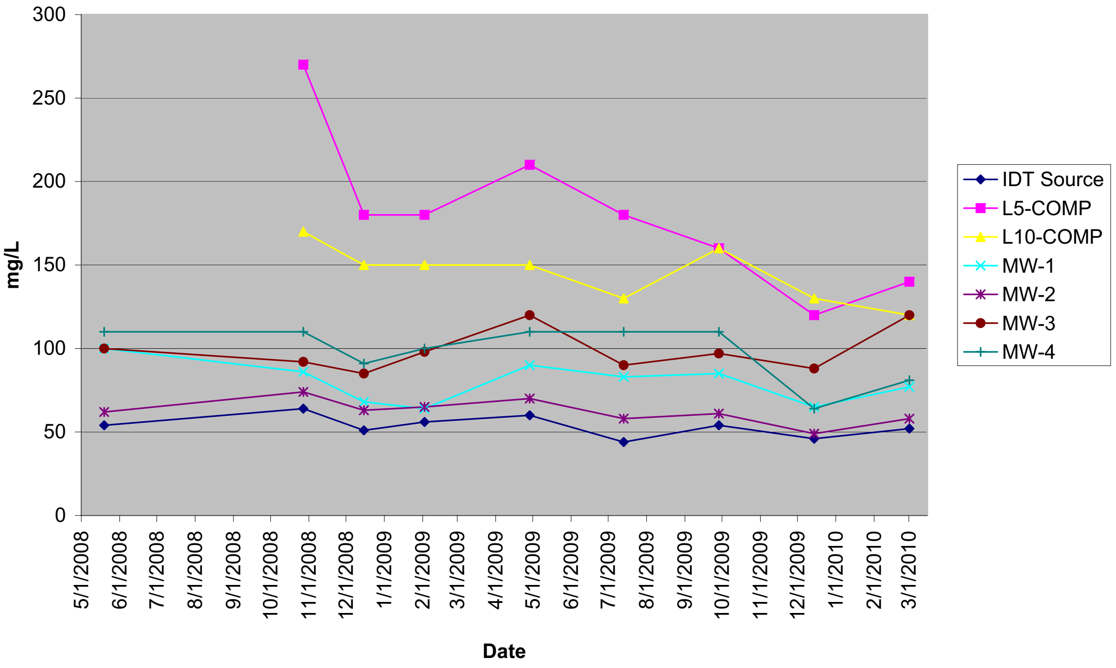


Figure III-4-16B Calcium

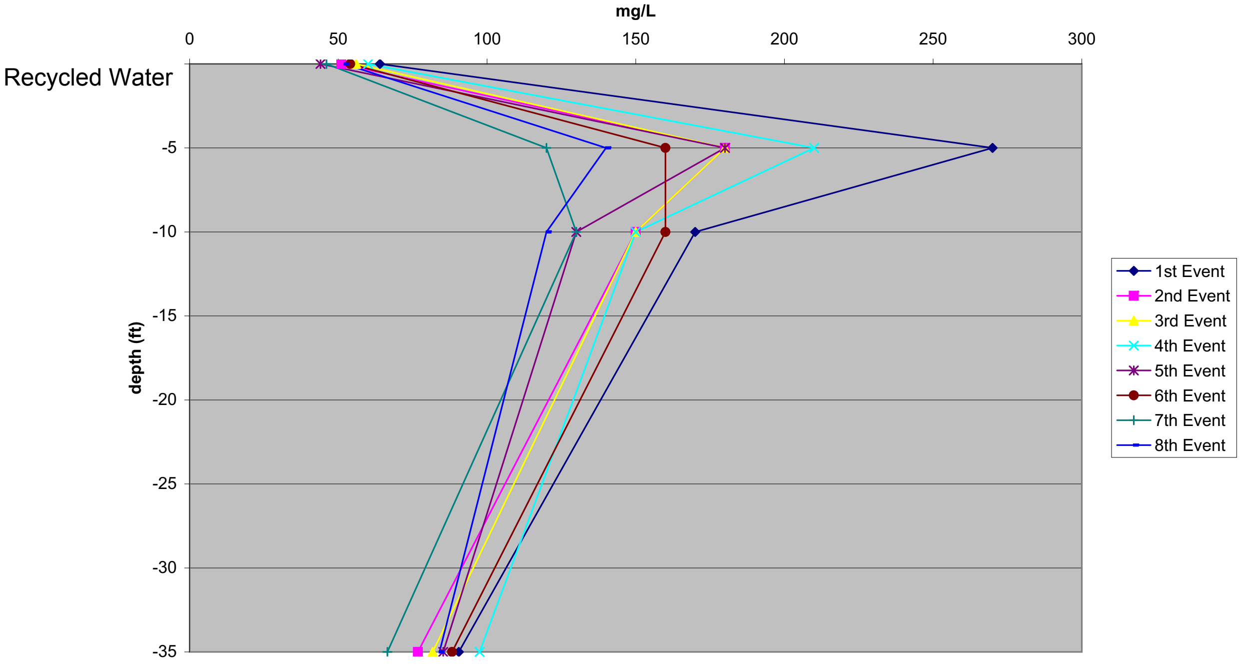


Figure III-4-17A Magnesium

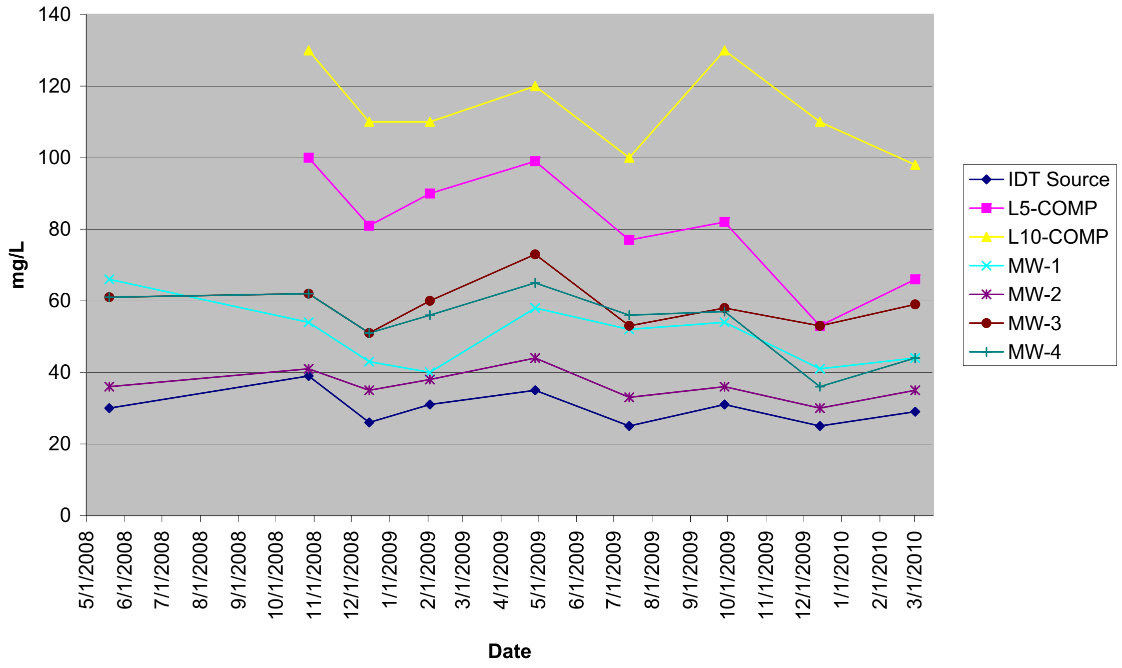


Figure III-4-17B Magnesium

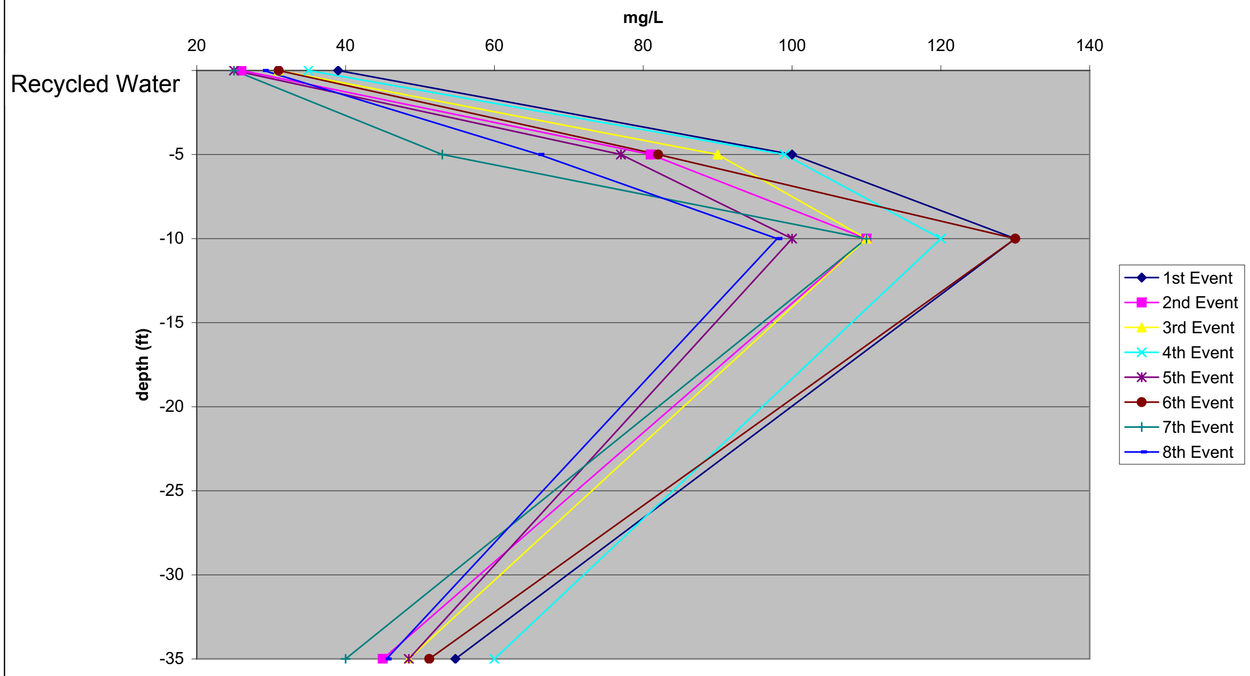


Figure III-4-18A Sodium

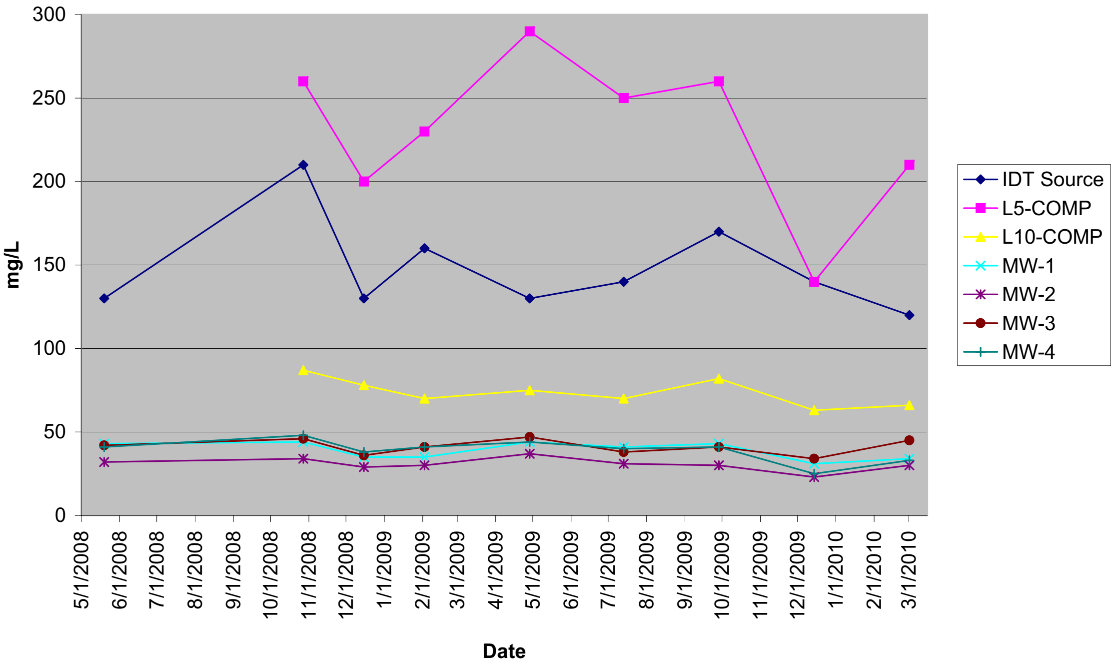


Figure III-4-18B Sodium

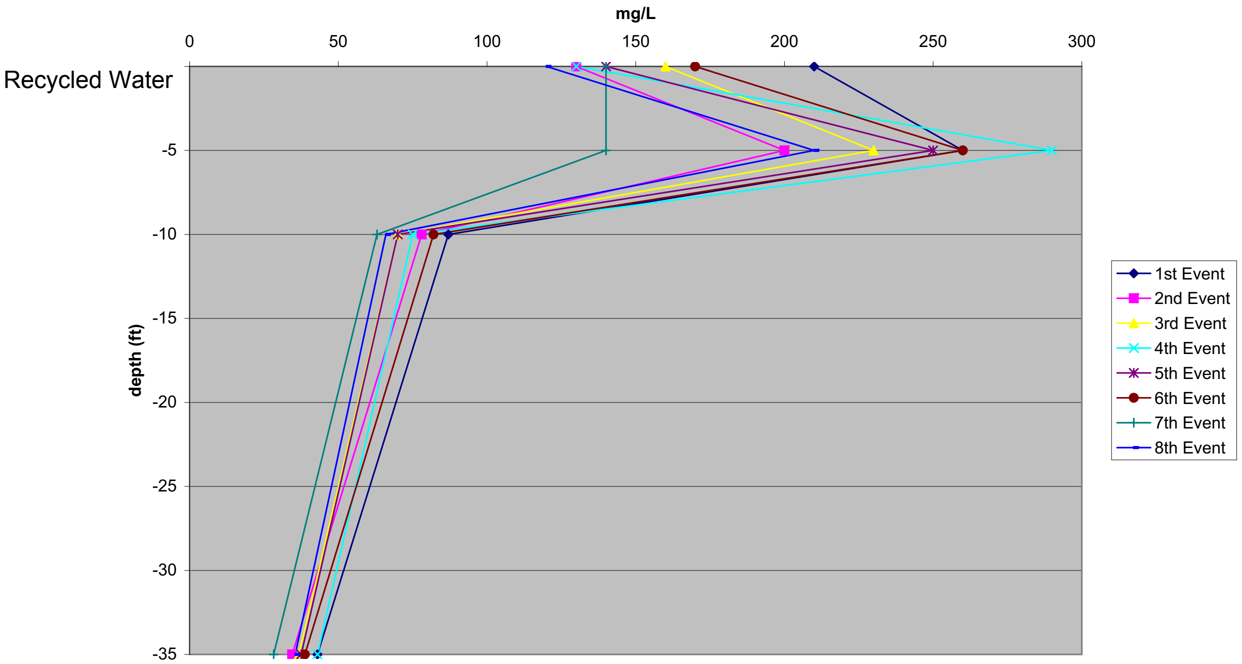


Figure III-4-19A Sodium Adsorption Ratio

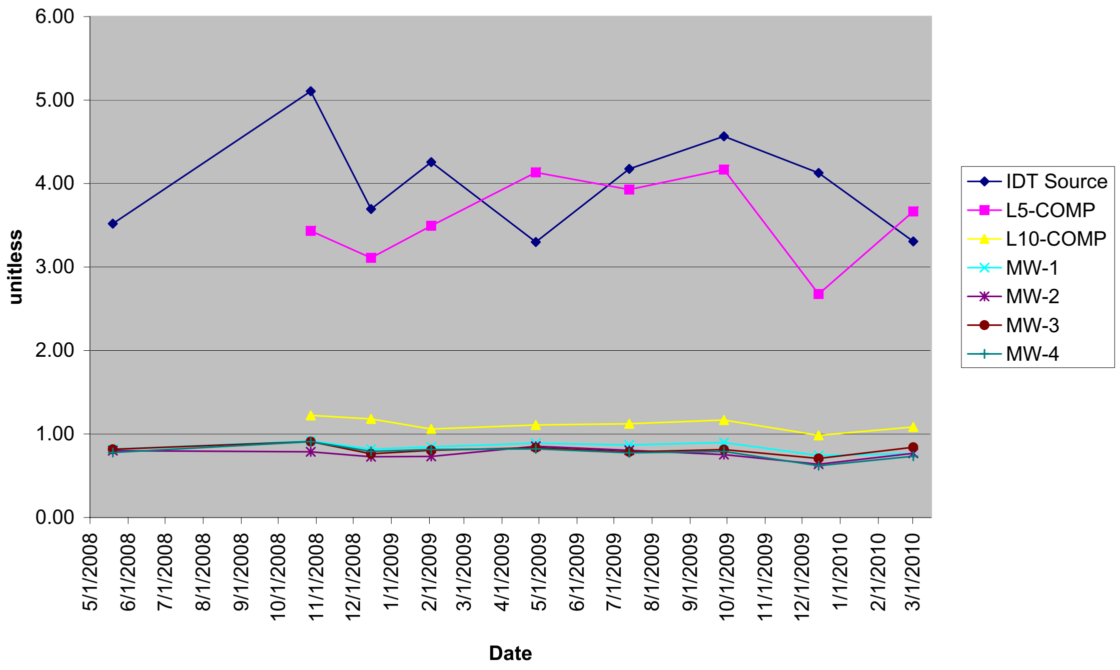


Figure III-4-19B Sodium Adsorption Ratio

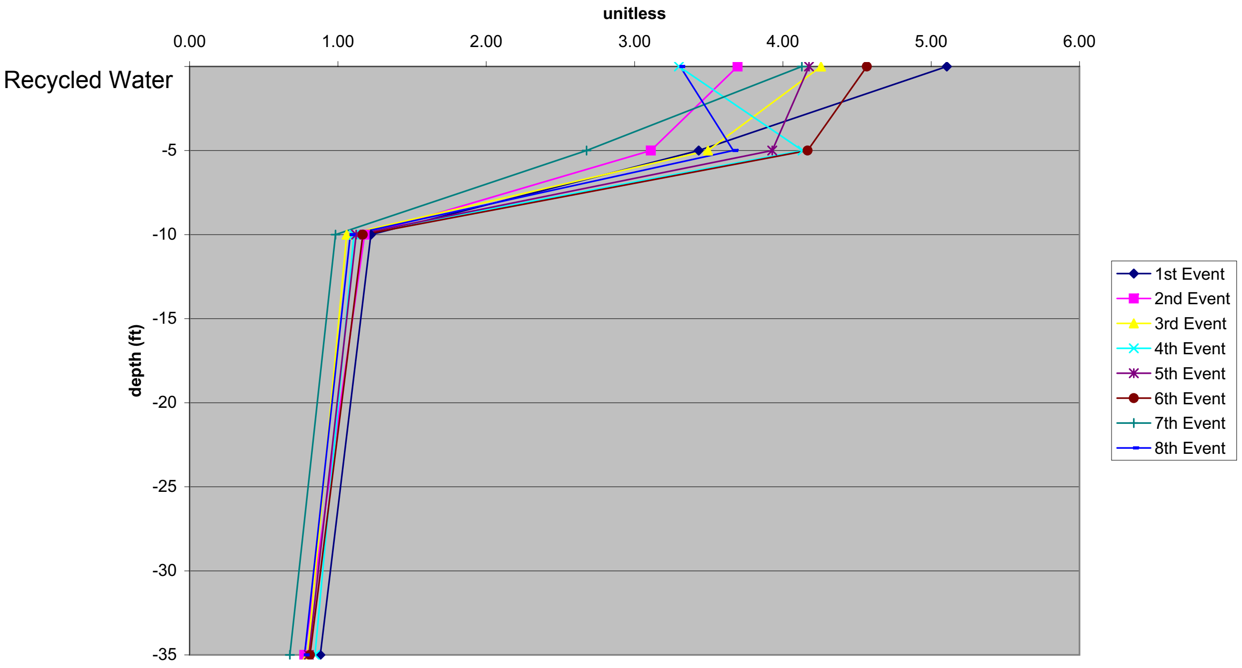
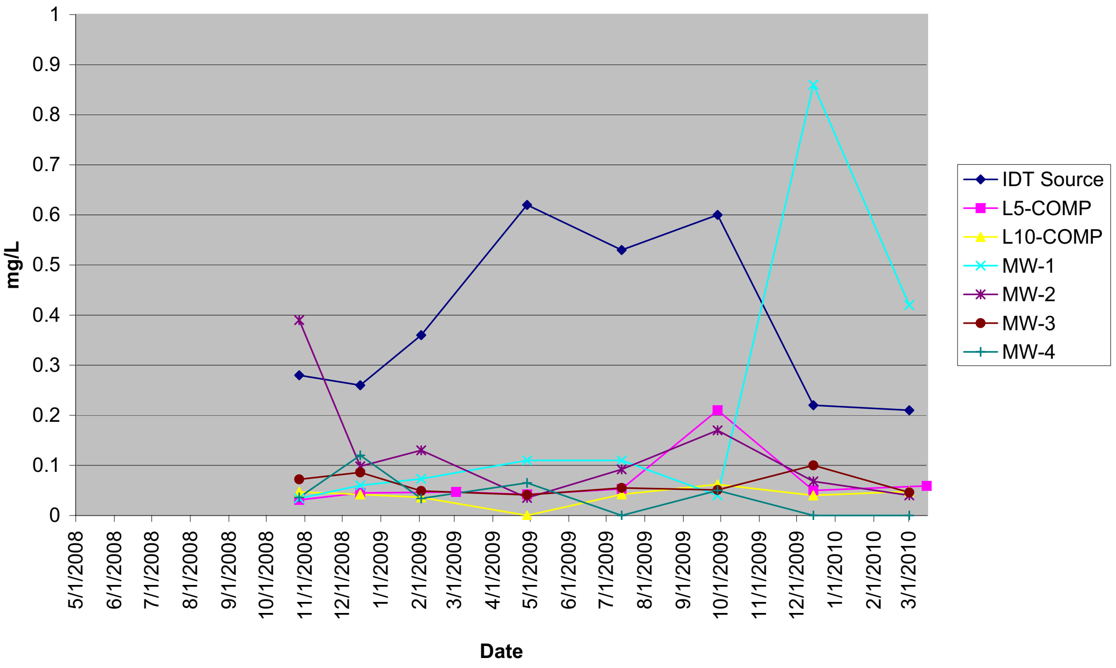
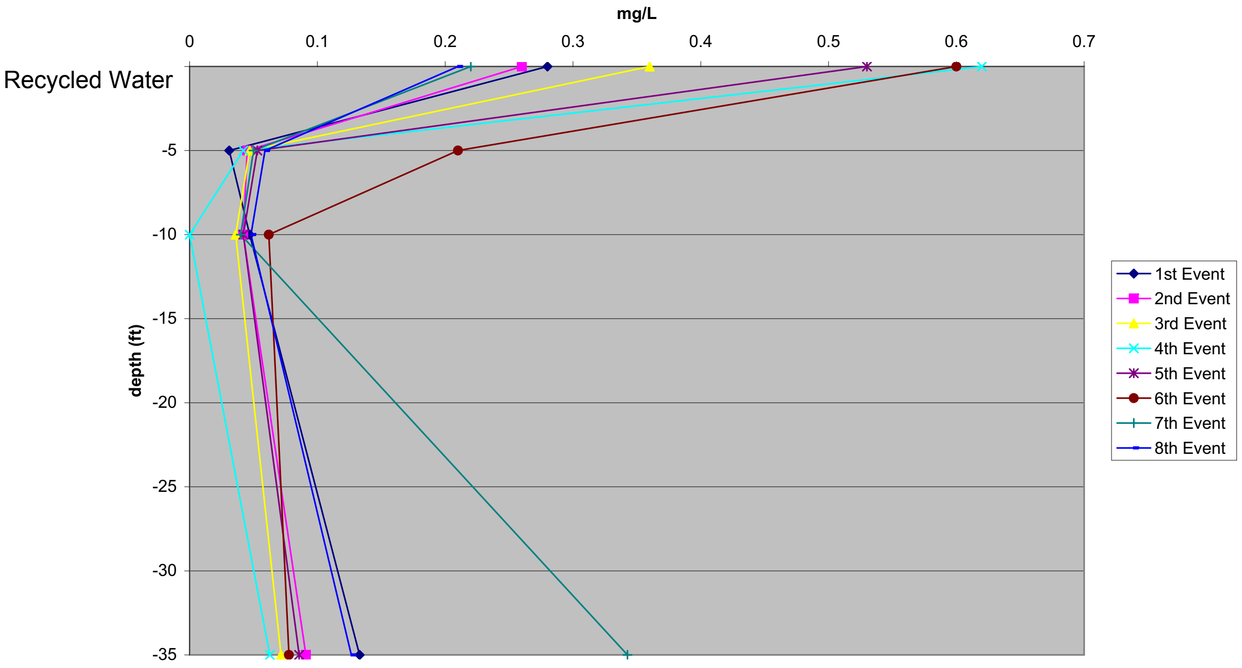


Figure III-4-20A Phosphorus, Total as P



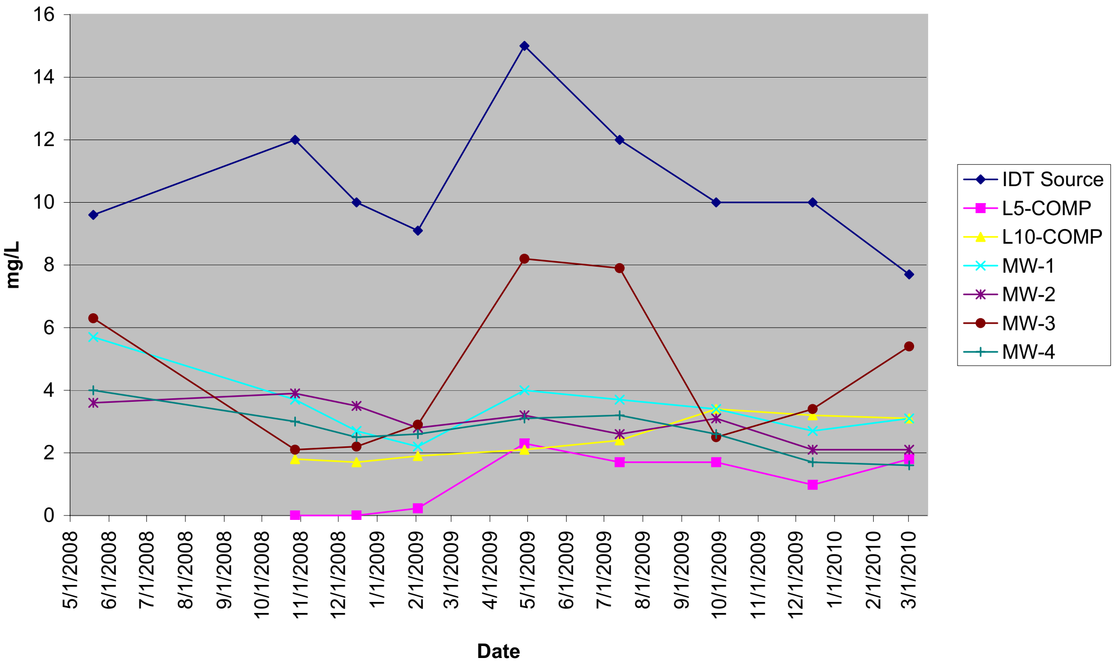
Note: non-detects are treated in the figure as zero.

Figure III-4-20B Phosphorus, Total as P



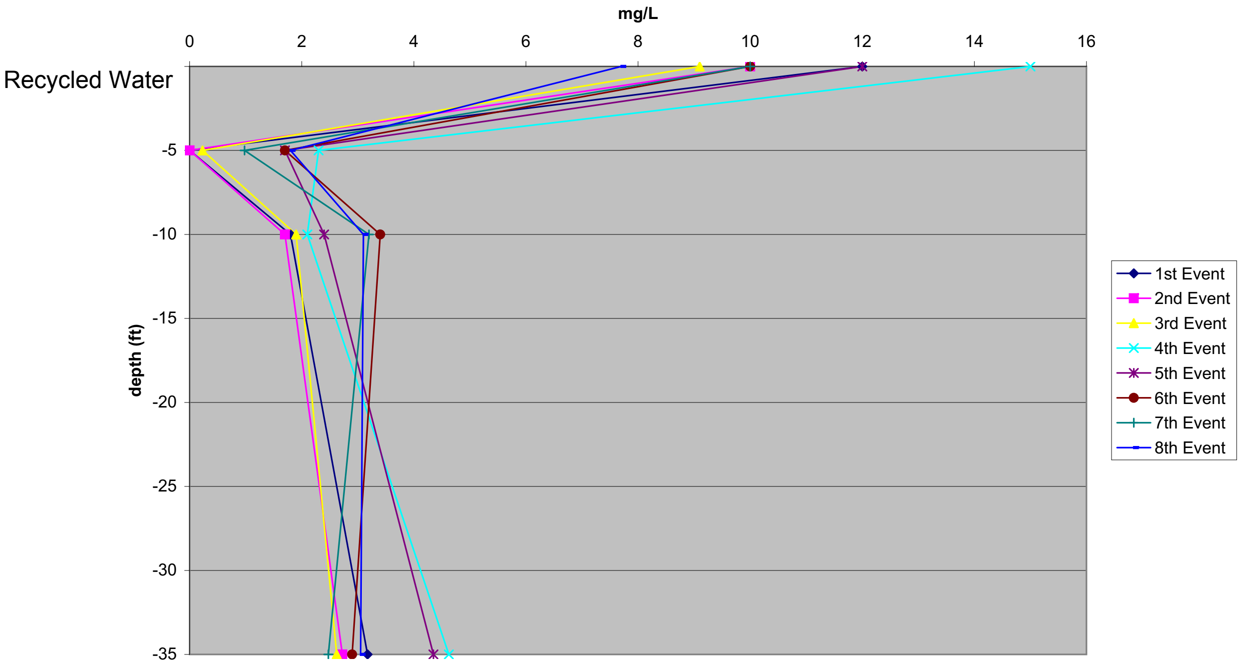
Note: non-detects are treated in the figure as zero.

Figure III-4-21A Nitrate as N



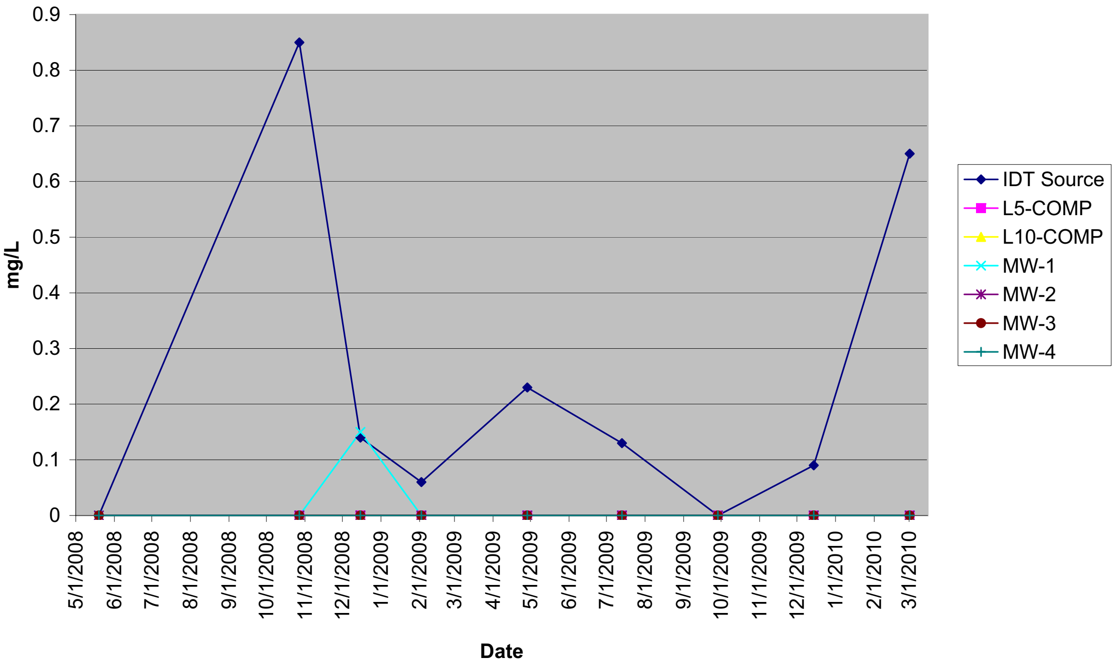
Note: non-detects are treated in the figure as zero.

Figure III-4-21B Nitrate as N



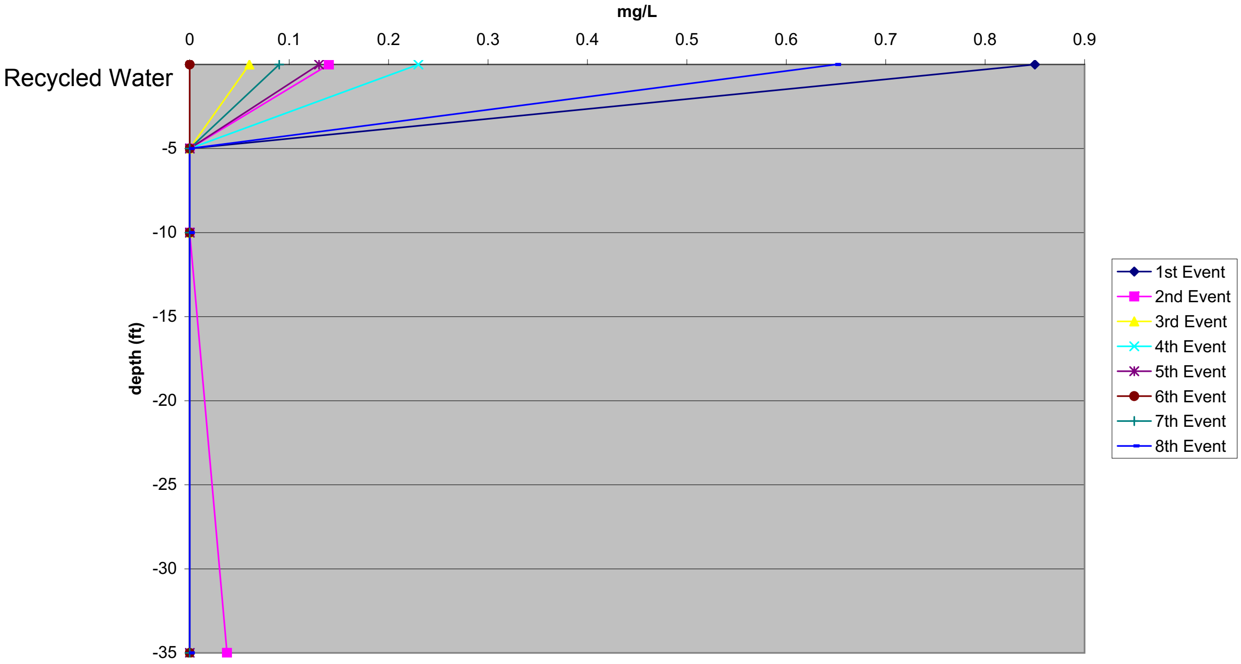
Note: non-detects are treated in the figure as zero.

Figure III-4-22A Nitrite as N



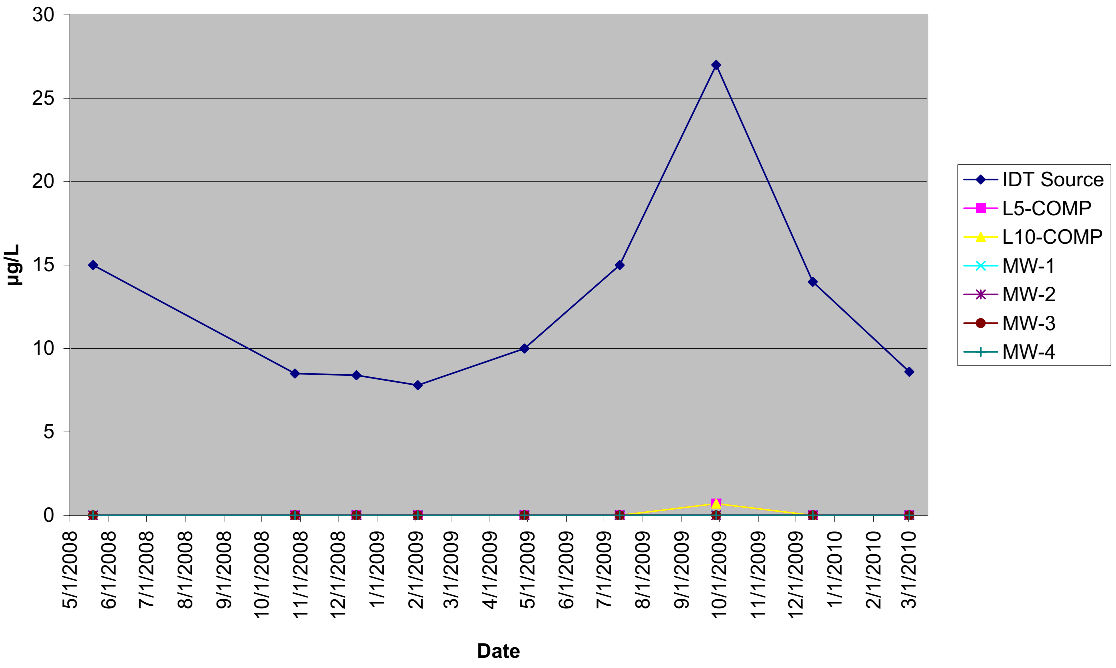
Note: non-detects are treated in the figure as zero.

Figure III-4-22B Nitrite as N



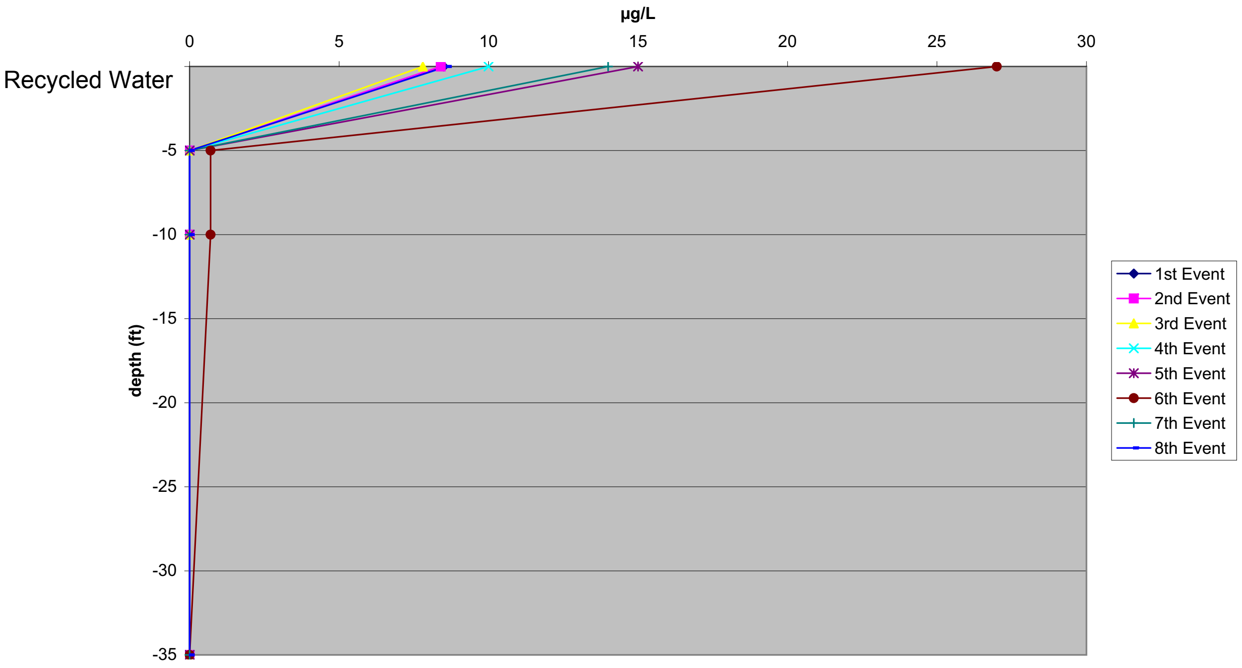
Note: non-detects are treated in the figure as zero.

Figure III-4-23A Bromodichloromethane



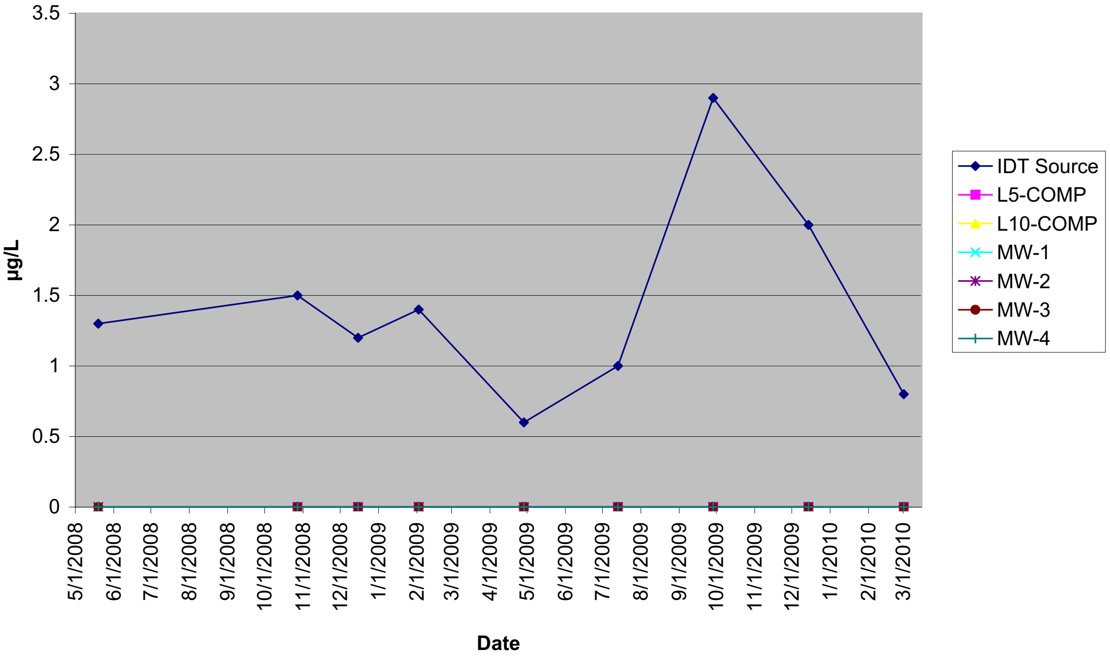
Note: non-detects are treated in the figure as zero.

Figure III-4-23B Bromodichloromethane



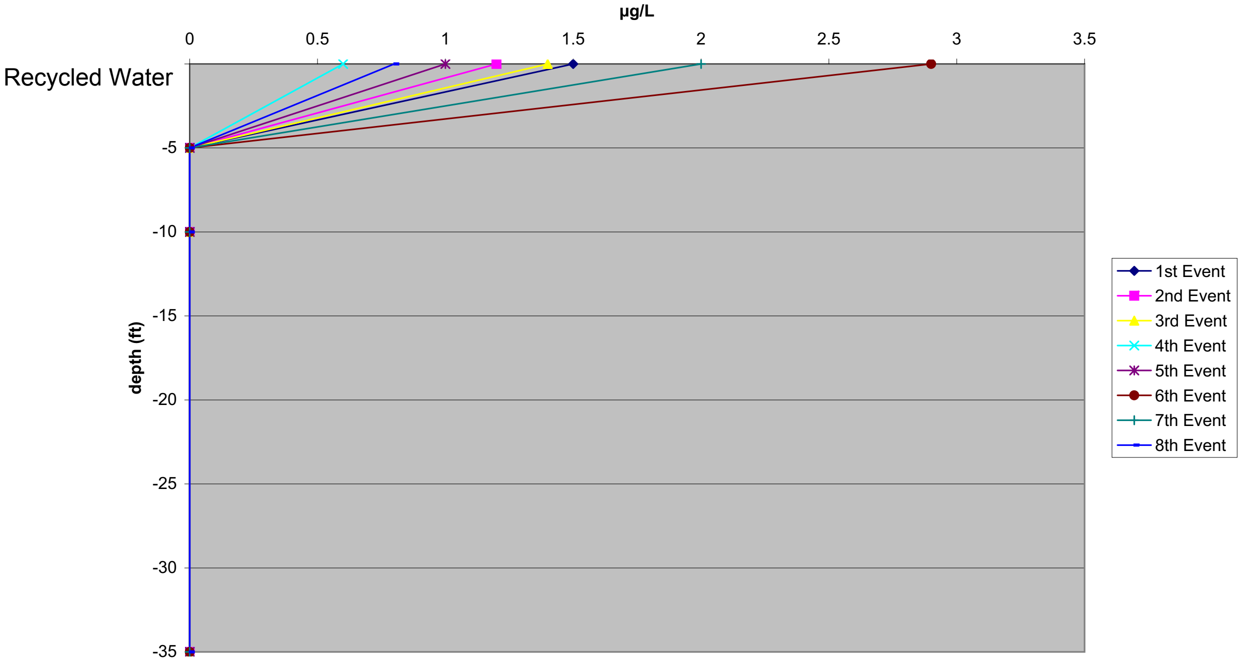
Note: non-detects are treated in the figure as zero.

Figure III-4-24A Bromoform



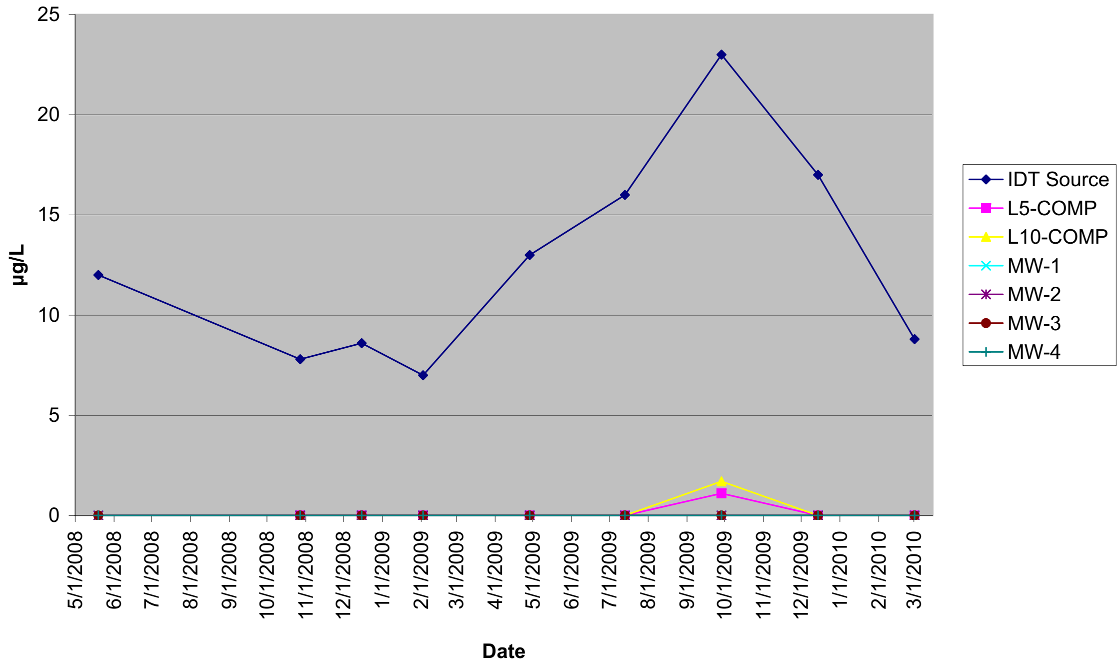
Note: non-detects are treated in the figure as zero.

Figure III-4-24B Bromoform



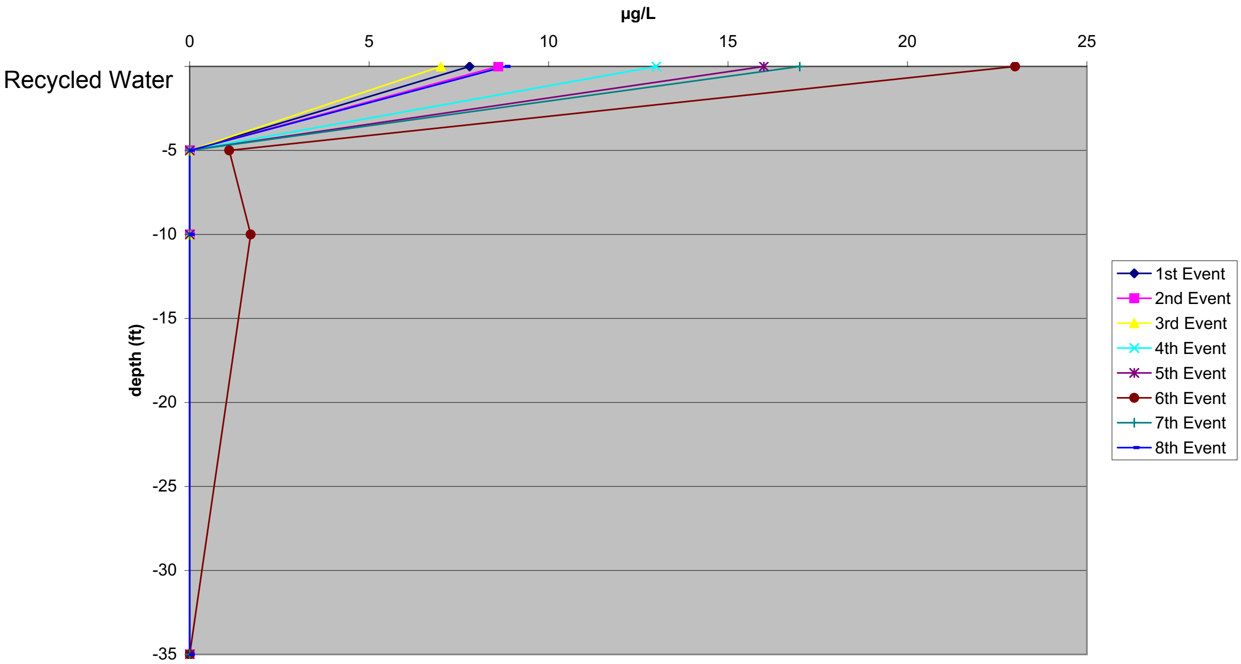
Note: non-detects are treated in the figure as zero.

Figure III-4-25A Chloroform



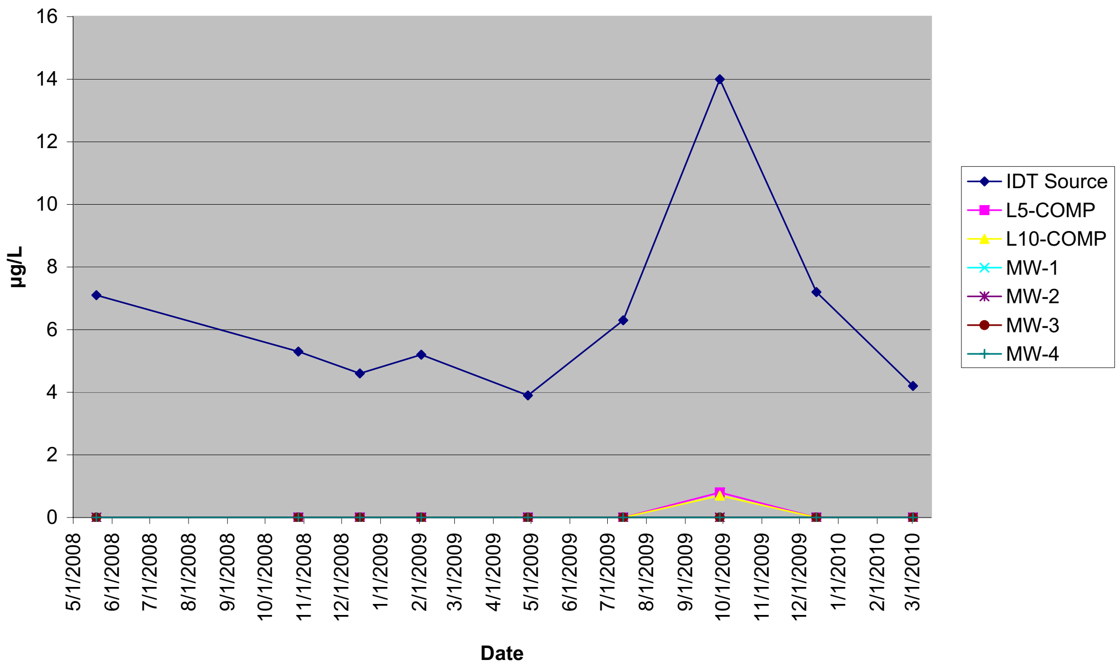
Note: non-detects are treated in the figure as zero.

Figure III-4-25B Chloroform



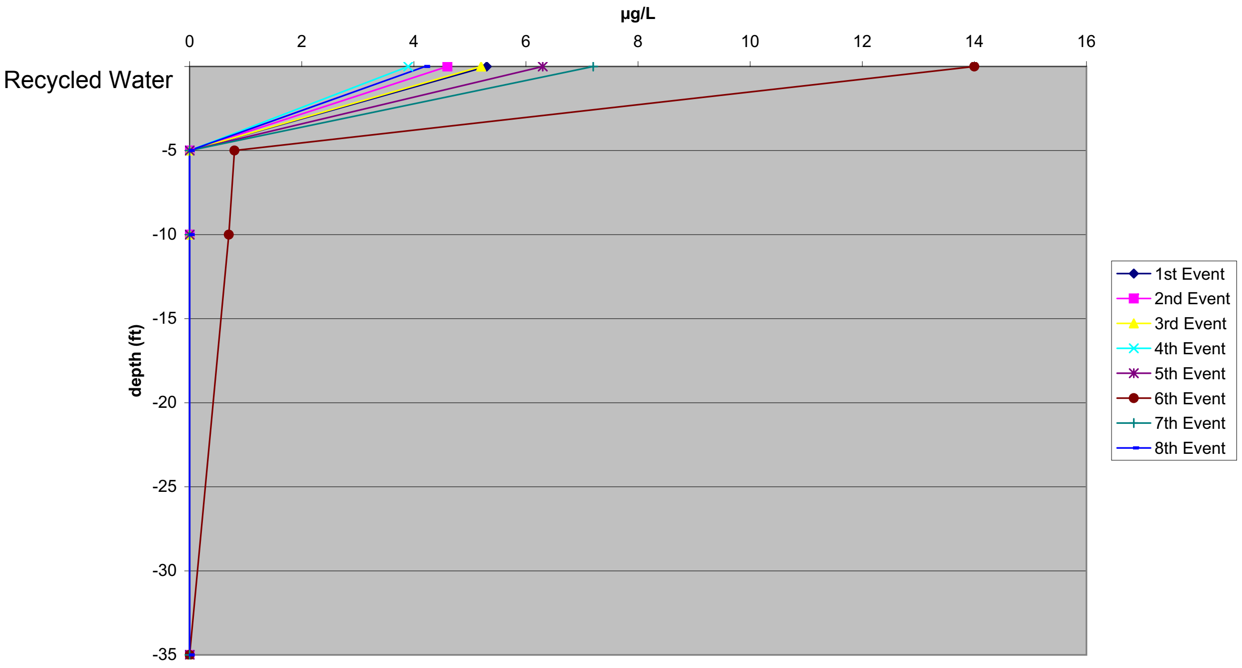
Note: non-detects are treated in the figure as zero.

Figure III-4-26A Dibromochloromethane



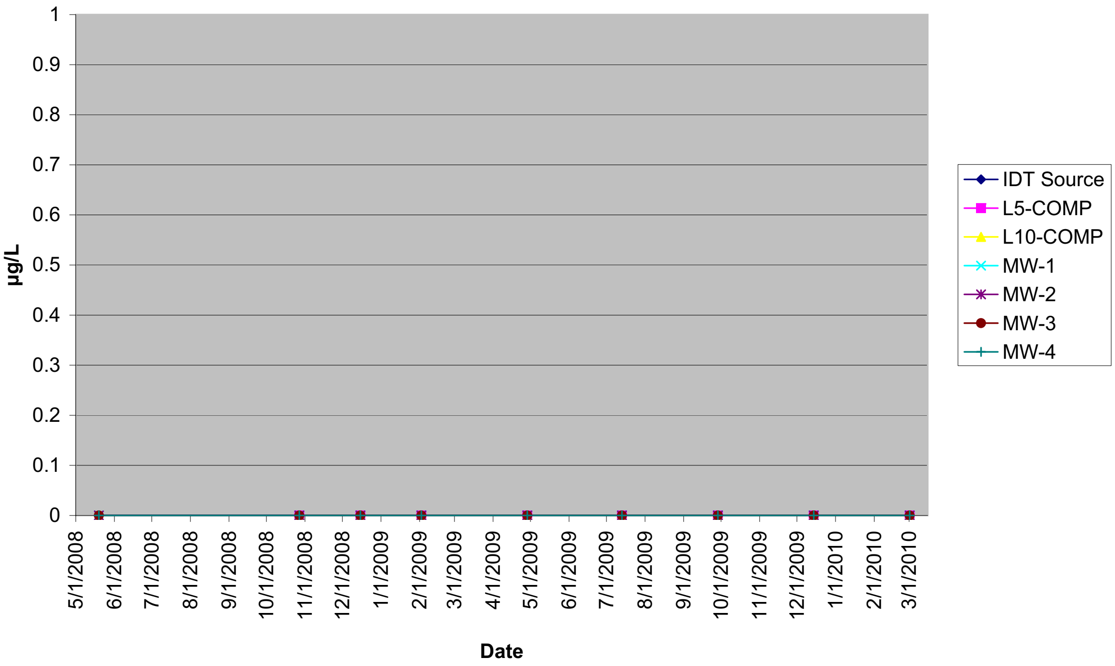
Note: non-detects are treated in the figure as zero.

Figure III-4-26B Dibromochloromethane



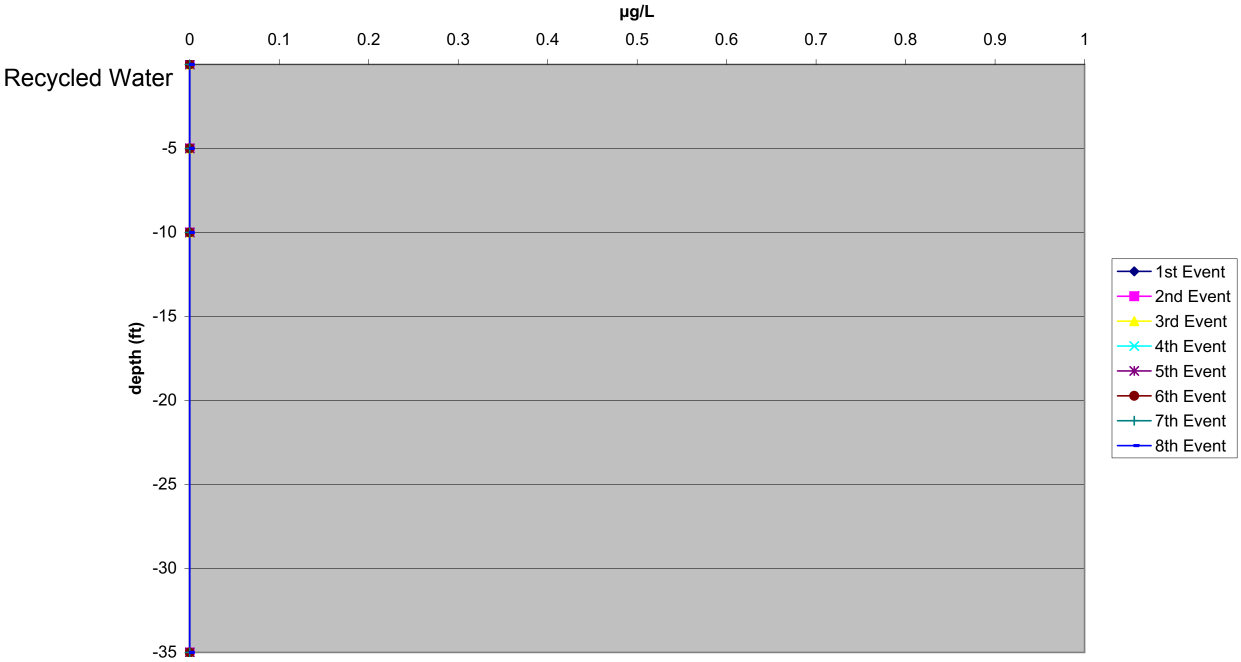
Note: non-detects are treated in the figure as zero.

Figure III-4-27A Carbon Tetrachloride



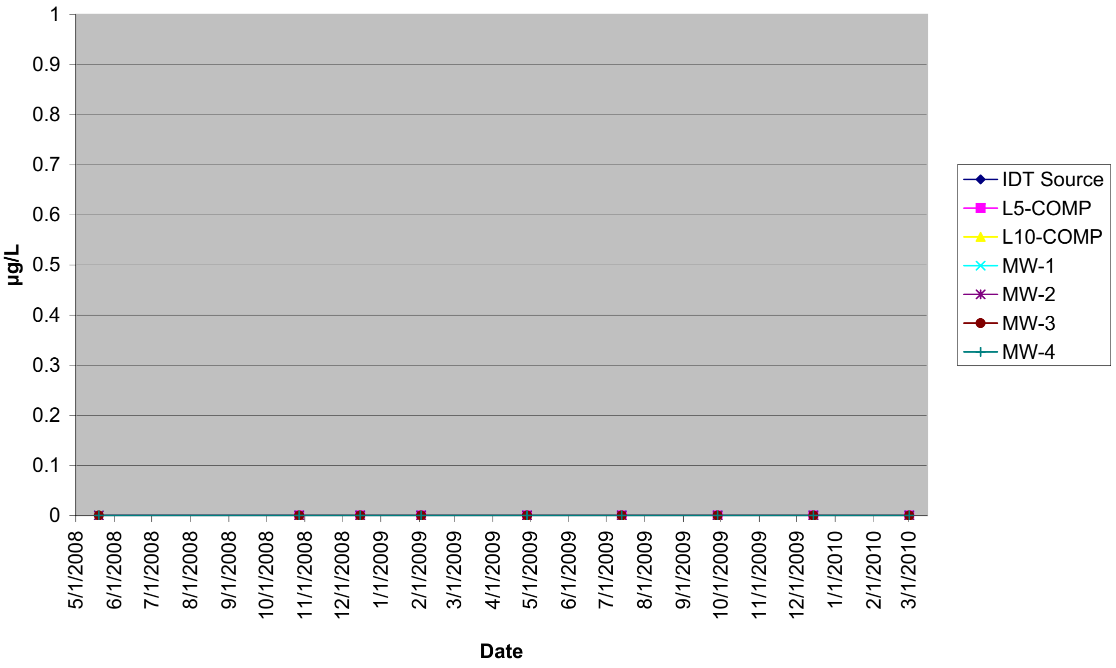
Note: non-detects are treated in the figure as zero.

Figure III-4-27B Carbon Tetrachloride



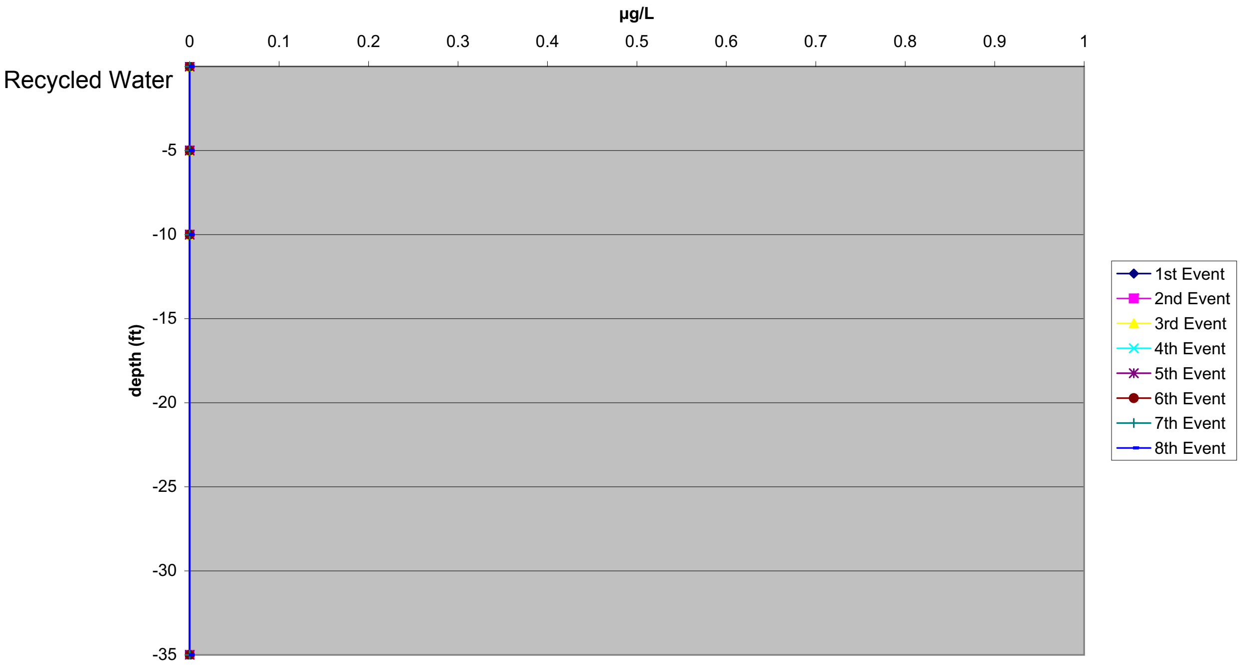
Note: non-detects are treated in the figure as zero.

Figure III-4-28A Xylenes (m,p-xylenes)



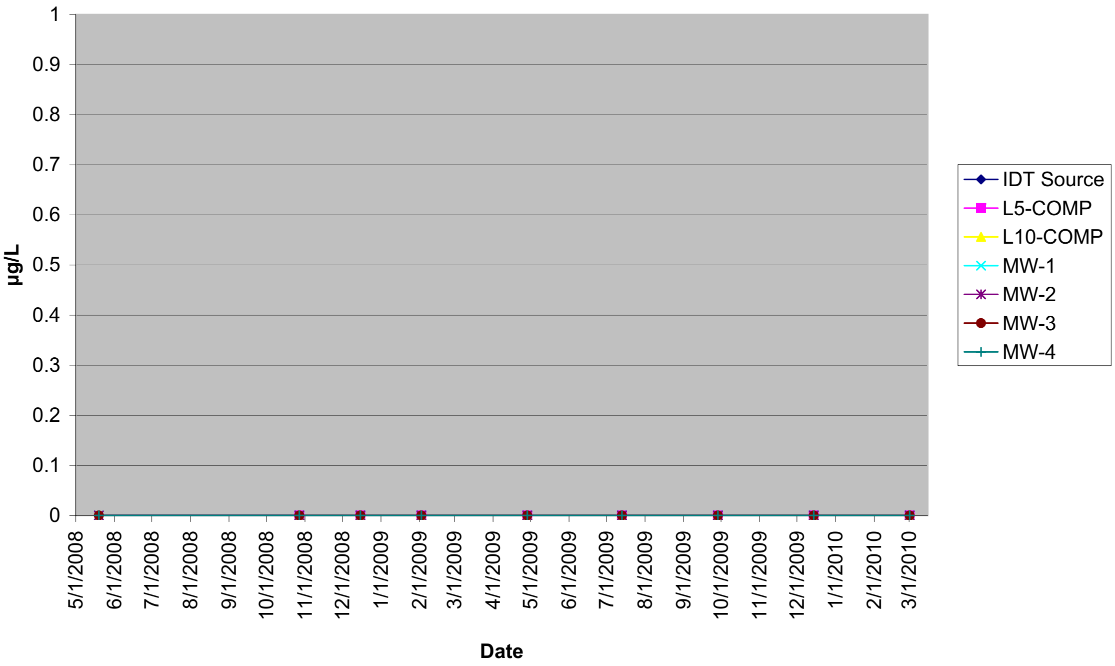
Note: non-detects are treated in the figure as zero.

Figure III-4-28B Xylenes (m,p-xylenes)



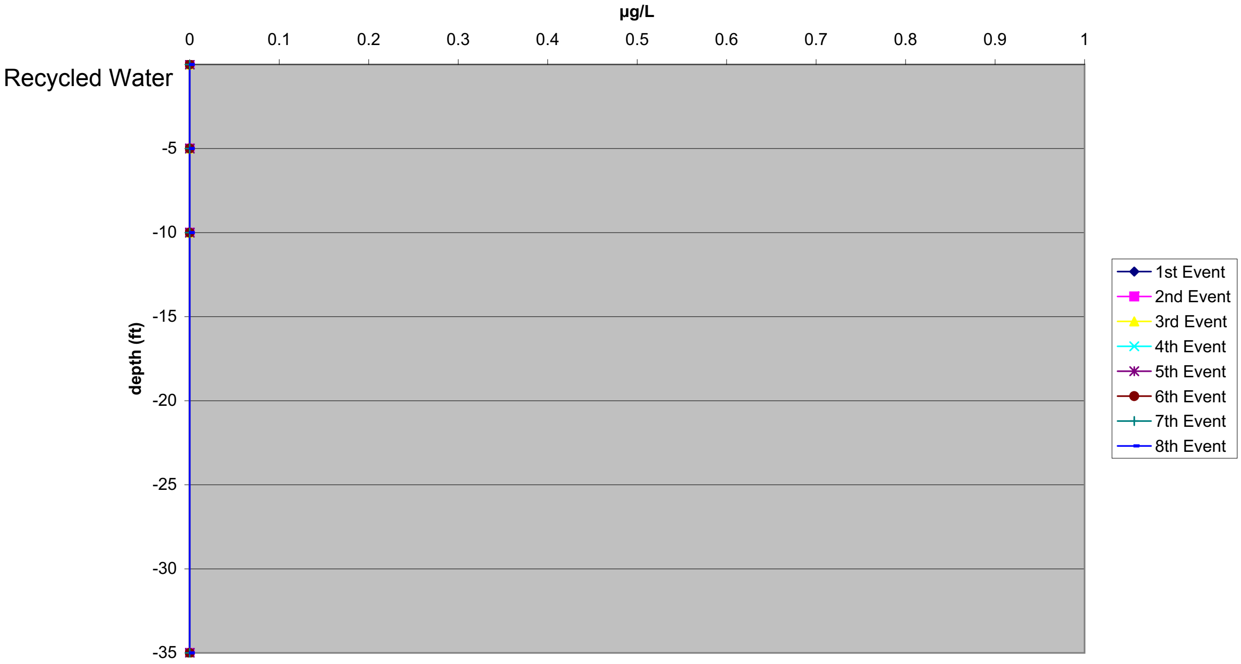
Note: non-detects are treated in the figure as zero.

Figure III-4-29A Xylenes (o-xylenes)



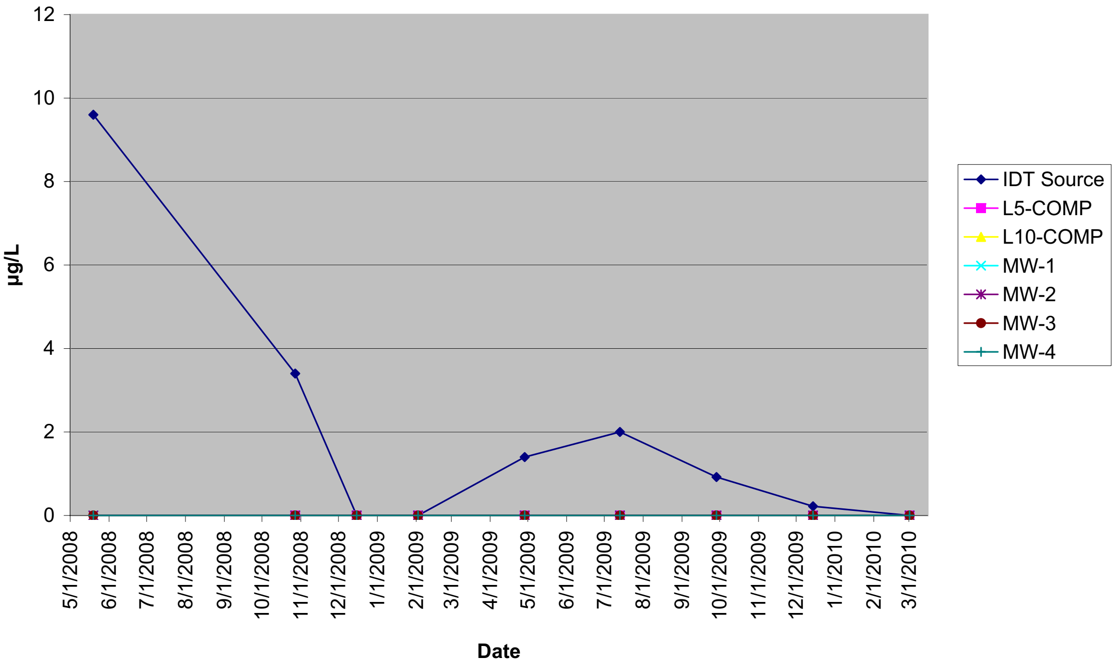
Note: non-detects are treated in the figure as zero.

Figure III-4-29B Xylenes (o-xylenes)



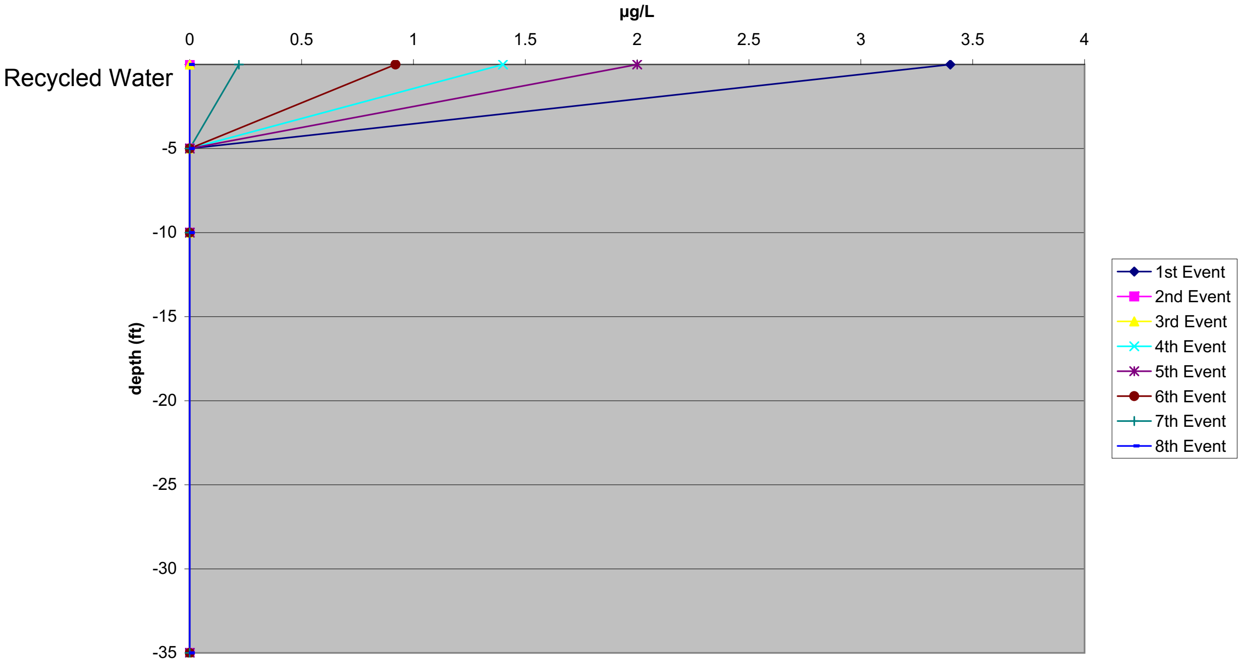
Note: non-detects are treated in the figure as zero.

Figure III-4-30A Bromochloroacetic Acid



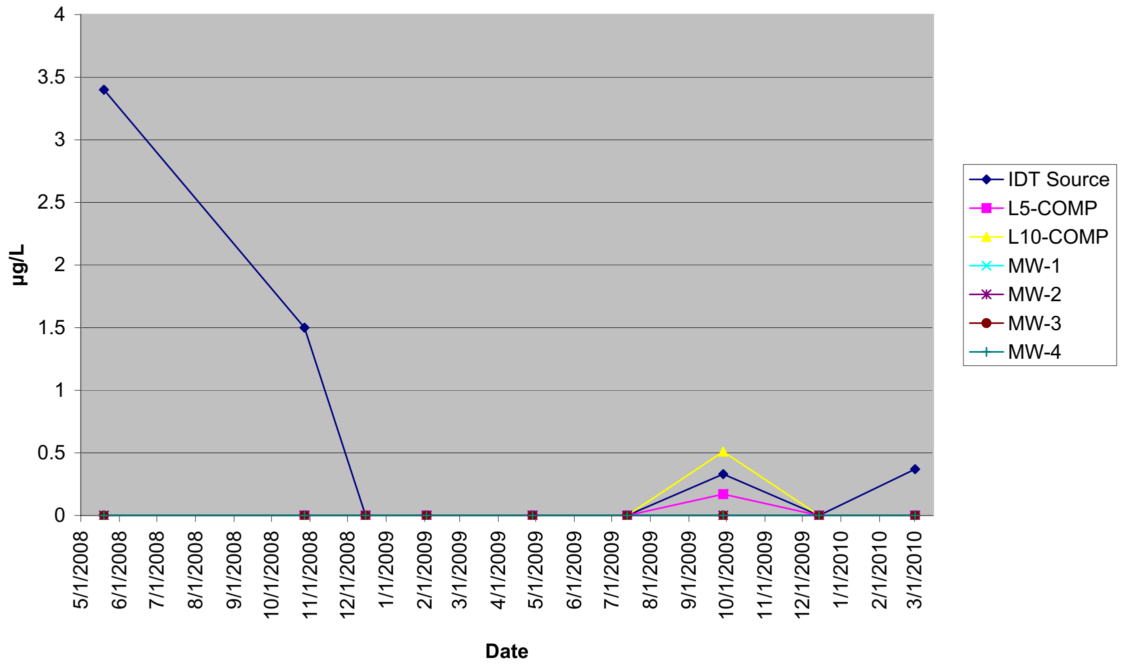
Note: non-detects are treated in the figure as zero.

Figure III-4-30B Bromochloroacetic Acid



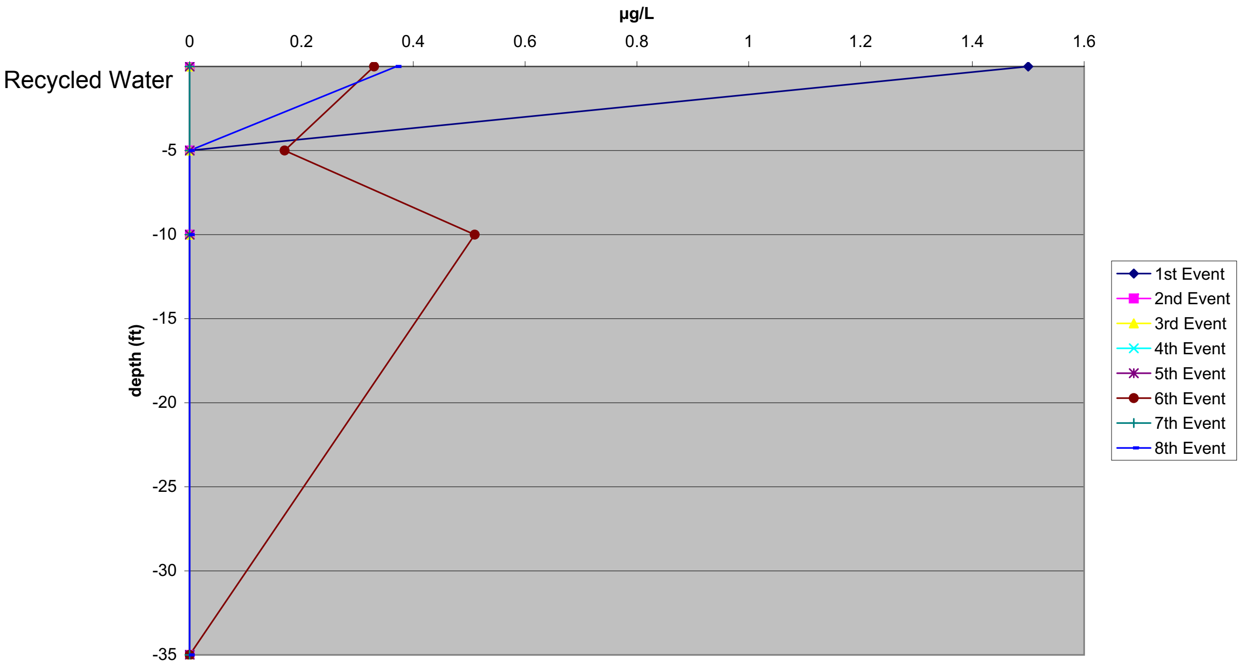
Note: non-detects are treated in the figure as zero.

Figure III-4-31A Dibromoacetic Acid



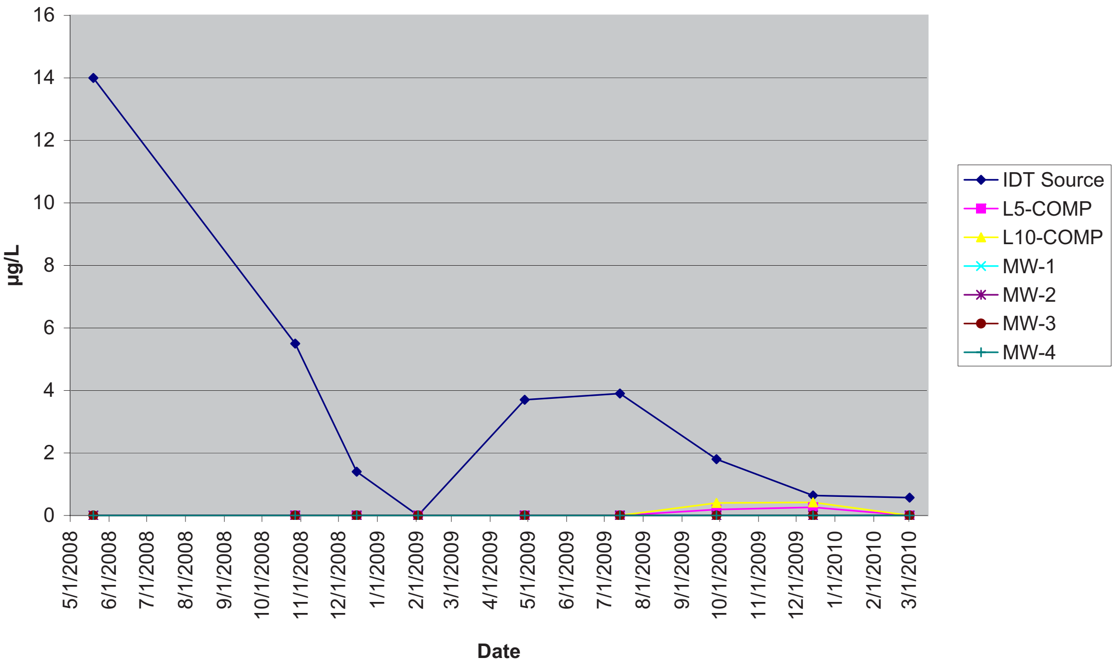
Note: non-detects are treated in the figure as zero.

Figure III-4-31B Dibromoacetic Acid



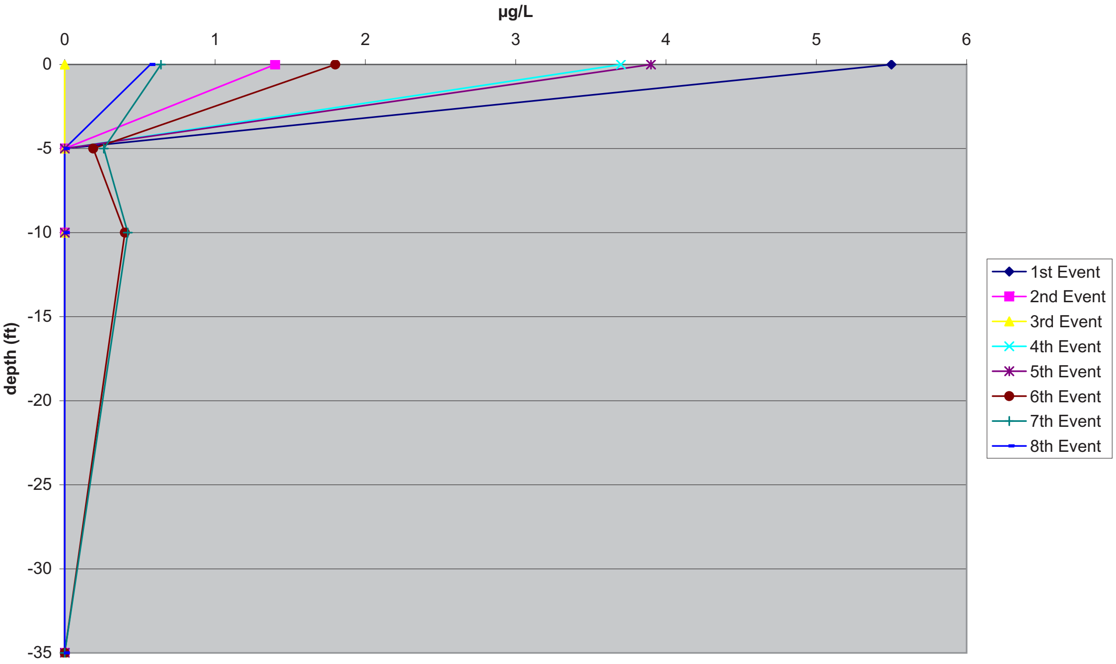
Note: non-detects are treated in the figure as zero.

Figure III-4-32A Dichloroacetic Acid



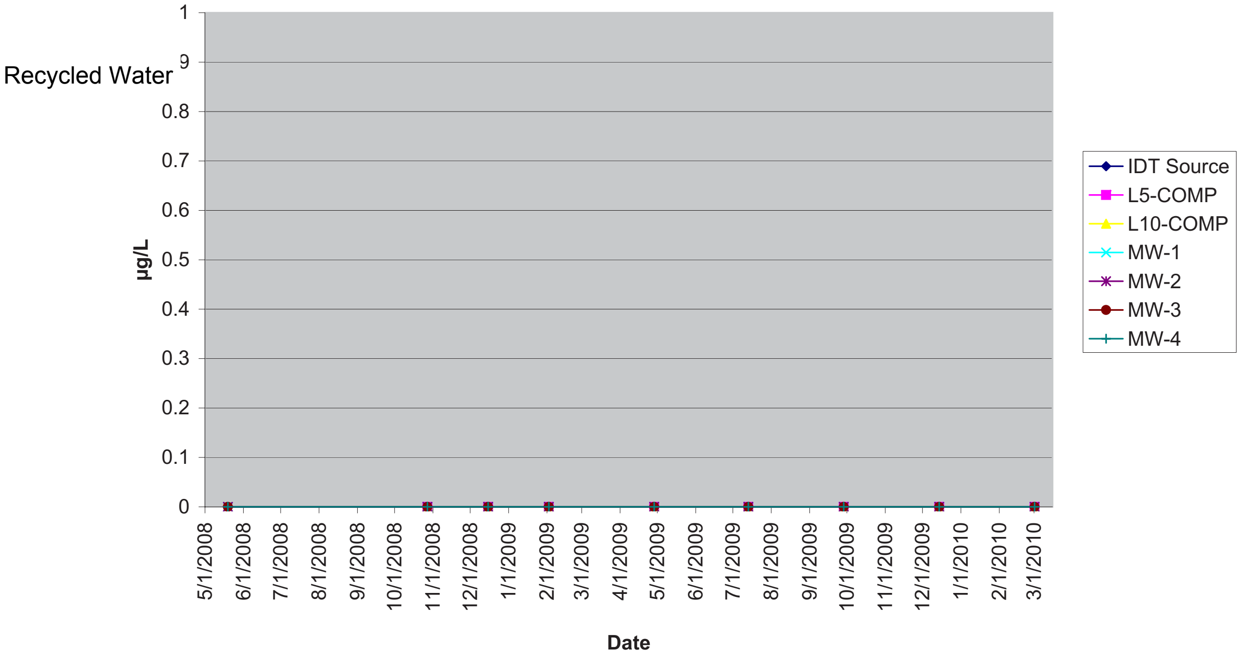
Note: non-detects are treated in the figure as zero.

Figure III-4-32B Dichloroacetic Acid



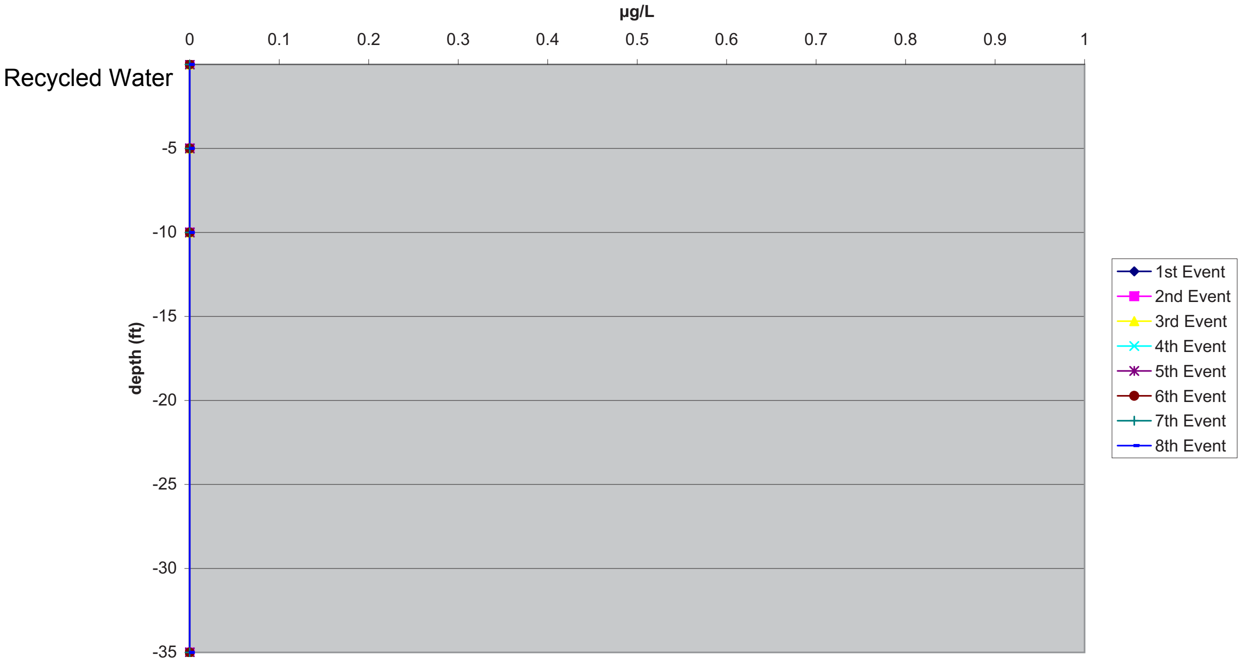
Note: non-detects are treated in the figure as zero.

Figure III-4-33A Monobromoacetic Acid



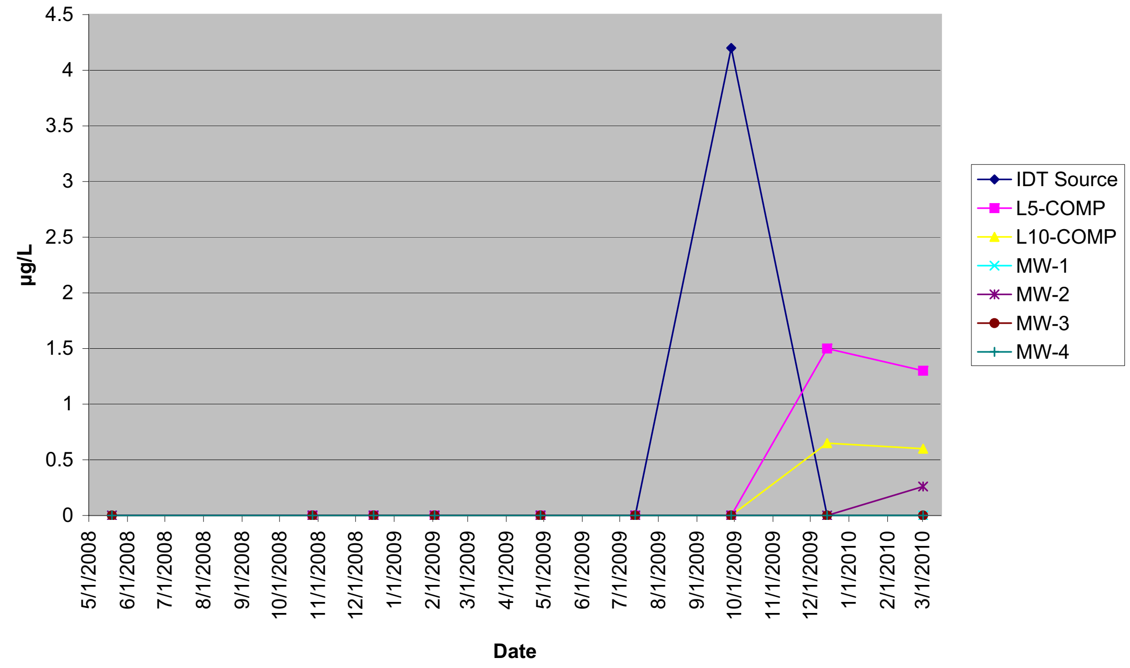
Note: non-detects are treated in the figure as zero.

Figure III-4-33B Monobromoacetic Acid



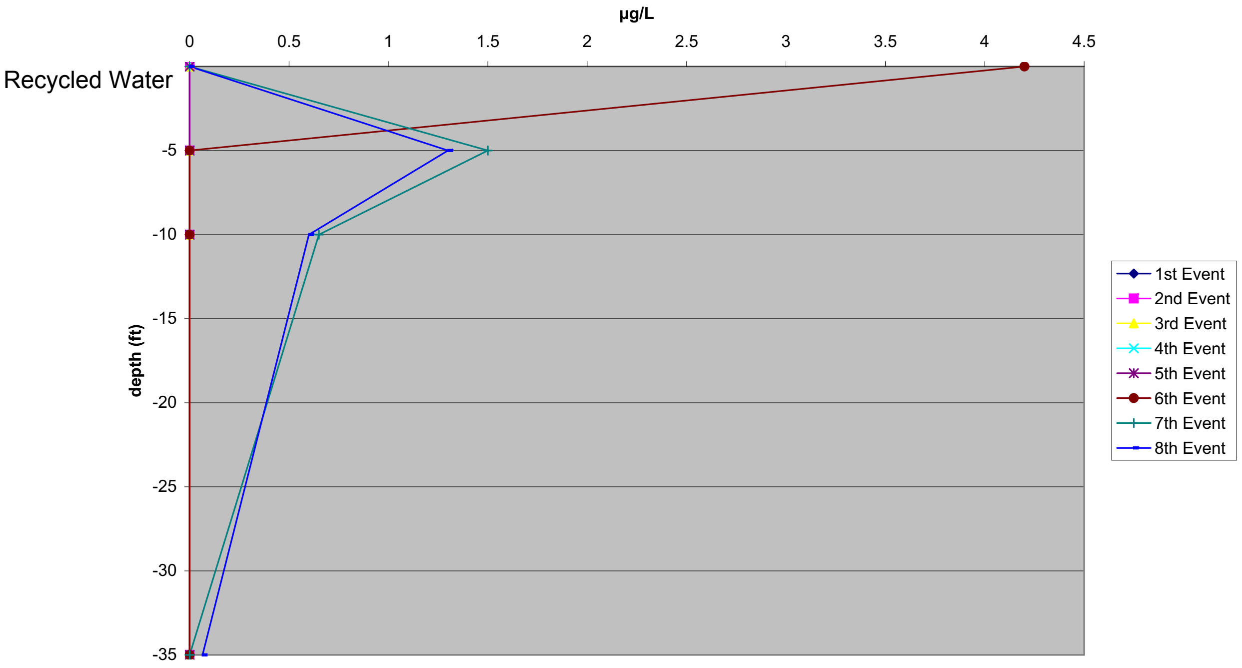
Note: non-detects are treated in the figure as zero.

Figure III-4-34A Monochloroacetic Acid



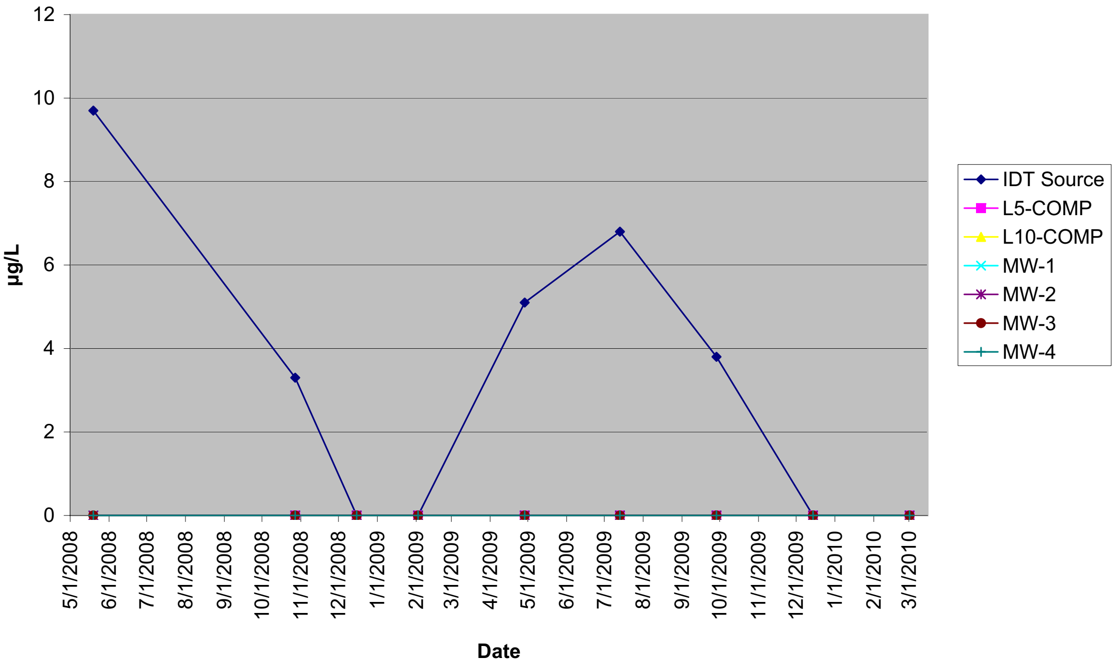
Note: non-detects are treated in the figure as zero.

Figure III-4-34B Monochloroacetic Acid



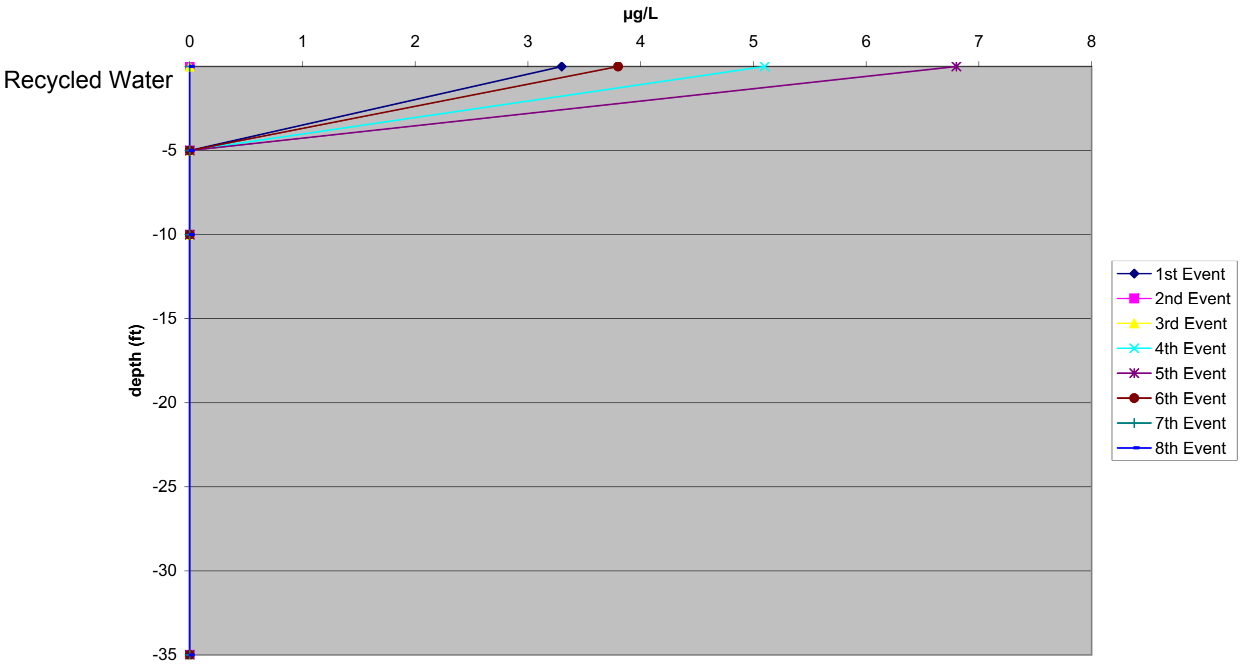
Note: non-detects are treated in the figure as zero.

Figure III-4-35A Trichloroacetic Acid



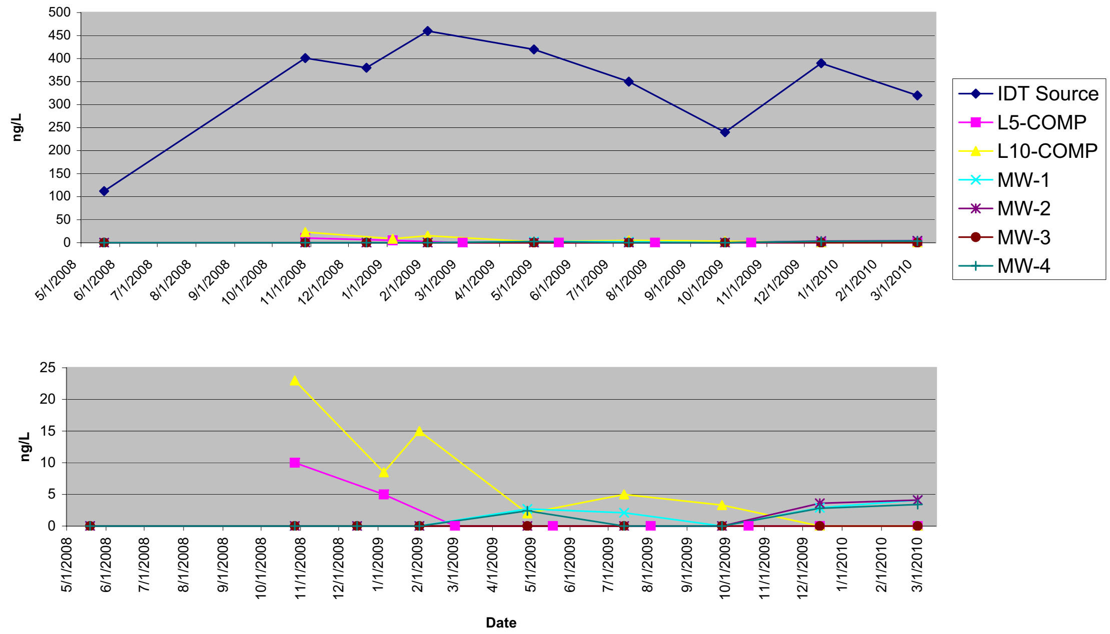
Note: non-detects are treated in the figure as zero.

Figure III-4-35B Trichloroacetic Acid



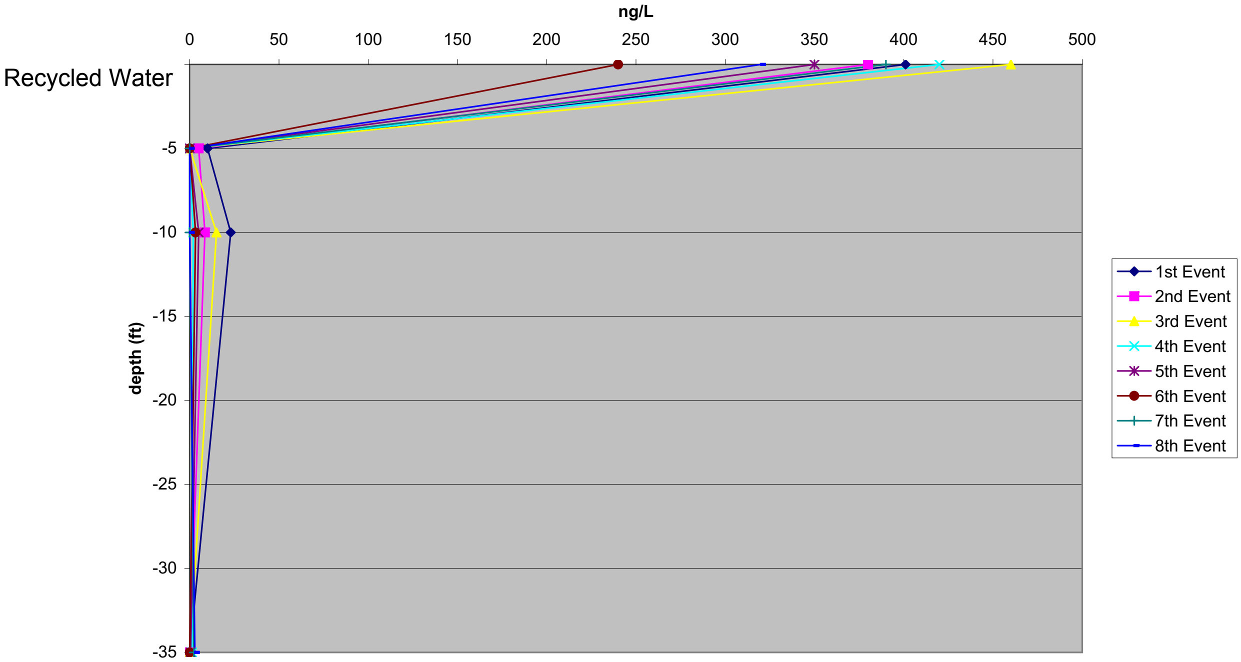
Note: non-detects are treated in the figure as zero.

Figure III-4-36A N-Nitroso Dimethylamine (NDMA)



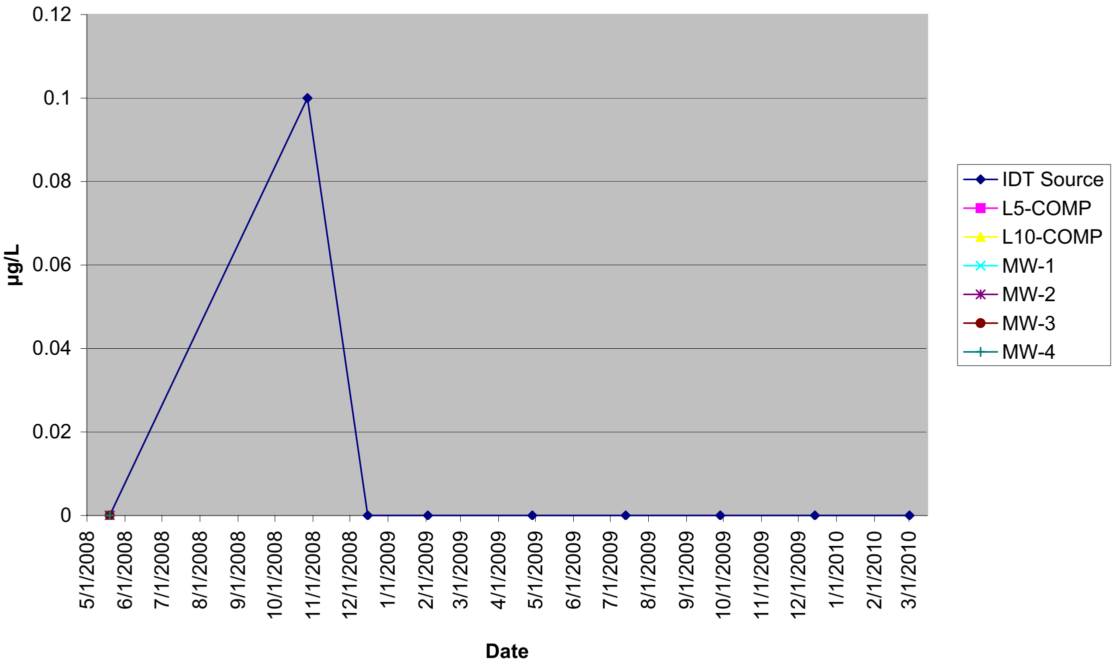
Note: non-detects are treated in the figure as zero.

Figure III-4-36B N-Nitroso Dimethylamine (NDMA)



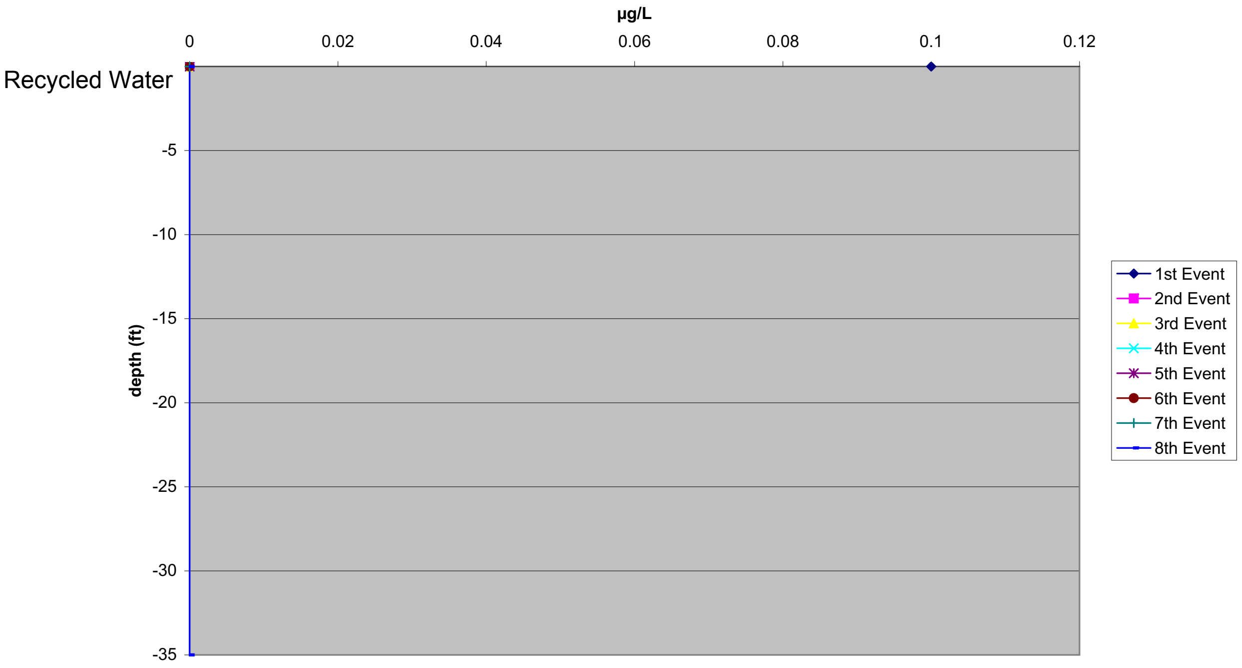
Note: non-detects are treated in the figure as zero.

Figure III-4-37A Terbuthylazine



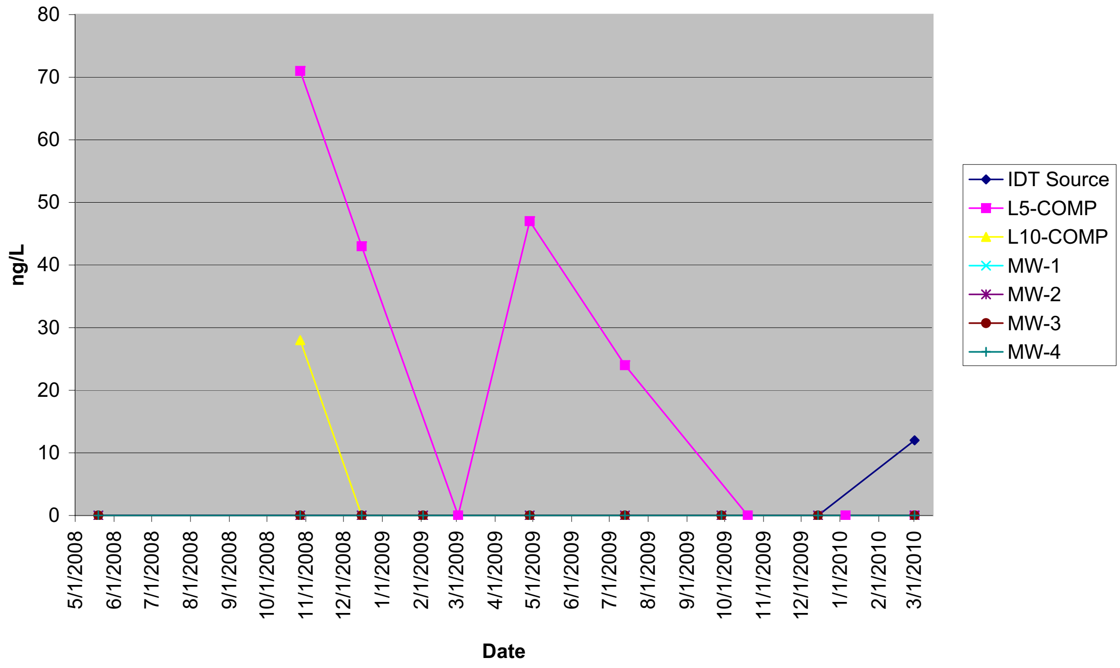
Note: non-detects are treated in the figure as zero.

Figure III-4-37B Terbuthylazine



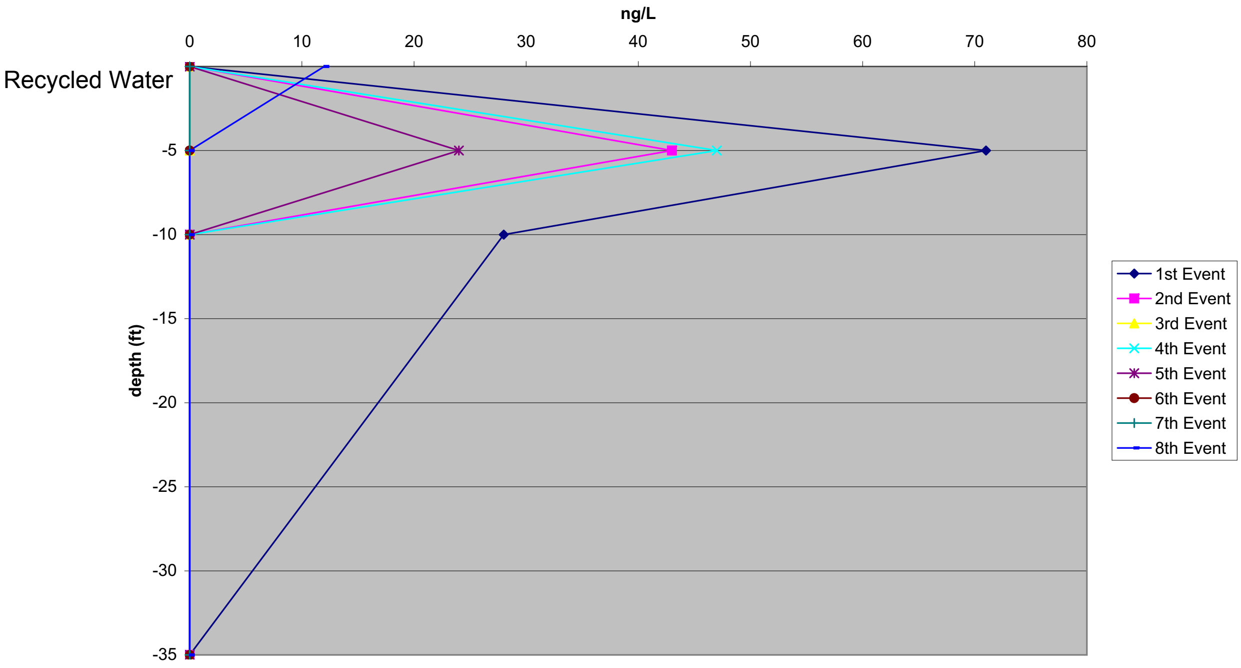
Note: non-detects are treated in the figure as zero.

Figure III-4-38A Perfluorochemicals (PFBA)



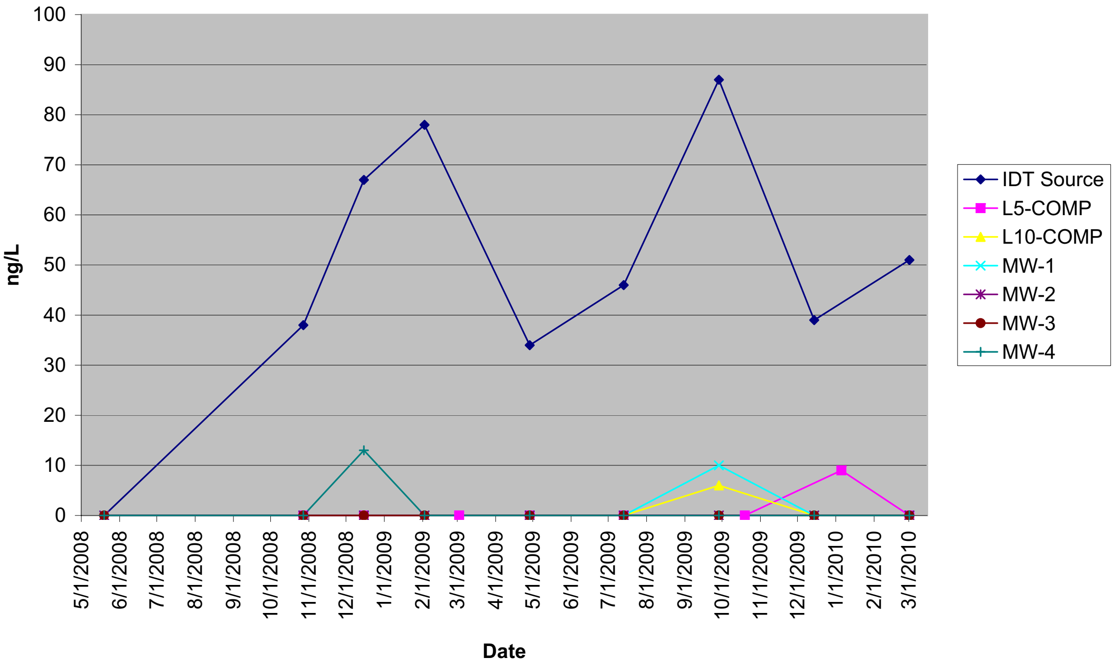
Note: non-detects are treated in the figure as zero.

Figure III-4-38B Perfluorochemicals (PFBA)



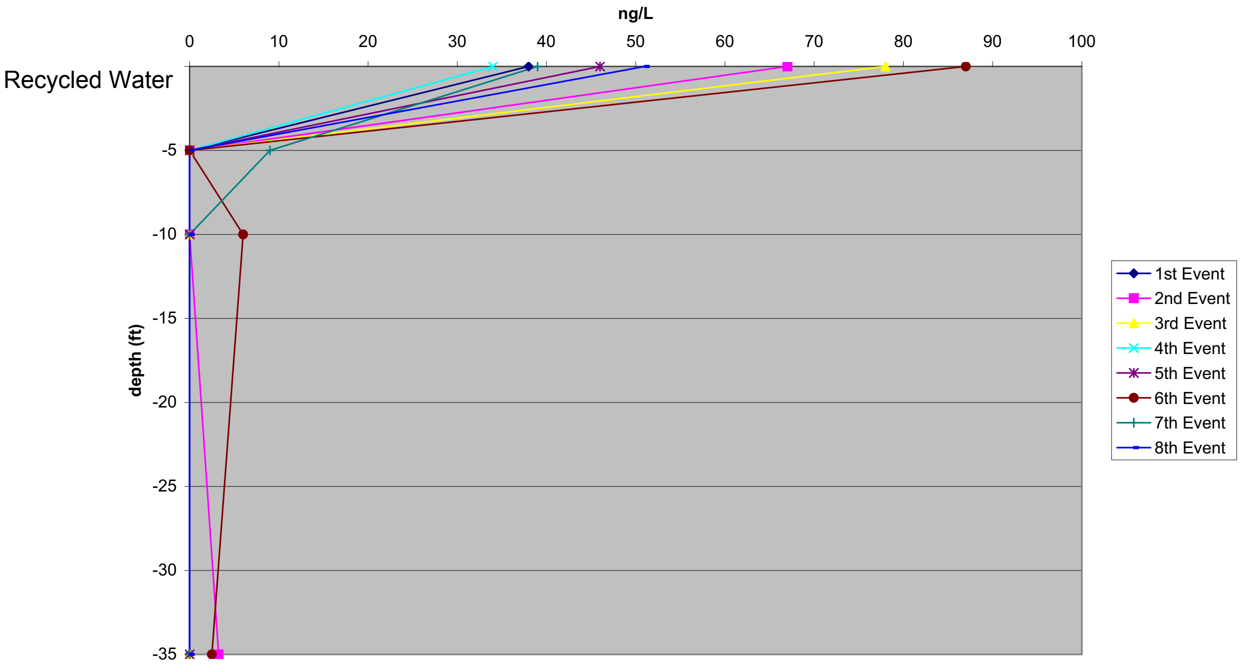
Note: non-detects are treated in the figure as zero.

Figure III-4-39A Perfluorochemicals (PFOS)



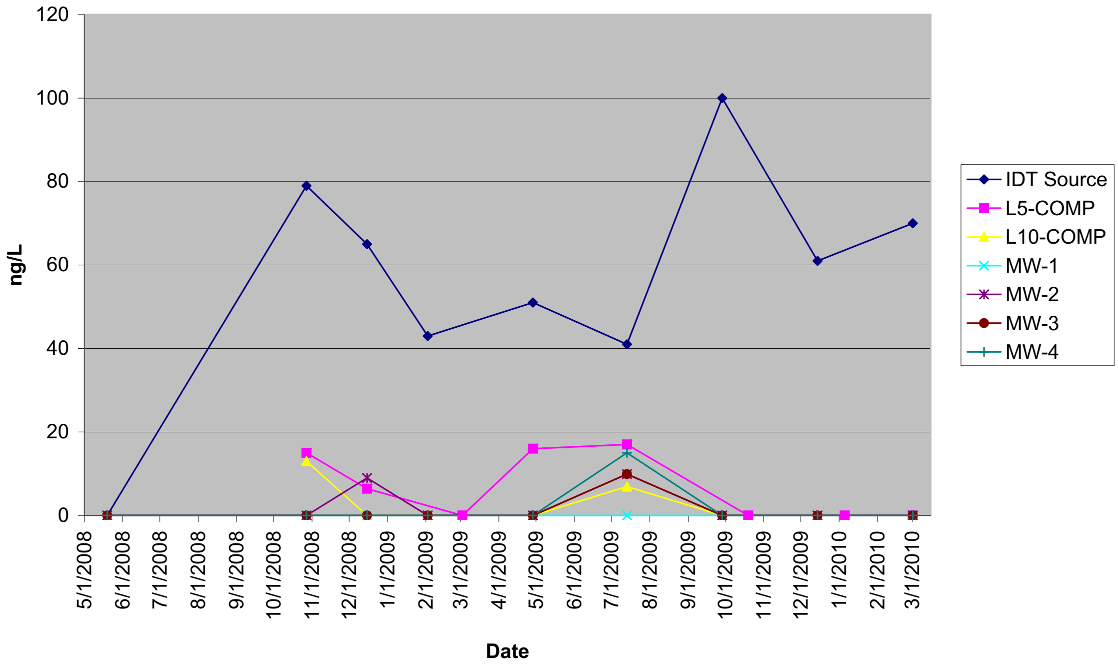
Note: non-detects are treated in the figure as zero.

Figure III-4-39B Perfluorochemicals (PFOS)



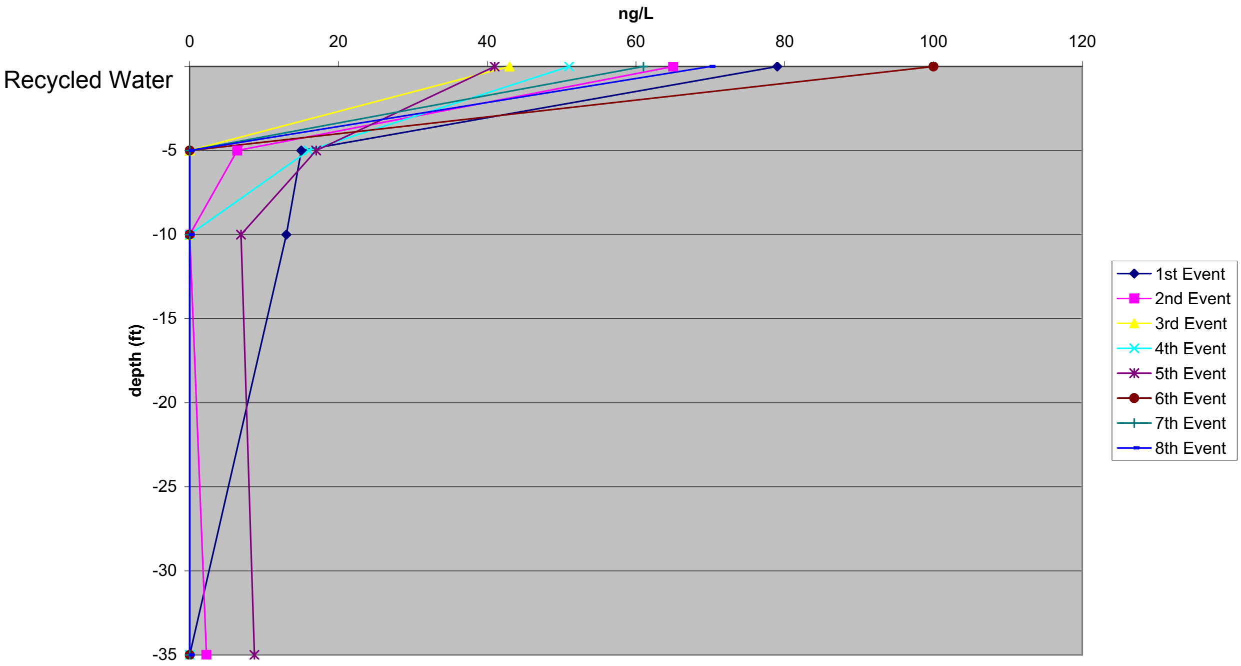
Note: non-detects are treated in the figure as zero.

Figure III-4-40A Perfluorochemicals (PFOA)



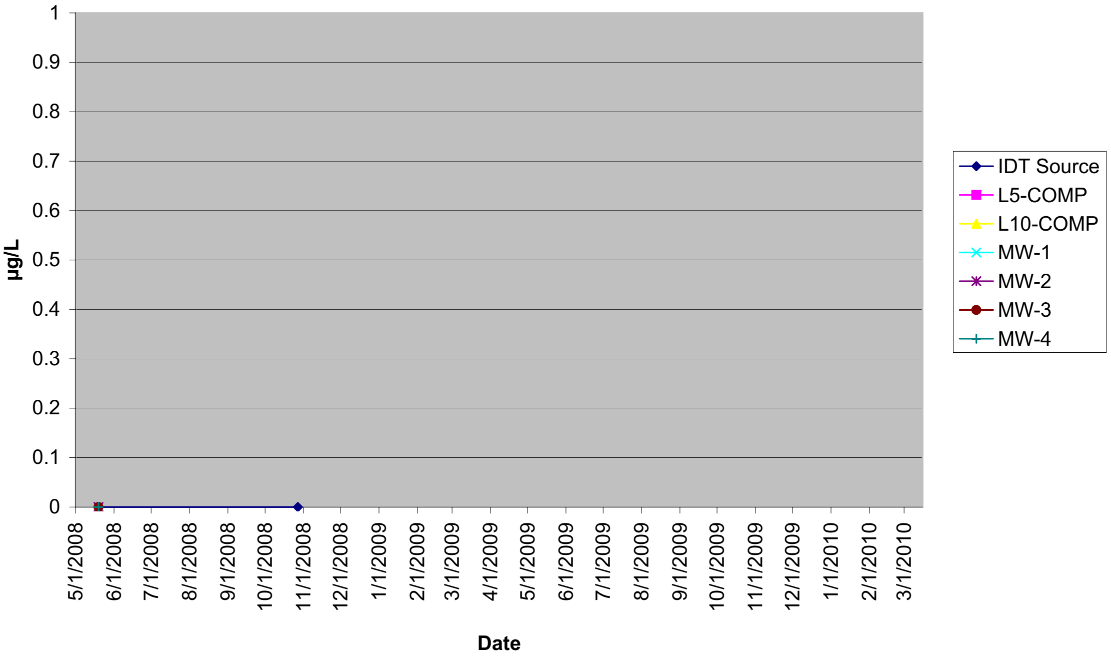
Note: non-detects are treated in the figure as zero.

Figure III-4-40B Perfluorochemicals (PFOA)



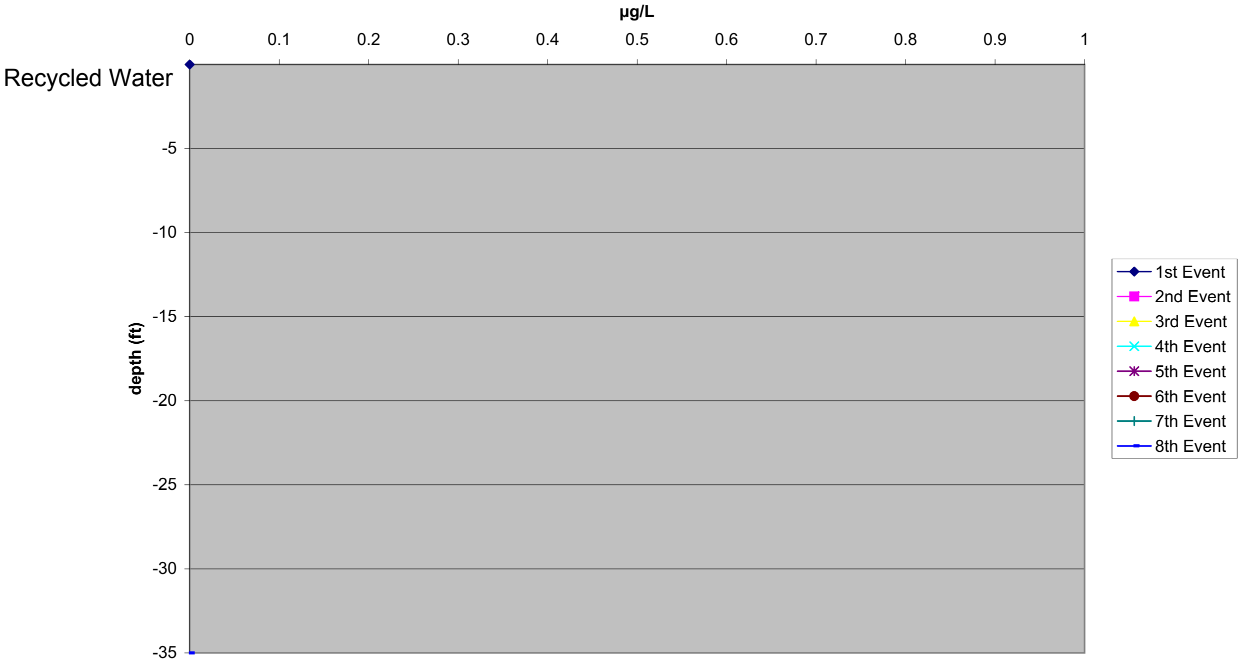
Note: non-detects are treated in the figure as zero.

Figure III-4-41A Nitrilotriacetic Acid (NTA)



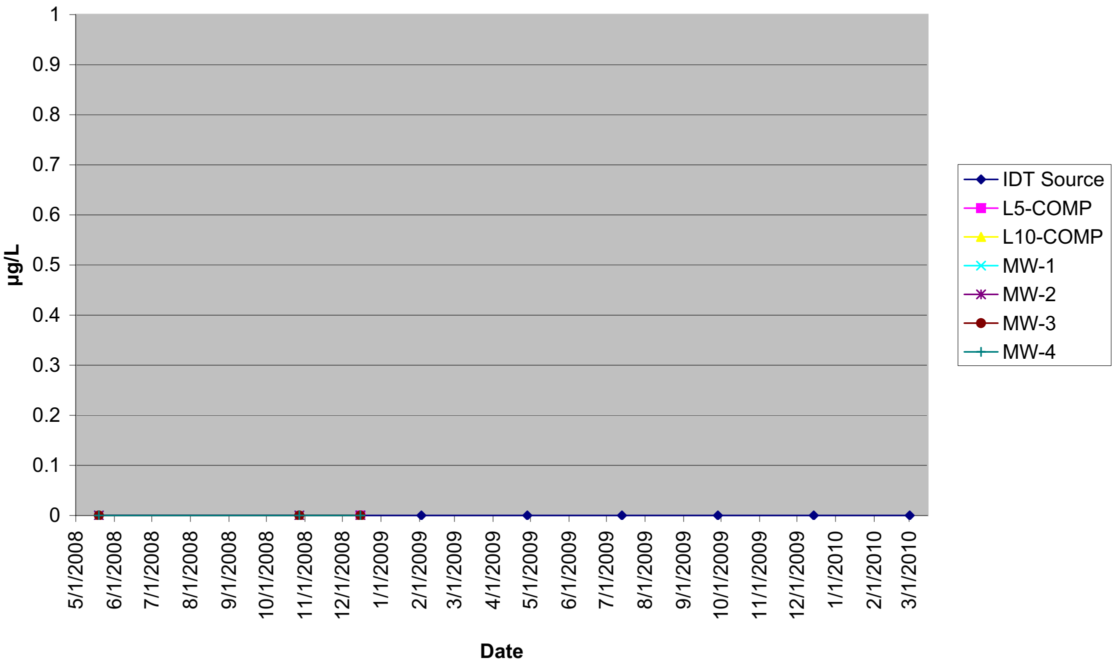
Note: non-detects are treated in the figure as zero.

Figure III-4-41B Nitrilotriacetic Acid (NTA)



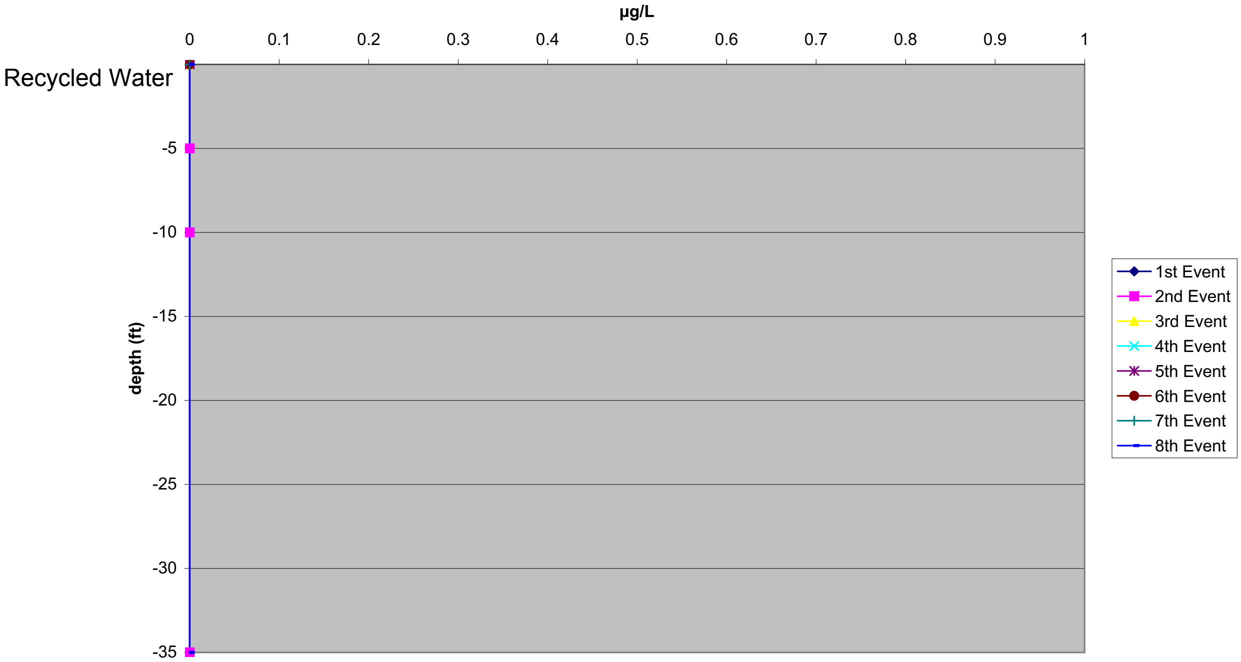
Note: non-detects are treated in the figure as zero.

Figure III-4-42A Ethylenediaminetetraacetic Acid (EDTA)



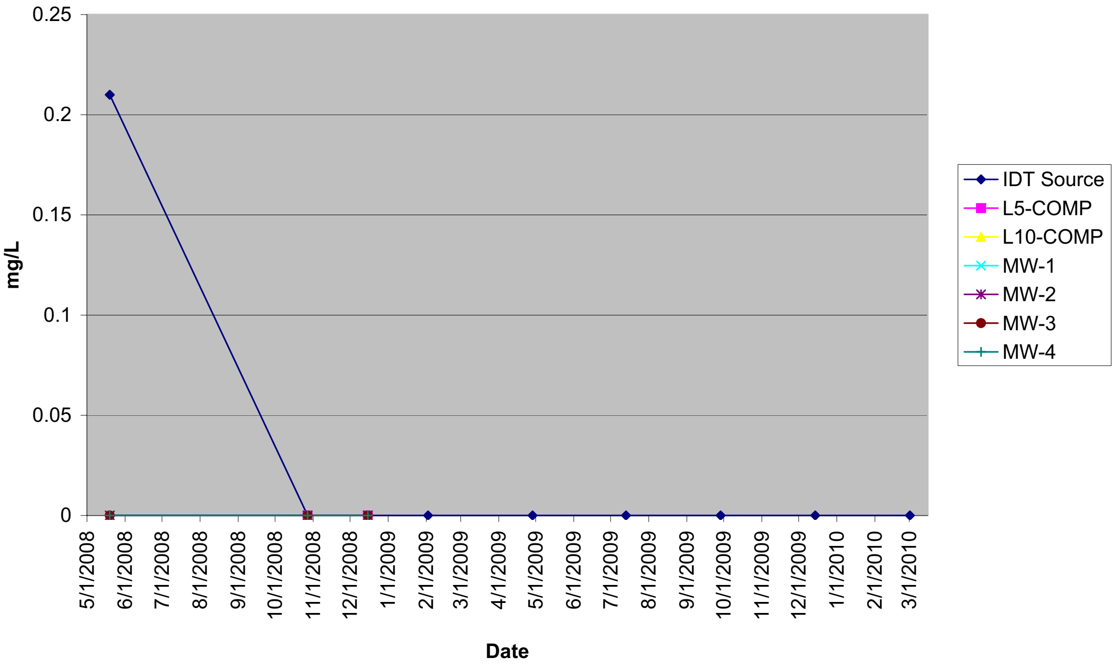
Note: non-detects are treated in the figure as zero.

Figure III-4-42B Ethylenediaminetetraacetic Acid (EDTA)



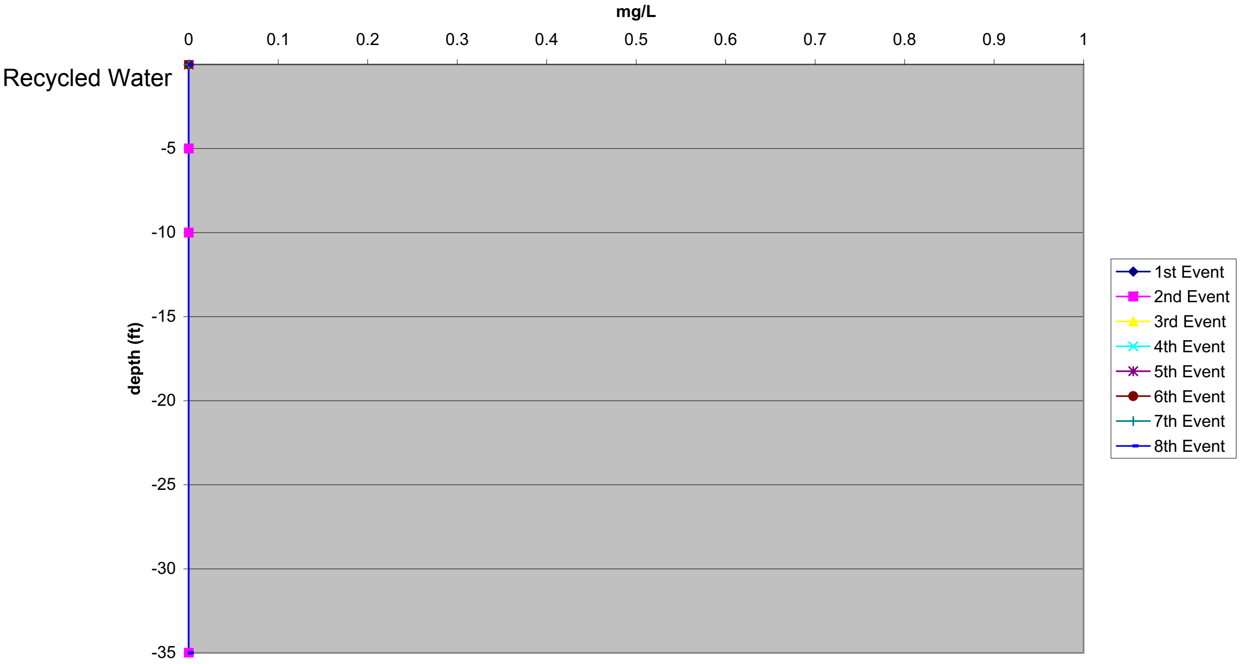
Note: non-detects are treated in the figure as zero.

Figure III-4-43A Surfactants (MBAS)



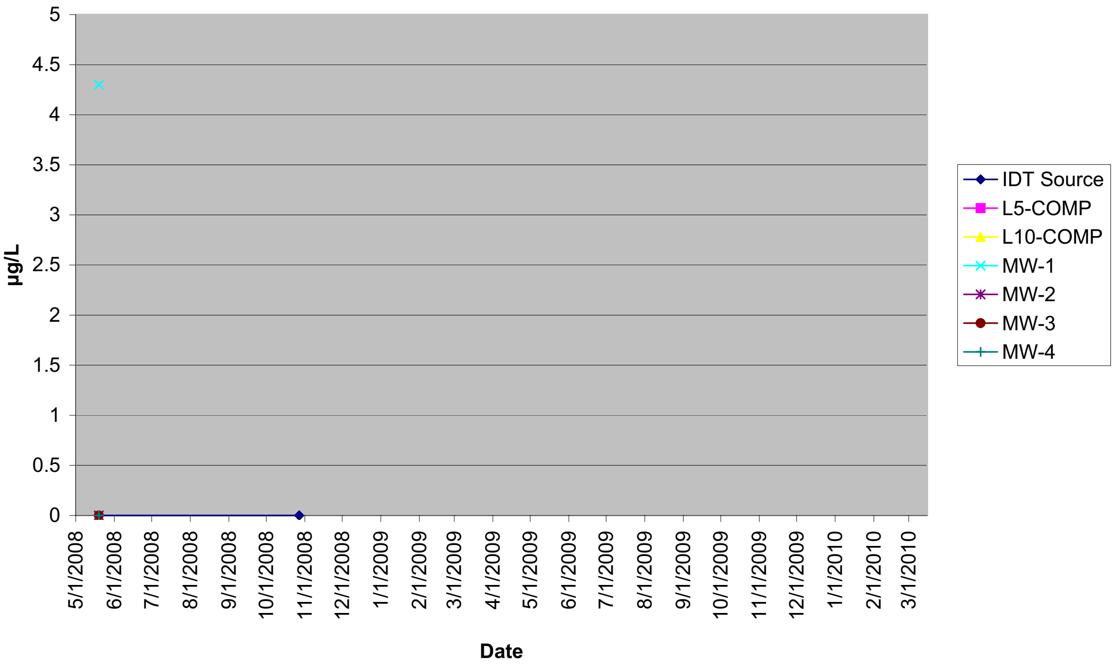
Note: non-detects are treated in the figure as zero.

Figure III-4-43B Surfactants (MBAS)



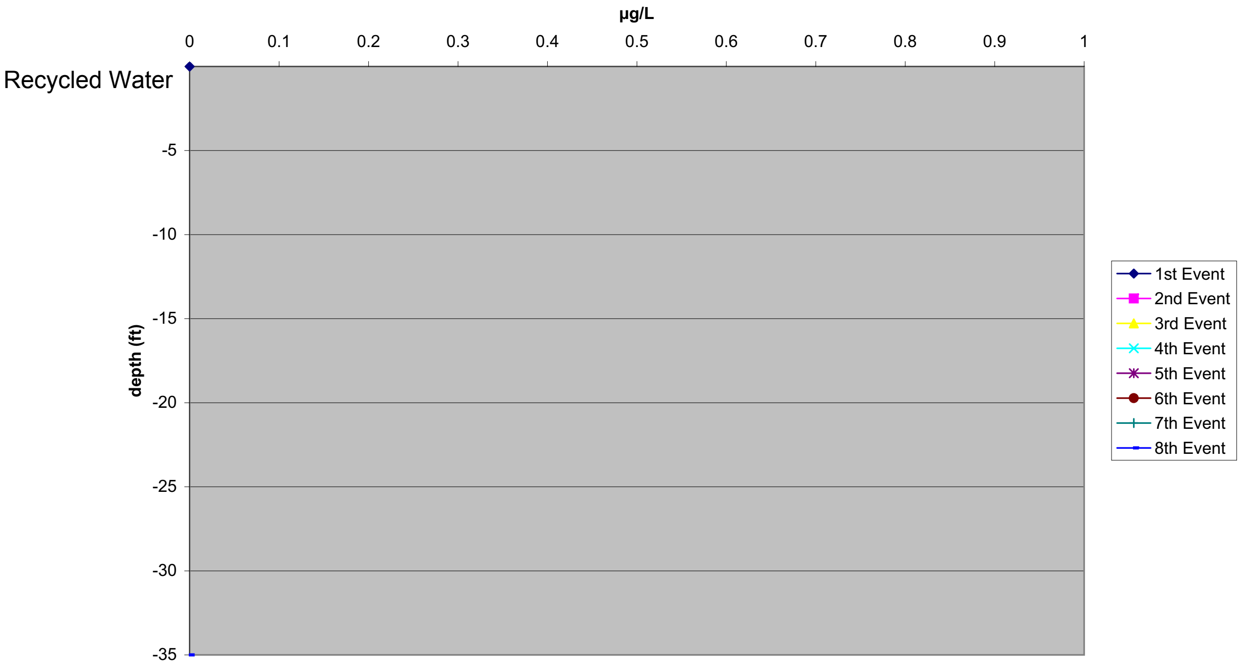
Note: non-detects are treated in the figure as zero.

Figure III-4-44A Perchlorate



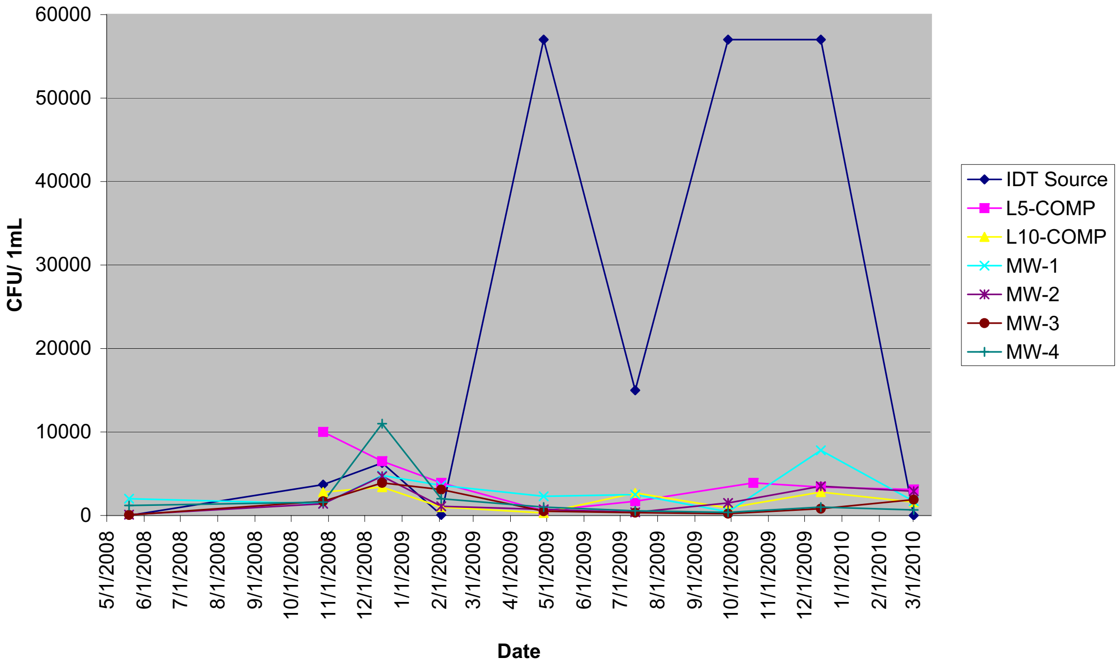
Note: non-detects are treated in the figure as zero.

Figure III-4-44B Perchlorate



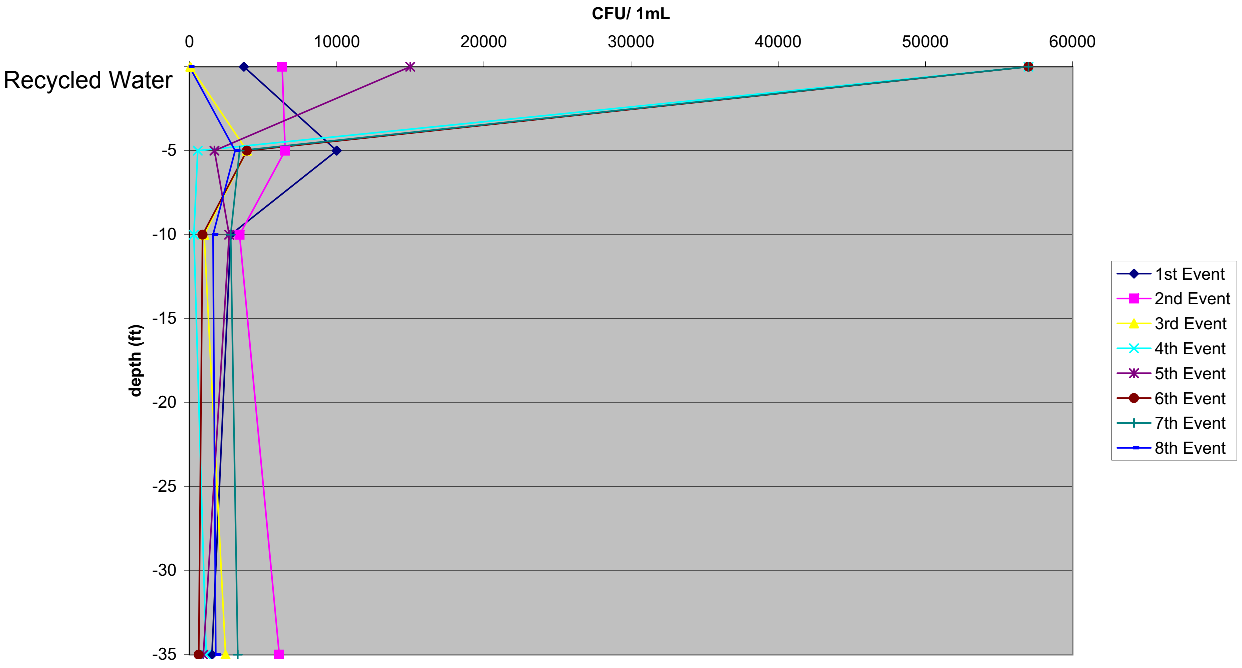
Note: non-detects are treated in the figure as zero.

Figure III-4-45A Heterotrophic Plate Count



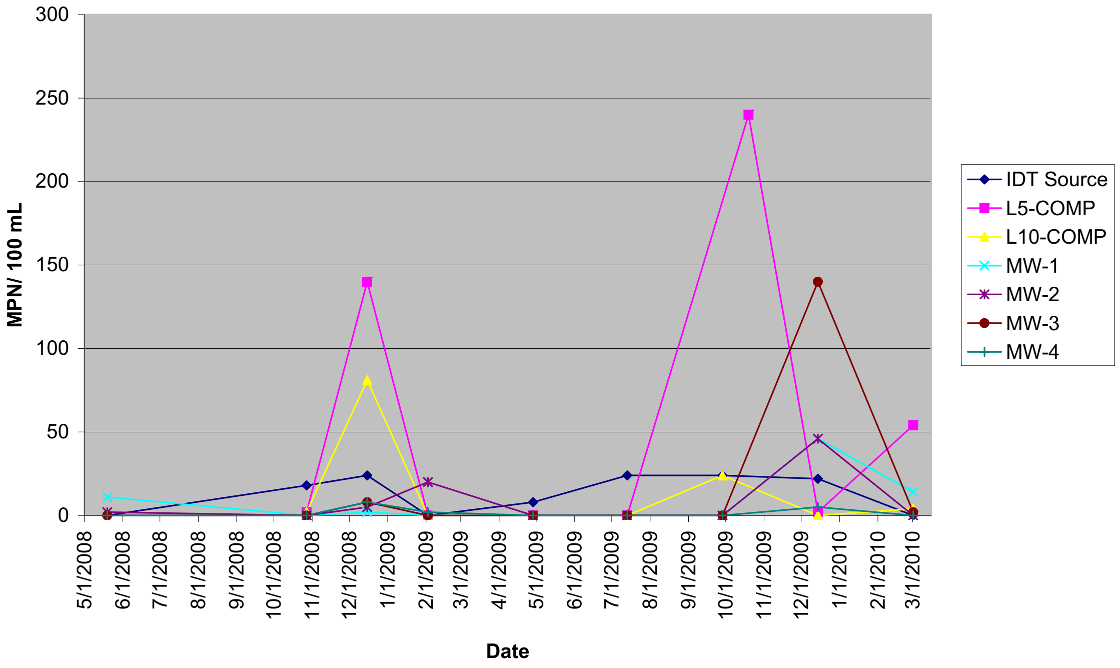
Note: non-detects are treated in the figure as zero.

Figure III-4-45B Heterotrophic Plate Count



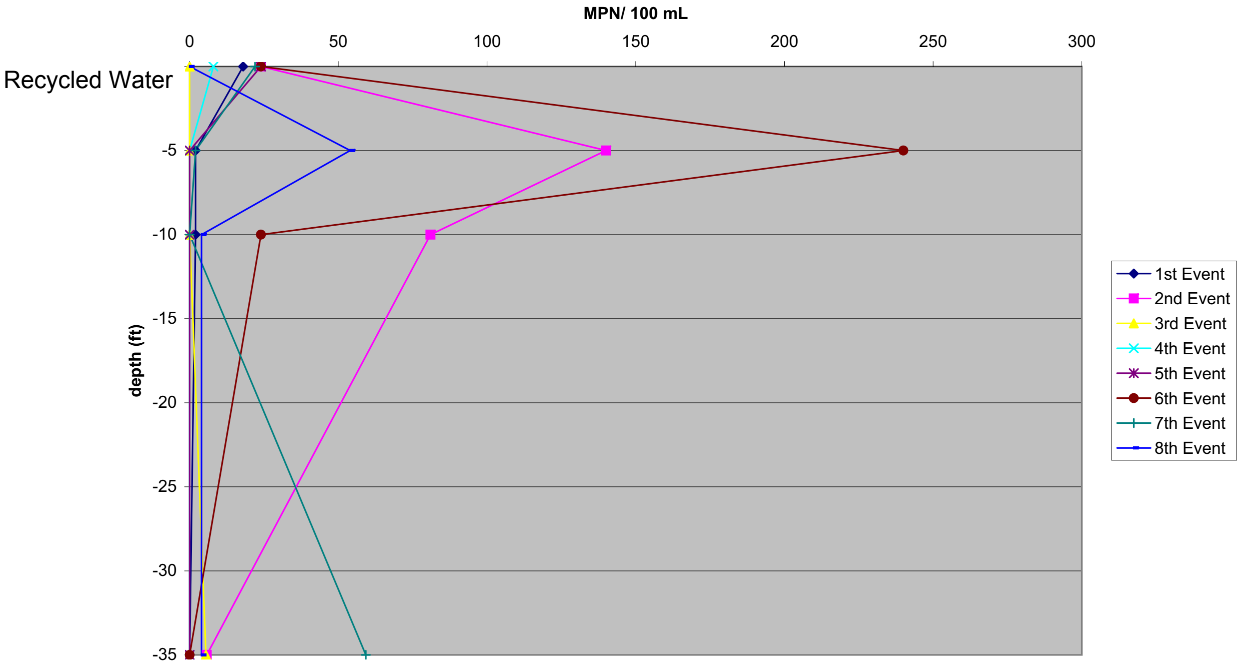
Note: non-detects are treated in the figure as zero.

Figure III-4-46A Coliforms, Total



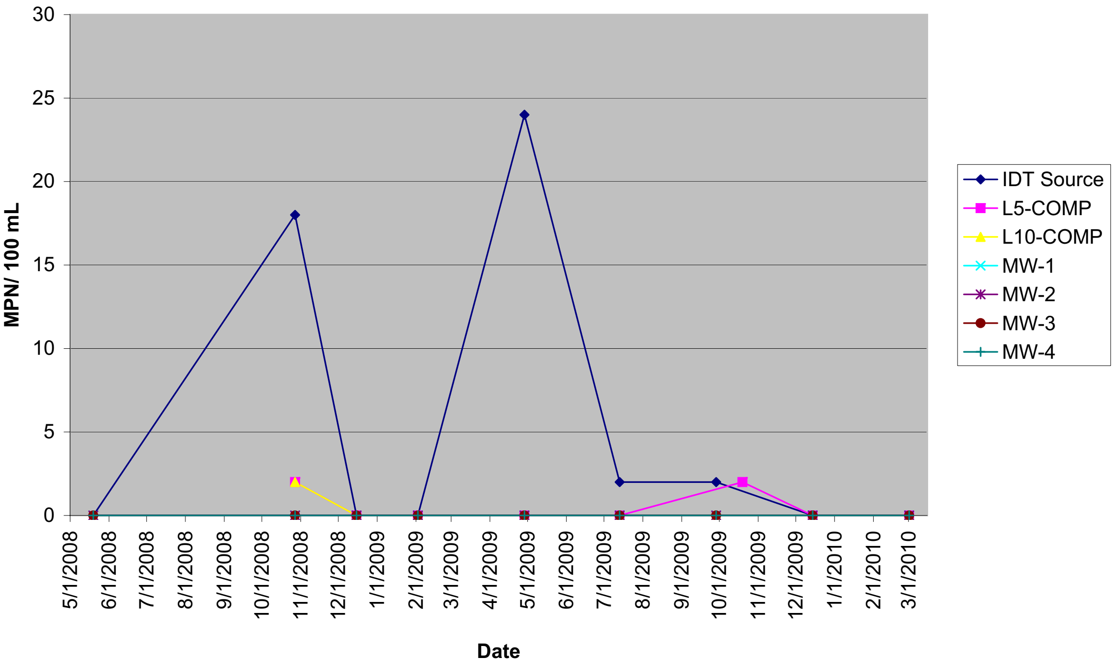
Note: non-detects are treated in the figure as zero.

Figure III-4-46B Coliforms, Total



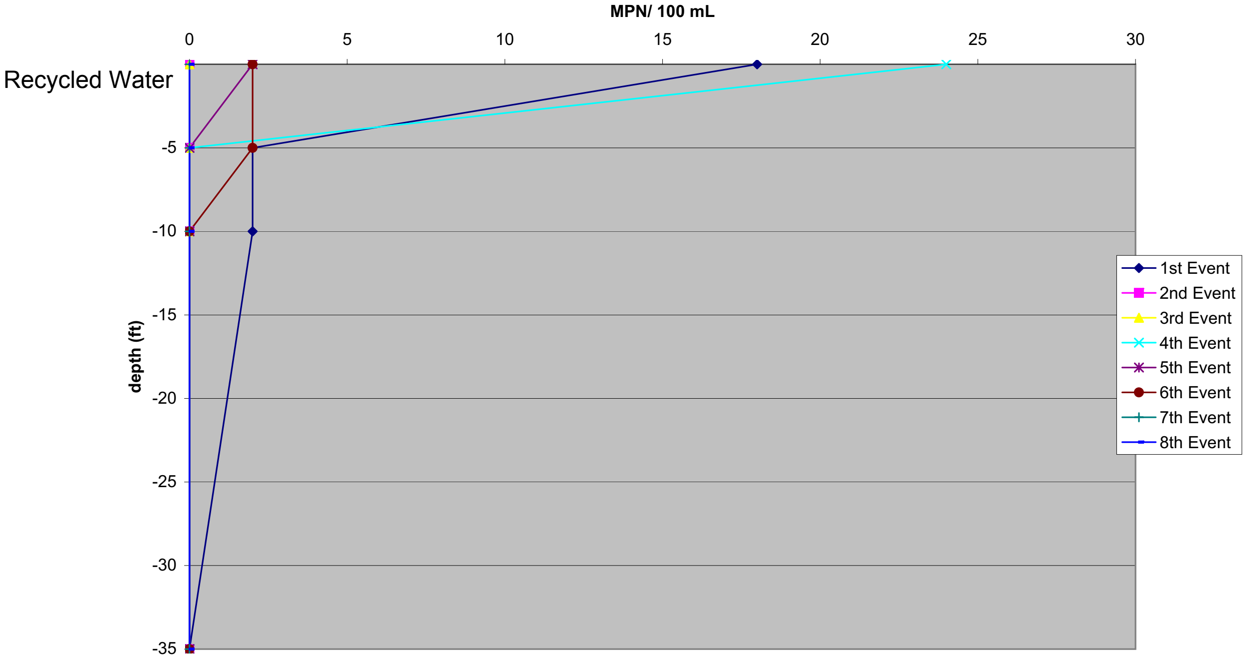
Note: non-detects are treated in the figure as zero.

Figure III-4-47A Fecal Coliforms



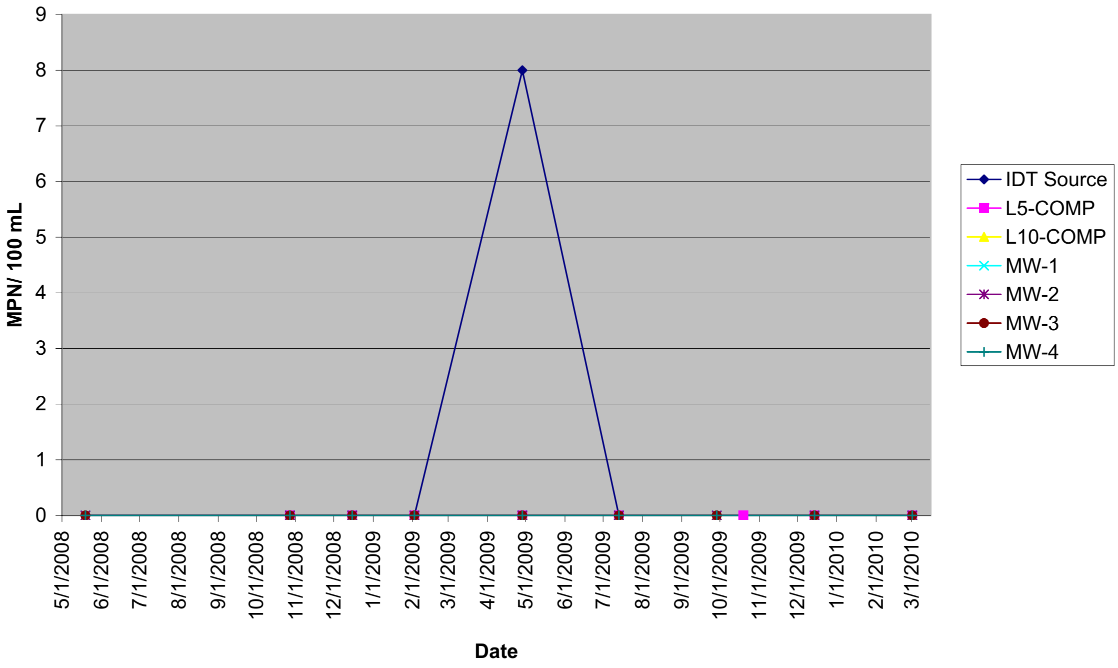
Note: non-detects are treated in the figure as zero.

Figure III-4-47B Fecal Coliforms



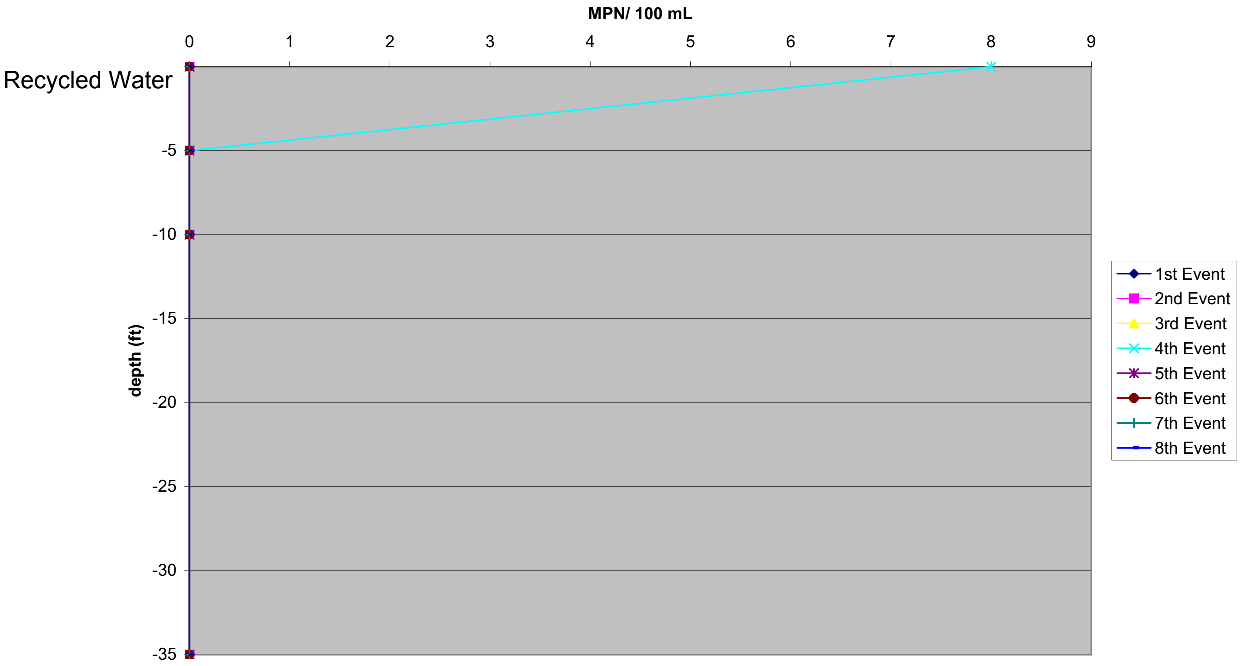
Note: non-detects are treated in the figure as zero.

Figure III-4-48A E. Coli



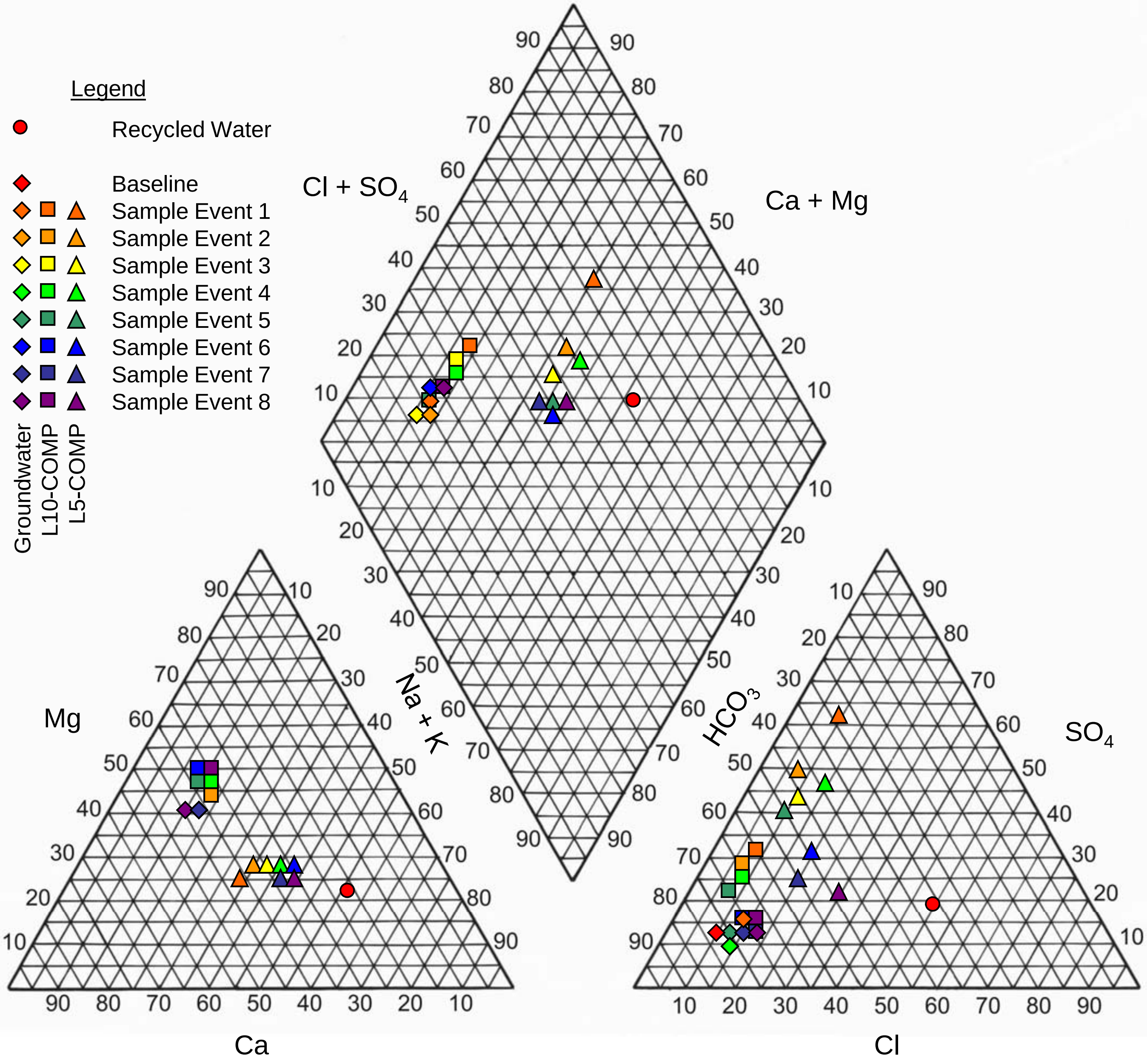
Note: non-detects are treated in the figure as zero.

Figure III-4-48B E. Coli



Note: non-detects are treated in the figure as zero.

Figure III-4-49 Piper Diagram Analysis



TABLES

TABLE III-3-1
CONSTITUENTS OF CONCERN
PILOT STUDY
RECYCLED WATER STUDY

Priority	Constituent	Method	Lab
1	ORP	multi-meter	field
2	pH	multi-meter	field
3	Chlorine, Total	Hach kit	field
4	Dissolved Oxygen	multi-meter	field
5	Alkalinity, Total	SM2320B	C&T
6	Bicarbonate Alkalinity	SM2320B	C&T
7	Boron	EPA 6010	C&T
8	Calcium	EPA 6010	C&T
9	Magnesium	EPA 6010	C&T
10	Sodium	EPA 6010	C&T
11	Potassium	EPA 6010	C&T
12	Sulfate	EPA 300.0	C&T
13	Nitrite	EPA 300.0	C&T
14	Nitrate	EPA 300.0	C&T
15	Chloride	EPA 300.0	C&T
16	Total Organic Carbon (TOC)	SM5310C	C&T
17	Total Filterable Residue at 180C (TDS)	SM2540C	C&T
18	Dissolved Organic Carbon	SM5310C	C&T
19	Bromodichloromethane	EPA 8260	C&T
20	Bromoform	EPA 8260	C&T
21	Chloroform	EPA 8260	C&T
22	Carbon Tetrachloride	EPA 8260	C&T
23	Dibromochloromethane	EPA 8260	C&T
24	Xylenes, Total	EPA 8260	C&T
25	Additional 8010-list VOCs	EPA 8260	C&T
26	Bromochloroacetic Acid	EPA 552.2	Subcontracted by C&T
27	Dibromoacetic Acid	EPA 552.2	Subcontracted by C&T
28	Dichloroacetic Acid	EPA 552.2	Subcontracted by C&T
29	Monobromoacetic Acid	EPA 552.2	Subcontracted by C&T
30	Monochloroacetic Acid	EPA 552.2	Subcontracted by C&T
31	Trichloroacetic Acid	EPA 552.2	Subcontracted by C&T
32	Heterotrophic Plate Count	SM 9215 B	EMLab P&K
33	Coliforms, Total	SM 9221 B	EMLab P&K
34	Fecal Coliforms	SM 9221 E	EMLab P&K
35	N-Nitroso Dimethylamine (NDMA)	EPA 1625	MWH
36	Perfluorochemicals	MWH LC/MS/MS	MWH
37	Phosphate	SM 4500P-E	C&T
38	Ethylenediaminetetraacetic acid (EDTA)	EPA 300 (mod)	subcontracted by MWH
39	Surfactants (MBAS)	SM 5540C	C&T
40	Bromide	EPA 300.0	Accutest / SCVWD
41	Nitrilotriacetic acid (NTA)	EPA 300 (mod)	subcontracted by MWH
42	E. Coli	SM 9221 F	EMLab P&K
43	Perchlorate	EPA 314.0	C&T
44	Cyanide	SM 4500CN E	C&T
45	Terbuthylazine	EPA 525 plus	MWH

Labs:
C&T - Curtis and Tompkins - 2323 Fifth Street, Berkeley, CA 94710
MWH - Montgomery Watson Harza Laboratories - 750 Royal Oaks Dr., Monrovia, CA 91016
EMLab P&K - EMLab P&K Laboratories - 1150 Bayhil Dr., Suite 100, San Bruno, CA 94066
Accutest - Accutest Laboratories - 3334 Victor Ct., Santa Clara, CA 95054
SCVWD - Santa Clara Valley Water District Laboratory Services Unit - 1026 Blossom Hill Rd., San Jose, CA 95123

TABLE III-3-2
SUMMARY OF PILOT STUDY EVENTS
PILOT STUDY
RECYCLED WATER STUDY

Task	Dates
Baseline Sampling Event	5/19/2008
Lysimeter Purge and Vacuum Recharge	8/15/2008
Recycled Water Irrigation Implementation	9/4/2008
Lysimeter Purge and Vacuum Recharge	9/16/2008
Lysimeter Vacuum Recharges	9/26/2008, 10/3/2008, 10/10/2008, 10/17/2008
Sampling Event 1	10/27/2008
Lysimeter Vacuum Recharges	10/27/2008, 11/7/2008, 11/14/2008
Sampling Event 1 (interim)	11/24/2008
Lysimeter Vacuum Recharges	11/24/2008, 12/5/2008
Sampling Event 2	12/15/2008
Lysimeter Vacuum Recharges	12/15/2008, 12/19/2008, 12/26/2008, 1/2/2009
Sampling Event 2 (interim)	1/5/2009
Lysimeter Vacuum Recharges	1/5/2009, 1/9/2009, 1/16/2009, 1/25/2009
Sampling Event 3	2/2/2009
Lysimeter Vacuum Recharges	2/2/2009, 2/13/2009, 2/20/2009, 2/27/2009
Sampling Event 3 (interim)	3/2/2009
Lysimeter Vacuum Recharges	3/2/2009, 3/6/2009, 3/13/2009, 3/20/2009, 3/27/2009, 4/10/2009, 4/24/2009
Sampling Event 4	4/28/2009
Lysimeter Vacuum Recharges	4/28/2009, 5/8/2009
Sampling Event 4 (interim)	5/18/2009
Lysimeter Vacuum Recharges	5/18/2009, 5/29/2009, 6/12/2009, 6/26/2009
Sampling Event 5	7/13/2009
Lysimeter Vacuum Recharges	7/13/2009, 7/27/2009
Sampling Event 5 (interim)	8/3/2009
Lysimeter Vacuum Recharges	8/3/2009, 8/7/2009, 8/21/2009, 9/4/2009
Sampling Event 6	9/28/2009
Lysimeter Vacuum Recharges	9/28/2009, 10/9/2009, 10/16/2009
Sampling Event 6 (interim)	10/19/2009
Lysimeter Vacuum Recharges	10/19/2009, 10/30/2009, 11/9/2009, 11/16/2009, 11/23/2009, 11/30/2009
Sampling Event 7	12/14/2009
Lysimeter Vacuum Recharges	12/14/2009, 12/21/2009
Sampling Event 7 (interim)	1/5/2010
Lysimeter Vacuum Recharges	1/5/2010, 1/25/2010, 2/8/2010, 2/22/2010
Sampling Event 8	3/1/2010
Lysimeter Vacuum Recharge	3/1/2010
Sampling Event 8 (interim)	3/15/2010

TABLE III-4-1
ANALYTICAL DATA
PILOT STUDY
RECYCLED WATER STUDY

	Location	IDT Source								
	Event	8th	7th	6th	5th	4th	3rd	2nd	1st	Baseline (5/19/2008)
Constituent	**Units**									
General Water Quality										
pH	pH unit	7.34	7.41	7.94	7.07	6.8	6.81	7.65	6.75	7.4
Alkalinity, Total (as CaCO3)	mg/L	210	170	170	170	200	180	170	170	190
Bicarbonate Alkalinity (as CaCO3)	mg/L	210	170	170	170	200	180	170	170	189
Total Filterable Residue at 180C (TDS)	mg/L	740	720	760	740	800	780	700	880	690
Total Organic Carbon (TOC)	mg/L	6.2	5.5	6.4	6.7	8	5.4	5.9	6.7	6.9
Dissolved Organic Carbon	mg/L	4.8	5.1	5.8	6.8	7.2	5.4	6.2	7.1	6.8
ORP	mV	149	174	124	84	78	111	126	128	417
Dissolved Oxygen	mg/L	7.19	1.76	6.26	5.02	5.69	8.1	6.28	1.6	0.04
Chlorine, Total	mg/L	0.07	1.26	0.12	0.13	0.14	0.04	0.1	0.3	8.8
Anions and Cations										
Chloride	mg/L	190	200	220	200	210	220	200	280	190
Sulfate	mg/L	100	94	99	94	100	95	89	110	94
Bromide	mg/L	0.28	0.32	0.25	0.25	0.27	0.38	0.18	0.38	ND 0.5
Cyanide	mg/L	0.02	0.01	ND 0.01	ND 0.01	0.02	ND 0.01	ND 0.01	0.02	ND 0.005
Boron	µg/L	390	380	480	420	480	480	440	460	480
Potassium	mg/L	12	13	17	13	15	16	13	19	16
Calcium	mg/L	52	46	54	44	60	56	51	64	54
Magnesium	mg/L	29	25	31	25	35	31	26	39	30
Sodium	mg/L	120	140	170	140	130	160	130	210	130
Nutrients										
Phosphate, Total as P	mg/L	0.21	0.22	0.6	0.53	0.62	0.36	0.26	0.28	NA
Nitrate as N	mg/L	7.7	10	10	12	15	9.1	10	12	9.6
Nitrite as N	mg/L	0.65	0.09	ND 0.5	0.13	0.23	0.06	0.14	0.85	ND 0.15
Anthropogenic Compounds										
Bromodichloromethane	µg/L	8.6	14	27	15	10	7.8	8.4	8.5	15
Bromoform	µg/L	0.8	2	2.9	1	0.6	1.4	1.2	1.5	1.3
Chloroform	µg/L	8.8	17	23	16	13	7	8.6	7.8	12
Dibromochloromethane	µg/L	4.2	7.2	14	6.3	3.9	5.2	4.6	5.3	7.1
Carbon Tetrachloride	µg/L	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5
Xylenes (m,p-xylenes)	µg/L	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 1
Xylenes (o-xylenes)	µg/L	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5
Additional 8010/8020-list VOCs *	µg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bromochloroacetic Acid	µg/L	ND 0.99	0.22 J	0.92 J	2	1.4	ND 1	ND 1	3.4	9.6
Dibromoacetic Acid	µg/L	0.37 J,P	ND 0.99	0.33 J	ND 1	ND 1	ND 1	ND 1	1.5	3.4
Dichloroacetic Acid	µg/L	0.57 J,P	0.64 J,P	1.8	3.9	3.7	ND 1	1.4	5.5	14
Monobromoacetic Acid	µg/L	ND 0.99	ND 0.99	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1
Monochloroacetic Acid	µg/L	ND 2	ND 2	4.2	ND 2	ND 2	ND 2	ND 2	ND 2	ND 2
Trichloroacetic Acid	µg/L	ND 0.99	ND 0.99	3.8	6.8	5.1	ND 1	ND 1	3.3	9.7
N-Nitroso Dimethylamine (NDMA)	ng/L	320	390	240	350 D	420	460	380 BB,BD,L3	401	112
Terbuthylazine	µg/L	ND 0.1	ND 0.1	ND 0.1	ND 0.1	ND 0.1	ND 0.1	ND 0.1	0.1	ND 0.1
Perfluorochemicals (PFBA)	ng/L	12	ND 20	ND 40	ND 20	ND 20	ND 20	ND 20	ND 20	ND 50
Perfluorochemicals (PFOS)	ng/L	51	39	87	46 D	34	78	67 D	38	ND 50
Perfluorochemicals (PFOA)	ng/L	70	61	100	41	51	43	65 D	79	ND 20
Nitrilotriacetic acid (NTA)	µg/L	NA	NA	NA	NA	NA	NA	NA	ND 100	ND 100
Ethylenediaminetetraacetic acid (EDTA)	µg/L	ND 100	ND 100	ND 100	ND 100	ND 100	ND 100	ND 100	ND 100	ND 100
Surfactants (MBAS)	mg/L	ND 0.2	ND 0.2	ND 0.2	ND 0.2	ND 0.2	ND 0.2	ND 0.2	ND 0.2	0.21
Perchlorate	µg/L	NA	NA	NA	NA	NA	NA	NA	ND 4	ND 4
Biological Indicators										
Heterotrophic Plate Count	CFU/ 1mL	<1 D	>57000	>57000	15000	>57000	64	6300	3700	2
Coliforms, Total	MPN/ 100 mL	ND 2	22	24	24	8	ND 2	24	18	ND 2
Fecal Coliforms	MPN/ 100 mL	ND 2	ND 2	2	2	24	ND 2	ND 2	18	ND 2
E. Coli	MPN/ 100 mL	ND 2	ND 2	ND 2	ND 2	8	ND 2	ND 2	ND 2	ND 2

Notes
* Detections of VOCs include TCE, cis-1,2-DCE and Freon 113
See Table III-4-2 for Legend of Qualifiers.

TABLE III-4-1
ANALYTICAL DATA
PILOT STUDY
RECYCLED WATER STUDY

	Location	L5-COMP							
	Event	8th	7th	6th	5th	4th	3rd	2nd	1st
Constituent	**Units**								
General Water Quality									
pH	pH unit	7.76	7.73	7.28	7.24	6.93	7.24	7.66	6.43
Alkalinity, Total (as CaCO3)	mg/L	600	590	670	720	710	640	590	470
Bicarbonate Alkalinity (as CaCO3)	mg/L	600	590	670	720	640	640	590	470
Total Filterable Residue at 180C (TDS)	mg/L	1470	1240	1380	1690	2000	1610	1750	2180
Total Organic Carbon (TOC)	mg/L	11	5.8	7	7.8	8.7	6.5	7.3	73
Dissolved Organic Carbon	mg/L	8.2	6.8	5.9 B	7.8	7.8	6.2	11	78
ORP	mV	124	182	103	90	60	121	148	25
Dissolved Oxygen	mg/L	9.27	10.28	6.98	6.48	7.36	11.3	10.1	5.84
Chlorine, Total	mg/L	0.25	0.11	0.12	0.19	0.07	0.09	0.42	0.13
Anions and Cations									
Chloride	mg/L	270	150	160	120	130	92	86	87
Sulfate	mg/L	270	260	370	540	740	550	660	980
Bromide	mg/L	0.27	0.34	NA	0.21	0.26	0.16	0.25	0.43
Cyanide	mg/L	NA	NA	NA	NA	NA	NA	NA	NA
Boron	µg/L	250	260	270	320	400	300	340	270
Potassium	mg/L	5.4	3.2	2.5	5	7.5	3.7	5.4	9.3
Calcium	mg/L	140	120	160	180	210	180	180	270
Magnesium	mg/L	66	53	82	77	99	90	81	100
Sodium	mg/L	210	140	260	250	290	230	200	260
Nutrients									
Phosphate, Total as P	mg/L	0.059	0.05	0.21	0.053	0.042	0.047	0.045	0.031
Nitrate as N	mg/L	1.8	0.98	1.7	1.7	2.3	0.23	ND 0.10	ND 0.25
Nitrite as N	mg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	ND 0.10	ND 0.10	ND 0.10	ND 0.05
Anthropogenic Compounds									
Bromodichloromethane	µg/L	ND 0.5	ND 0.5	0.7	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 42
Bromoform	µg/L	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 42
Chloroform	µg/L	ND 0.5	ND 0.5	1.1	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 42
Dibromochloromethane	µg/L	ND 0.5	ND 0.5	0.8	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 42
Carbon Tetrachloride	µg/L	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 42
Xylenes (m,p-xylenes)	µg/L	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 42
Xylenes (o-xylenes)	µg/L	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 42
Additional 8010/8020-list VOCs *	µg/L	ND	ND	ND	ND	ND	ND	ND	ND
Bromochloroacetic Acid	µg/L	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1
Dibromoacetic Acid	µg/L	ND 1	ND 1	0.17 J	ND 1	ND 1	ND 1	ND 1	ND 1
Dichloroacetic Acid	µg/L	ND 1	0.26 J	0.19 J	ND 1	ND 1	ND 1	ND 1	ND 1
Monobromoacetic Acid	µg/L	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1
Monochloroacetic Acid	µg/L	1.3 J,P	1.5 J	ND 2	ND 2	ND 2	ND 2	ND 2	ND 2
Trichloroacetic Acid	µg/L	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1
N-Nitroso Dimethylamine (NDMA)	ng/L	ND 2	ND 2	ND 2	ND 2	ND 2	ND 2	5	10
Terbuthylazine	µg/L	NA	NA	NA	NA	NA	NA	NA	NA
Perfluorochemicals (PFBA)	ng/L	ND 10	ND 20	ND 20	24	47	ND 20	43	71
Perfluorochemicals (PFOS)	ng/L	ND 5	9	ND 5	ND 5	ND 5	ND 5	ND 5	ND 5
Perfluorochemicals (PFOA)	ng/L	ND 5	ND 5	ND 5	17	16	ND 5	6.4	15
Nitrilotriacetic acid (NTA)	µg/L	NA	NA	NA	NA	NA	NA	NA	NA
Ethylenediaminetetraacetic acid (EDTA)	µg/L	NA	NA	NA	NA	NA	NA	ND 100	NA
Surfactants (MBAS)	mg/L	NA	NA	NA	NA	NA	NA	ND 0.2	ND 0.2
Perchlorate	µg/L	NA	NA	NA	NA	NA	NA	NA	NA
Biological Indicators									
Heterotrophic Plate Count	CFU/ 1mL	3100	3400	3900	1700	560	3900	6500	10000
Coliforms, Total	MPN/ 100 mL	54	2	240	ND 2	ND 2	ND 2	140	2
Fecal Coliforms	MPN/ 100 mL	ND 2	ND 2	2	ND 2	ND 2	ND 2	ND 2	2
E. Coli	MPN/ 100 mL	ND 2	ND 2	ND 2	ND 2	ND 2	ND 2	ND 2	ND 2

Notes
* Detections of VOCs include TCE, cis-1,2-DCE and Freon 11
See Table III-4-2 for Legend of Qualifiers.

TABLE III-4-1
ANALYTICAL DATA
PILOT STUDY
RECYCLED WATER STUDY

	Location	L10-COMP							
	Event	8th	7th	6th	5th	4th	3rd	2nd	1st
Constituent	**Units**								
General Water Quality									
pH	pH unit	7.1	7.23	7.4	7.55	7.21	6.84	7.84	6.55
Alkalinity, Total (as CaCO3)	mg/L	680	700	670	730	720	670	710	660
Bicarbonate Alkalinity (as CaCO3)	mg/L	680	700	670	730	660	670	710	660
Total Filterable Residue at 180C (TDS)	mg/L	1060	1060	1010	1080	1070	1150	1160	1280
Total Organic Carbon (TOC)	mg/L	4.6	3.5	2.9	3.1	3.1	3.2	4.8	6.6
Dissolved Organic Carbon	mg/L	3.6	3.3	2.9	5.1	2.7	3.1	5	6.4
ORP	mV	137	179	96	100	75	120	101	69
Dissolved Oxygen	mg/L	8.44	8.88	6.22	8.08	8.36	9.89	8.37	6.21
Chlorine, Total	mg/L	0.16	1.05	0.08	0.14	0.12	0.04	0.21	0.06
Anions and Cations									
Chloride	mg/L	130	120	96	81	81	71	72	77
Sulfate	mg/L	130	140	150	170	220	240	270	320
Bromide	mg/L	0.26	0.3	0.25	0.23	0.24	0.22	0.17	0.15 J
Cyanide	mg/L	NA	NA	NA	NA	NA	NA	NA	NA
Boron	µg/L	240	280	300	230	290	270	300	330
Potassium	mg/L	1.1	1.3	1.2	1.2	1.5	1.4	2.3	3.6
Calcium	mg/L	120	130	160	130	150	150	150	170
Magnesium	mg/L	98	110	130	100	120	110	110	130
Sodium	mg/L	66	63	82	70	75	70	78	87
Nutrients									
Phosphate, Total as P	mg/L	0.048	0.04	0.062	0.042	ND 0.03	0.036	0.042	0.047
Nitrate as N	mg/L	3.1	3.2	3.4	2.4	2.1	1.9	1.7	1.8
Nitrite as N	mg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	ND 0.05	ND 0.10	ND 0.05	ND 0.05
Anthropogenic Compounds									
Bromodichloromethane	µg/L	ND 0.5	ND 0.5	0.7	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5
Bromoform	µg/L	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5
Chloroform	µg/L	ND 0.5	ND 0.5	1.7	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5
Dibromochloromethane	µg/L	ND 0.5	ND 0.5	0.7	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5
Carbon Tetrachloride	µg/L	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5
Xylenes (m,p-xylenes)	µg/L	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5
Xylenes (o-xylenes)	µg/L	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5
Additional 8010/8020-list VOCs *	µg/L	ND	ND	ND	ND	ND	ND	ND	ND
Bromochloroacetic Acid	µg/L	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1
Dibromoacetic Acid	µg/L	ND 1	ND 1	0.51 J	ND 1	ND 1	ND 1	ND 1	ND 1
Dichloroacetic Acid	µg/L	ND 1	0.42 J,P	0.40 J	ND 1	ND 1	ND 1	ND 1	ND 1
Monobromoacetic Acid	µg/L	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1
Monochloroacetic Acid	µg/L	0.60 J	0.65 J	ND 2	ND 2	ND 2	ND 2	ND 2	ND 2
Trichloroacetic Acid	µg/L	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1
N-Nitroso Dimethylamine (NDMA)	ng/L	ND 2	ND 2 S7	3.3	5	2	15	8.5	23
Terbuthylazine	µg/L	NA	NA	NA	NA	NA	NA	NA	NA
Perfluorochemicals (PFBA)	ng/L	ND 10	ND 20	ND 20	ND 20	ND 20	ND 20	ND 20	28
Perfluorochemicals (PFOS)	ng/L	ND 5	ND 5	6	ND 5	ND 5	ND 5	ND 5	ND 5
Perfluorochemicals (PFOA)	ng/L	ND 5	ND 5	ND 5	6.9	ND 5	ND 5	ND 5	13
Nitrilotriacetic acid (NTA)	µg/L	NA	NA	NA	NA	NA	NA	NA	NA
Ethylenediaminetetraacetic acid (EDTA)	µg/L	NA	NA	NA	NA	NA	NA	ND 100	ND 100
Surfactants (MBAS)	mg/L	NA	NA	NA	NA	NA	NA	ND 0.2	ND 0.2
Perchlorate	µg/L	NA	NA	NA	NA	NA	NA	NA	NA
Biological Indicators									
Heterotrophic Plate Count	CFU/ 1mL	1600	2800	890	2700	300	1000	3400	2800
Coliforms, Total	MPN/ 100 mL	4	ND 2	24	ND 2	ND 2	ND 2	81	2
Fecal Coliforms	MPN/ 100 mL	ND 2	ND 2	ND 2	ND 2	ND 2	ND 2	ND 2	2
E. Coli	MPN/ 100 mL	ND 2	ND 2	ND 2	ND 2	ND 2	ND 2	ND 2	ND 2

Notes
* Detections of VOCs include TCE, cis-1,2-DCE and Freon 11
See Table III-4-2 for Legend of Qualifiers.

TABLE III-4-1
ANALYTICAL DATA
PILOT STUDY
RECYCLED WATER STUDY

	Location	MW-1											
	Event	8th	7th	6th	5th	4th	3rd	2nd	1st	Baseline (5/19/2008)	Baseline (12/20/2007)	Baseline (8/16/2007)	Baseline (5/17/2007)
Constituent	**Units**												
General Water Quality													
pH	pH unit	6.65	6.61	6.41	6.46	6.48	6.88	6.8	6.75	6.24	6.6	6.7	6.7
Alkalinity, Total (as CaCO3)	mg/L	330	300	310	360	376	270	300	320	420	331	383	460
Bicarbonate Alkalinity (as CaCO3)	mg/L	330	300	310	360	370	270	300	320	426	331	383	460
Total Filterable Residue at 180C (TDS)	mg/L	570	520	530	580	550	440	490	550	580	552	738	678
Total Organic Carbon (TOC)	mg/L	0.66	0.73	0.54	0.58	ND 0.5	ND 0.5	0.69	0.82	0.5	0.7	0.91	0.81
Dissolved Organic Carbon	mg/L	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	0.57	1.5	1.4	1.6
ORP	mV	177	182	190	112	915	126	130	127	174	NA	NA	NA
Dissolved Oxygen	mg/L	1.24	1.47	1.64	1.94	2.14	1.99	1.39	1.47	0.01	NA	NA	NA
Chlorine, Total	mg/L	0.27	0.36	0.43	2.04	2.02	2.12	2.1	2.17	NA	NA	NA	NA
Anions and Cations													
Chloride	mg/L	60	57	59	60	60	49	49	54	61	50	72	55
Sulfate	mg/L	68	63	72	76	80	55	60	71	89	84.4	129	113
Bromide	mg/L	0.22	0.24	0.2	0.22	0.23	0.17	0.14	ND 0.065	ND 0.5	0.23	0.32	0.32
Cyanide	mg/L	NA	NA	NA	NA	NA	NA	NA	NA	ND 0.005	NA	NA	NA
Boron	µg/L	170	170	200	190	200	160	180	200	180	189	197	185
Potassium	mg/L	1.1	0.66	0.61	0.77	0.98	0.6	0.95	0.73	2.3	0.8	1.1	1
Calcium	mg/L	77	65	85	83	90	64	68	86	100	83.3	122	101
Magnesium	mg/L	44	41	54	52	58	40	43	54	66	53	73.1	65.3
Sodium	mg/L	34	31	43	41	44	35	35	44	43	35.7	47.8	43.9
Nutrients													
Phosphate, Total as P	mg/L	0.42	0.86	0.04	0.11	0.11	0.073	0.06	0.034	NA	NA	NA	NA
Nitrate as N	mg/L	3.1	2.7	3.4	3.7	4	2.2	2.7	3.7	5.7	5.6	10	8.5
Nitrite as N	mg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	ND 0.05	ND 0.05	0.15	ND 0.05	ND 0.15	ND 0.4	ND 0.4	ND 0.4
Anthropogenic Compounds													
Bromodichloromethane	µg/L	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5
Bromoform	µg/L	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5
Chloroform	µg/L	ND 0.5	ND 0.5	ND 1.0	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5
Dibromochloromethane	µg/L	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5
Carbon Tetrachloride	µg/L	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5
Xylenes (m,p-xylenes)	µg/L	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 1	NA	NA	NA
Xylenes (o-xylenes)	µg/L	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	NA	NA	NA
Additional 8010/8020-list VOCs *	µg/L	1.9	10.5	2.4	ND	ND	ND	1.4	2.5	ND	ND	ND	ND
Bromochloroacetic Acid	µg/L	ND 1	ND 1	ND 0.99	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	NA	NA	NA
Dibromoacetic Acid	µg/L	ND 1	ND 1	ND 0.99	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1
Dichloroacetic Acid	µg/L	ND 1	ND 1	ND 0.99	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1
Monobromoacetic Acid	µg/L	ND 1	ND 1	ND 0.99	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1
Monochloroacetic Acid	µg/L	ND 2	ND 2	ND 2	ND 2	ND 2	ND 2	ND 2	ND 2	ND 2	ND 2	ND 2	ND 2
Trichloroacetic Acid	µg/L	ND 1	ND 1	ND 0.99	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1
N-Nitroso Dimethylamine (NDMA)	ng/L	4.1	2.9	ND 2	2.1	2.7	ND 2	ND 2 BD,L3	ND 2	ND 2	ND 1.9	ND 2000	ND 4800
Terbuthylazine	µg/L	NA	NA	NA	NA	NA	NA	NA	NA	ND 0.1	NA	NA	NA
Perfluorochemicals (PFBA)	ng/L	ND 10	ND 20	ND 20	ND 20	ND 20	ND 20	ND 20	ND 20	ND 50	NA	NA	NA
Perfluorochemicals (PFOS)	ng/L	ND 5	ND 5	10	ND 5	ND 5	ND 5	ND 5	ND 5	ND 50	NA	NA	NA
Perfluorochemicals (PFOA)	ng/L	ND 5	ND 5	ND 5	ND 5	ND 5	ND 5	ND 5	ND 5	ND 20	NA	NA	NA
Nitrilotriacetic acid (NTA)	µg/L	NA	NA	NA	NA	NA	NA	NA	NA	ND 100	NA	NA	NA
Ethylenediaminetetraacetic acid (EDTA)	µg/L	NA	NA	NA	NA	NA	NA	ND 100	ND 100	ND 100	NA	NA	NA
Surfactants (MBAS)	mg/L	NA	NA	NA	NA	NA	NA	ND 0.2	ND 0.2	ND 0.1	NA	NA	NA
Perchlorate	µg/L	NA	NA	NA	NA	NA	NA	NA	NA	4.3	NA	NA	NA
Biological Indicators													
Heterotrophic Plate Count	CFU/ 1mL	1700	7800	430	2500	2300	3600	4800	1400	2000	NA	NA	NA
Coliforms, Total	MPN/ 100 mL	14	46	ND 2	ND 2	ND 2	ND 2	2	ND 2	11	NA	NA	NA
Fecal Coliforms	MPN/ 100 mL	ND 2	ND 2	ND 2	ND 2	ND 2	ND 2	ND 2	ND 2	ND 2	NA	NA	NA
E. Coli	MPN/ 100 mL	ND 2	ND 2	ND 2	ND 2	ND 2	ND 2	ND 2	ND 2	ND 2	NA	NA	NA

Notes
* Detections of VOCs include TCE, cis-1,2-DCE and Freon 11
See Table III-4-2 for Legend of Qualifiers.

TABLE III-4-1
ANALYTICAL DATA
PILOT STUDY
RECYCLED WATER STUDY

	Location	MW-2											
	Event	8th	7th	6th	5th	4th	3rd	2nd	1st	Baseline (5/19/2008)	Baseline (12/20/2007)	Baseline (8/16/2007)	Baseline (5/16/2007)
Constituent	Units												
General Water Quality													
pH	pH unit	6.88	6.9	6.72	6.79	6.71	6.8	6.84	6.8	6.51	6.7	6.9	6.9
Alkalinity, Total (as CaCO3)	mg/L	300	280	240	300	340	300	410	300	320	299	308	334
Bicarbonate Alkalinity (as CaCO3)	mg/L	300	280	240	300	340	300	410	300	320	299	308	334
Total Filterable Residue at 180C (TDS)	mg/L	430	400	400	420	440	410	440	490	380	468	486	508
Total Organic Carbon (TOC)	mg/L	0.75	0.86	ND 0.5	ND 0.5	ND 0.5	ND 0.5	0.68	0.75	0.44	0.76	0.6	0.87
Dissolved Organic Carbon	mg/L	ND 1	ND 1	ND 1	2.1	ND 1	ND 1	ND 1	ND 1	0.44	1	1.2	1.6
ORP	mV	78	74	72	68	70	118	111	118	188	NA	NA	NA
Dissolved Oxygen	mg/L	1.71	1.92	2.4	2.1	1.2	0.87	0.7	0.74	0.05	NA	NA	NA
Chlorine, Total	mg/L	0.33	1.67	1.72	2.2	2.2	2.2	2.2	2.2	NA	NA	NA	NA
Anions and Cations													
Chloride	mg/L	36	29	26	28	36	25	34	39	26	37	38	33
Sulfate	mg/L	45	35	34	38	46	35	46	48	40	52.5	56.8	63.7
Bromide	mg/L	0.13	0.13	0.12	0.11	0.15	0.1	0.07	ND 0.065	ND 0.5	0.17	0.18	0.22
Cyanide	mg/L	NA	NA	NA	NA	NA	NA	NA	NA	ND 0.005	NA	NA	NA
Boron	µg/L	130	140	150	140	180	150	150	160	140	177	162	171
Potassium	mg/L	0.98	0.84	0.9	0.74	0.91	0.87	0.65	1.1	1.4	1	1.1	1.1
Calcium	mg/L	58	49	61	58	70	65	63	74	62	71.8	78.9	74.4
Magnesium	mg/L	35	30	36	33	44	38	35	41	36	41.2	45	44.5
Sodium	mg/L	30	23	30	31	37	30	29	34	32	33	40.1	42
Nutrients													
Phosphate, Total as P	mg/L	0.04	0.068	0.17	0.092	0.035	0.13	0.098	0.39	NA	NA	NA	NA
Nitrate as N	mg/L	2.1	2.1	3.1	2.6	3.2	2.8	3.5	3.9	3.6	5.9	7.3	9.3
Nitrite as N	mg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	ND 0.05	ND 0.05	ND 0.05	ND 0.05	ND 0.15	ND 0.4	ND 0.4	ND 0.4
Anthropogenic Compounds													
Bromodichloromethane	µg/L	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5
Bromoform	µg/L	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5
Chloroform	µg/L	ND 0.5	ND 0.5	ND 1.0	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5
Dibromochloromethane	µg/L	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5
Carbon Tetrachloride	µg/L	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5
Xylenes (m,p-xylenes)	µg/L	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 1	NA	NA	NA
Xylenes (o-xylenes)	µg/L	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	NA	NA	NA
Additional 8010/8020-list VOCs *	µg/L	ND	ND	ND	ND	ND	0.5	1.4	2.7	ND	ND	ND	ND
Bromochloroacetic Acid	µg/L	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	NA	NA	NA
Dibromoacetic Acid	µg/L	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1
Dichloroacetic Acid	µg/L	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1
Monobromoacetic Acid	µg/L	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1
Monochloroacetic Acid	µg/L	0.26 J	ND 2	ND 2	ND 2	ND 2	ND 2	ND 2	ND 2	ND 2	ND 2	ND 2	ND 2
Trichloroacetic Acid	µg/L	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1
N-Nitroso Dimethylamine (NDMA)	ng/L	4.1	3.6	ND 2 R4	ND 2	ND 2	ND 2	ND 2 BD,L3	ND 2	ND 2	ND 1.9	ND 2000	ND 4800
Terbuthylazine	µg/L	NA	NA	NA	NA	NA	NA	NA	NA	ND 0.1	NA	NA	NA
Perfluorochemicals (PFBA)	ng/L	ND 10	ND 20	ND 20	ND 20	ND 20	ND 20	ND 20	ND 20	ND 50	NA	NA	NA
Perfluorochemicals (PFOS)	ng/L	ND 5	ND 5	ND 5	ND 5	ND 5	ND 5	ND 5	ND 5	ND 50	NA	NA	NA
Perfluorochemicals (PFOA)	ng/L	ND 5	ND 5	ND 5	9.9	ND 5	ND 5	9	ND 5	ND 20	NA	NA	NA
Nitrilotriacetic acid (NTA)	µg/L	NA	NA	NA	NA	NA	NA	NA	NA	ND 100	NA	NA	NA
Ethylenediaminetetraacetic acid (EDTA)	µg/L	NA	NA	NA	NA	NA	NA	ND 100	ND 100	ND 100	NA	NA	NA
Surfactants (MBAS)	mg/L	NA	NA	NA	NA	NA	NA	ND 0.2	ND 0.2	ND 0.1	NA	NA	NA
Perchlorate	µg/L	NA	NA	NA	NA	NA	NA	NA	NA	ND 4	NA	NA	NA
Biological Indicators													
Heterotrophic Plate Count	CFU/ 1mL	2900	3500	1500	380	730	1100	4700	1400	92	NA	NA	NA
Coliforms, Total	MPN/ 100 mL	ND 2	46	ND 2	ND 2	ND 2	20	5	ND 2	2	NA	NA	NA
Fecal Coliforms	MPN/ 100 mL	ND 2	ND 2	ND 2	ND 2	ND 2	ND 2	ND 2	ND 2	ND 2	NA	NA	NA
E. Coli	MPN/ 100 mL	ND 2	ND 2	ND 2	ND 2	ND 2	ND 2	ND 2	ND 2	ND 2	NA	NA	NA

Notes
* Detections of VOCs include TCE, cis-1,2-DCE and Freon 11
See Table III-4-2 for Legend of Qualifiers.

TABLE III-4-1
ANALYTICAL DATA
PILOT STUDY
RECYCLED WATER STUDY

	Location	**MW-3**											
	Event	**8th**	**7th**	**6th**	**5th**	**4th**	**3rd**	**2nd**	**1st**	**Baseline (5/19/2008)**	**Baseline (12/20/2007)**	**Baseline (8/16/2007)**	**Baseline (5/17/2007)**
Constituent	**Units**												
General Water Quality													
pH	pH unit	6.59	6.63	6.41	6.49	6.65	6.8	6.86	6.79	6.65	7	7.2	7.1
Alkalinity, Total (as CaCO3)	mg/L	450	440	390	460	490	430	400	380	490	402	369	380
Bicarbonate Alkalinity (as CaCO3)	mg/L	450	440	390	460	490	430	400	380	492	402	369	380
Total Filterable Residue at 180C (TDS)	mg/L	720	640	580	700	760	550	560	560	610	546	562	616
Total Organic Carbon (TOC)	mg/L	0.79	ND 0.5	ND 0.5	0.55	0.61	ND 0.5	0.63	0.75	0.48	0.68	0.62	0.72
Dissolved Organic Carbon	mg/L	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	0.49	0.92	1.6	1.6
ORP	mV	117	91	98	119	119	135	143	144	178	NA	NA	NA
Dissolved Oxygen	mg/L	1.41	2.25	2.65	3.85	0.84	0.77	0.8	0.88	0.04	NA	NA	NA
Chlorine, Total	mg/L	0.56	0.71	0.24	0.31	0.29	0.21	0.26	0.28	NA	NA	NA	NA
Anions and Cations													
Chloride	mg/L	95	71	59	60	71	47	48	51	45	35	41	33
Sulfate	mg/L	70	60	62	69	76	55	54	56	65	63.1	72.2	81.7
Bromide	mg/L	0.23	0.26	0.19	0.22	0.25	0.16	0.13	ND 0.065	ND 0.5	0.15	0.19	0.22
Cyanide	mg/L	NA	NA	NA	NA	NA	NA	NA	NA	ND 0.005	NA	NA	NA
Boron	µg/L	190	180	210	190	240	190	190	200	200	210	207	229
Potassium	mg/L	0.71	ND 0.5	ND 0.5	ND 0.5	0.55	ND 0.5	0.51	ND 0.5	0.85	ND 0.5	0.5	ND 0.5
Calcium	mg/L	120	88	97	90	120	98	85	92	100	90.8	96.2	92
Magnesium	mg/L	59	53	58	53	73	60	51	62	61	55	55.7	52.9
Sodium	mg/L	45	34	41	38	47	41	36	46	42	36.4	43.3	44.5
Nutrients													
Phosphate, Total as P	mg/L	0.046	0.1	0.051	0.055	0.041	0.049	0.086	0.072	NA	NA	NA	NA
Nitrate as N	mg/L	5.4	3.4	2.5	7.9	8.2	2.9	2.2	2.1	6.3	3.4	5.2	8.3
Nitrite as N	mg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	ND 0.05	ND 0.05	ND 0.05	ND 0.05	ND 0.15	ND 0.4	ND 0.4	ND 0.4
Anthropogenic Compounds													
Bromodichloromethane	µg/L	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5
Bromoform	µg/L	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5
Chloroform	µg/L	ND 0.5	ND 0.5	ND 1.0	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5
Dibromochloromethane	µg/L	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5
Carbon Tetrachloride	µg/L	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5
Xylenes (m,p-xylenes)	µg/L	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 1	NA	NA	NA
Xylenes (o-xylenes)	µg/L	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	NA	NA	NA
Additional 8010/8020-list VOCs *	µg/L	ND	ND	ND	ND	ND	0.5	2	3.6	ND	ND	ND	ND
Bromochloroacetic Acid	µg/L	ND 1	ND 0.99	ND 0.99	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	NA	NA	NA
Dibromoacetic Acid	µg/L	ND 1	ND 0.99	ND 0.99	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1
Dichloroacetic Acid	µg/L	ND 1	ND 0.99	ND 0.99	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1
Monobromoacetic Acid	µg/L	ND 1	ND 0.99	ND 0.99	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1
Monochloroacetic Acid	µg/L	ND 2	ND 2	ND 2	ND 2	ND 2	ND 2	ND 2	ND 2	ND 2	ND 2	ND 2	ND 2
Trichloroacetic Acid	µg/L	ND 1	ND 0.99	ND 0.99	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1
N-Nitroso Dimethylamine (NDMA)	ng/L	ND 2	ND 2	ND 2	ND 2	ND 2	ND 2	ND 2 BD,L3	ND 2	ND 2	ND 1.9	ND 2000	ND 4800
Terbuthylazine	µg/L	NA	NA	NA	NA	NA	NA	NA	NA	ND 0.1	NA	NA	NA
Perfluorochemicals (PFBA)	ng/L	ND 10	ND 20	ND 20	ND 20	ND 20	ND 20	ND 20	ND 20	ND 50	NA	NA	NA
Perfluorochemicals (PFOS)	ng/L	ND 5	ND 5	ND 5	ND 5	ND 5	ND 5	ND 5	ND 5	ND 50	NA	NA	NA
Perfluorochemicals (PFOA)	ng/L	ND 5	ND 5	ND 5	9.9	ND 5	ND 5	ND 5	ND 5	ND 20	NA	NA	NA
Nitrilotriacetic acid (NTA)	µg/L	NA	NA	NA	NA	NA	NA	NA	NA	ND 100	NA	NA	NA
Ethylenediaminetetraacetic acid (EDTA)	µg/L	NA	NA	NA	NA	NA	NA	ND 100	ND 100	ND 100	NA	NA	NA
Surfactants (MBAS)	mg/L	NA	NA	NA	NA	NA	NA	ND 0.2	ND 0.2	ND 0.1	NA	NA	NA
Perchlorate	µg/L	NA	NA	NA	NA	NA	NA	NA	NA	ND 4	NA	NA	NA
Biological Indicators													
Heterotrophic Plate Count	CFU/ 1mL	1900	810	220	340	510	3100	3900	1700	65	NA	NA	NA
Coliforms, Total	MPN/ 100 mL	2	140	ND 2	ND 2	ND 2	ND 2	8	ND 2	ND 2	NA	NA	NA
Fecal Coliforms	MPN/ 100 mL	ND 2	ND 2	ND 2	ND 2	ND 2	ND 2	ND 2	ND 2	ND 2	NA	NA	NA
E. Coli	MPN/ 100 mL	ND 2	ND 2	ND 2	ND 2	ND 2	ND 2	ND 2	ND 2	ND 2	NA	NA	NA

Notes
* Detections of VOCs include TCE, cis-1,2-DCE and Freon 11
See Table III-4-2 for Legend of Qualifiers.

TABLE III-4-1
ANALYTICAL DATA
PILOT STUDY
RECYCLED WATER STUDY

Constituent	Location	MW-4											
	Event	8th	7th	6th	5th	4th	3rd	2nd	1st	Baseline (5/19/2008)	Baseline (12/20/2007)	Baseline (8/16/2007)	Baseline (5/16/2007)
	Units												
General Water Quality													
pH	pH unit	6.79	6.83	6.61	6.75	6.68	6.9	6.87	6.84	7.4	6.6	6.8	6.8
Alkalinity, Total (as CaCO3)	mg/L	360	350	390	460	490	430	410	430	510	314	323	311
Bicarbonate Alkalinity (as CaCO3)	mg/L	360	350	390	460	490	430	410	430	508	314	323	311
Total Filterable Residue at 180C (TDS)	mg/L	560	560	590	670	720	600	560	610	630	464	508	484
Total Organic Carbon (TOC)	mg/L	0.59	ND 0.5	0.6	0.56	0.64	ND 0.5	0.75	0.88	0.86	0.77	0.57	0.57
Dissolved Organic Carbon	mg/L	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	0.9	1.1	1.3	1.4
ORP	mV	144	89	98	112	110	89	89	91	192	NA	NA	NA
Dissolved Oxygen	mg/L	1.07	1.14	1.07	0.9	4.94	0.51	0.57	0.61	0.05	NA	NA	NA
Chlorine, Total	mg/L	0.28	0.3	0.24	0.27	2.07	1.07	1.14	1.22	NA	NA	NA	NA
Anions and Cations													
Chloride	mg/L	61	59	56	61	57	43	42	44	50	37	50	31
Sulfate	mg/L	61	59	68	73	71	60	62	66	69	64.3	74.2	69.9
Bromide	mg/L	0.2	0.21	0.18	0.22	0.2	0.15	0.12	ND 0.065	ND 0.5	0.15	0.17	0.17
Cyanide	mg/L	NA	NA	NA	NA	NA	NA	NA	NA	ND 0.005	NA	NA	NA
Boron	µg/L	170	150	230	200	240	200	210	230	200	193	189	169
Potassium	mg/L	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	0.51	ND 0.5	0.81	ND 0.5	ND 0.5	ND 0.5
Calcium	mg/L	81	64	110	110	110	100	91	110	110	77.6	84.7	74.8
Magnesium	mg/L	44	36	57	56	65	56	51	62	61	44.1	47.2	41.1
Sodium	mg/L	33	25	41	40	44	41	38	48	41	33.9	39.1	35.3
Nutrients													
Phosphate, Total as P	mg/L	ND 0.03	ND 0.03	0.05	ND 0.03	0.065	0.034	0.12	0.036	NA	NA	NA	NA
Nitrate as N	mg/L	1.6	1.7	2.6	3.2	3.1	2.6	2.5	3	4	3.5	5.6	3.3
Nitrite as N	mg/L	ND 0.05	ND 0.05	ND 0.05	ND 0.05	ND 0.05	ND 0.05	ND 0.05	ND 0.05	ND 0.15	ND 0.4	ND 0.4	ND 0.4
Anthropogenic Compounds													
Bromodichloromethane	µg/L	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5
Bromoform	µg/L	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5
Chloroform	µg/L	ND 0.5	ND 0.5	ND 1.0	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5
Dibromochloromethane	µg/L	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5
Carbon Tetrachloride	µg/L	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5
Xylenes (m,p-xylenes)	µg/L	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 1	NA	NA	NA
Xylenes (o-xylenes)	µg/L	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	ND 0.5	NA	NA	NA
Additional 8010/8020-list VOCs *	µg/L	ND	ND	ND	ND	ND	ND	1.4	3.5	ND	ND	ND	ND
Bromochloroacetic Acid	µg/L	ND 0.99	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	NA	NA	NA
Dibromoacetic Acid	µg/L	ND 0.99	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1
Dichloroacetic Acid	µg/L	ND 0.99	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1
Monobromoacetic Acid	µg/L	ND 0.99	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1
Monochloroacetic Acid	µg/L	ND 2	ND 2	ND 2	ND 2	ND 2	ND 2	ND 2	ND 2	ND 2	ND 2	ND 2	ND 2
Trichloroacetic Acid	µg/L	ND 0.99	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1	ND 1
N-Nitroso Dimethylamine (NDMA)	ng/L	3.4	2.8	ND 2	ND 2	2.4	ND 2	ND 2 BD,L3	ND 2	ND 2	ND 1.9	ND 2000	ND 4800
Terbuthylazine	µg/L	NA	NA	NA	NA	NA	NA	NA	NA	ND 0.1	NA	NA	NA
Perfluorochemicals (PFBA)	ng/L	ND 10	ND 20	ND 20	ND 20	ND 20	ND 20	ND 20	ND 20	ND 50	NA	NA	NA
Perfluorochemicals (PFOS)	ng/L	ND 5	ND 5	ND 5	ND 5	ND 5	ND 5	13	ND 5	ND 50	NA	NA	NA
Perfluorochemicals (PFOA)	ng/L	ND 5	ND 5	ND 5	15	ND 5	ND 5	ND 5	ND 5	ND 20	NA	NA	NA
Nitrilotriacetic acid (NTA)	µg/L	NA	NA	NA	NA	NA	NA	NA	NA	ND 100	NA	NA	NA
Ethylenediaminetetraacetic acid (EDTA)	µg/L	NA	NA	NA	NA	NA	NA	ND 100	ND 100	ND 100	NA	NA	NA
Surfactants (MBAS)	mg/L	NA	NA	NA	NA	NA	NA	ND 0.2	ND 0.2	ND 0.1	NA	NA	NA
Perchlorate	µg/L	NA	NA	NA	NA	NA	NA	NA	NA	ND 4	NA	NA	NA
Biological Indicators													
Heterotrophic Plate Count	CFU/ 1mL	660 T	1000	370	560	1000	2000	11000	1600	1200	NA	NA	NA
Coliforms, Total	MPN/ 100 mL	ND 2	5	ND 2	ND 2	ND 2	2	8	ND 2	ND 2	NA	NA	NA
Fecal Coliforms	MPN/ 100 mL	ND 2	ND 2	ND 2	ND 2	ND 2	ND 2	ND 2	ND 2	ND 2	NA	NA	NA
E. Coli	MPN/ 100 mL	ND 2	ND 2	ND 2	ND 2	ND 2	ND 2	ND 2	ND 2	ND 2	NA	NA	NA

Notes
* Detections of VOCs include TCE, cis-1,2-DCE and Freon 11
See Table III-4-2 for Legend of Qualifiers.

TABLE III-4-2
LEGEND OF QUALIFIERS
PILOT STUDY
RECYCLED WATER STUDY

Flag	Description
B	Low recovery in MS/MSD and RPD out of limits.
BB	Target analyte detected in method blank at or above the laboratory minimum reporting limit (MRL). No major impact on the reported result since the target analyte is 10x the concentration level.
BD	Target analyte detected in method blank is above CA DHS recommended value of 0.5 and did not meet the internal blank limit of 1/3 MRL (1/3 of MRL = 0.7).
D	Field duplicate sample was out of RPD limits from regular sample.
J	The result is an estimated value detected outside the quantitation range.
L3	The associated blank spike reocvery was above method acceptance limits.
NA	Not analyzed.
ND	Not detected.
P	GC or HPLC confirmation criteria was exceeded. The RPD is greater than 40% between the two analytical results.
R4	MS/MSD RPD out exceeded method limits.
S7	Surrogate recovery was below laboratory and method acceptance limits. Unable to confirm matrix effect.
T	Detection found in associated trip blank.

TABLE III-4-3
QA/QC ANALYTICAL DATA
IDT PILOT STUDY
6024 SILVER CREEK VALLEY ROAD, SAN JOSE, CA

	Location	IDT Source	IDT Source	IDT Source	IDT Source	IDT Source	IDT Source	IDT Source
	Date	12/15/2008	12/15/2008	1/5/2009	1/5/2009	7/13/2009	7/13/2009	3/1/2010
	Sample Purpose	FD	REG	FD	REG	FD	REG	FD
Parameter	Units							
1,1,1,2-TETRACHLOROETHANE	µg/l	NT	NT	NT	NT	NT	NT	NT
1,1,1-TRICHLOROETHANE	µg/l	ND 0.50	ND 0.50	NT	NT	ND 0.50	ND 0.50	ND 0.50
1,1,2,2-TETRACHLOROETHANE	µg/l	ND 0.50	ND 0.50	NT	NT	ND 0.50	ND 0.50	ND 0.50
1,1,2-TRICHLOROETHANE	µg/l	ND 0.50	ND 0.50	NT	NT	ND 0.50	ND 0.50	ND 0.50
1,1-DICHLOROETHANE	µg/l	ND 0.50	ND 0.50	NT	NT	ND 0.50	ND 0.50	ND 0.50
1,1-DICHLOROETHENE	µg/l	ND 0.50	ND 0.50	NT	NT	ND 0.50	ND 0.50	ND 0.50
1,1-DICHLOROPROPENE	µg/l	NT	NT	NT	NT	NT	NT	NT
1,2,3-TRICHLOROBENZENE	µg/l	NT	NT	NT	NT	NT	NT	NT
1,2,3-TRICHLOROPROPANE	µg/l	NT	NT	NT	NT	NT	NT	NT
1,2,4-TRICHLOROBENZENE	µg/l	NT	NT	NT	NT	NT	NT	NT
1,2-DICHLOROBENZENE	µg/l	ND 0.50	ND 0.50	NT	NT	ND 0.50	ND 0.50	ND 0.50
1,2-DICHLOROETHANE	µg/l	ND 0.50	ND 0.50	NT	NT	ND 0.50	ND 0.50	ND 0.50
1,2-DICHLOROPROPANE	µg/l	ND 0.50	ND 0.50	NT	NT	ND 0.50	ND 0.50	ND 0.50
1,2-DIMETHYLBENZENE	µg/l	ND 0.50	ND 0.50	NT	NT	ND 0.50	ND 0.50	ND 0.50
1,3 Dichloropropene (Total)	µg/l	NT	NT	NT	NT	NT	NT	NT
1,3-DICHLOROBENZENE	µg/l	ND 0.50	ND 0.50	NT	NT	ND 0.50	ND 0.50	ND 0.50
1,3-DICHLOROPROPANE	µg/l	NT	NT	NT	NT	NT	NT	NT
1,4-DICHLOROBENZENE	µg/l	ND 0.50	ND 0.50	NT	NT	ND 0.50	ND 0.50	ND 0.50
2-BUTANONE	µg/l	NT	NT	NT	NT	NT	NT	NT
2-CHLOROETHYL VINYL ETHER	µg/l	ND 1.0	ND 1.0	NT	NT	ND 1.0	ND 1.0	NT
2-HEXANONE	µg/l	NT	NT	NT	NT	NT	NT	NT
4-METHYL-2-PENTANONE	µg/l	NT	NT	NT	NT	NT	NT	NT
ACETIC ACID, CHLORO-	µg/l	ND 2.0	ND 2.0	NT	NT	ND 2.0	ND 2.0	ND 2.0
Alkalinity Total, as CaCO3	µg/l	170000	170000	NT	NT	170000	170000 T	210000
Alkalinity, Bicarbonate as CaCO3	µg/l	170000	170000	NT	NT	170000	170000	210000
Alkalinity, Bicarbonate as HCO3	mg/l	NT	NT	NT	NT	NT	NT	NT
Alkalinity, Carbonate as CaCO3	µg/l	ND 4000	ND 6700	NT	NT	ND 6700	ND 6700	ND 6700
Alkalinity, Hydroxide as CaCO3	µg/l	ND 4000	ND 6700	NT	NT	ND 6700	ND 6700	ND 6700

<u>Notes:</u>

ND - denotes result was below the detection limit

NT - sample not tested for the given parameter

Project sample associated with field duplicate sample included for comparison

TABLE III-4-3
QA/QC ANALYTICAL DATA
IDT PILOT STUDY
6024 SILVER CREEK VALLEY ROAD, SAN JOSE, CA

	Location	IDT Source	IDT Source	IDT Source	IDT Source	IDT Source	IDT Source	IDT Source
	Date	12/15/2008	12/15/2008	1/5/2009	1/5/2009	7/13/2009	7/13/2009	3/1/2010
	Sample Purpose	FD	REG	FD	REG	FD	REG	FD
Parameter	Units							
BENZENE, 1,2,4-TRIMETHYL	µg/l	NT	NT	NT	NT	NT	NT	NT
BENZENE, 1,3,5-TRIMETHYL-	µg/l	NT	NT	NT	NT	NT	NT	NT
BENZENE	µg/l	ND 0.50	ND 0.50	NT	NT	ND 0.50	ND 0.50	ND 0.50
BORON	µg/l	410	440	NT	NT	420	420	400
BROMIDE	µg/l	NT	NT	170	180	250	250	280
BROMOBENZENE	µg/l	NT	NT	NT	NT	NT	NT	NT
BROMOCHLOROACETIC ACID	µg/l	ND 1.0	ND 1.0	NT	NT	1.7	2.0	ND 0.99
BROMOCHLOROMETHANE	µg/l	NT	NT	NT	NT	NT	NT	NT
BROMODICHLOROMETHANE	µg/l	8.4	8.4	NT	NT	14	15	8.1
BROMOFORM	µg/l	1.2	1.2	NT	NT	1.0	1.0	0.90
BROMOMETHANE	µg/l	ND 1.0	ND 1.0	NT	NT	ND 1.0	ND 1.0	ND 1.0
CALCIUM	µg/l	47000	51000	NT	NT	48000	44000	54000
CARBON TETRACHLORIDE	µg/l	ND 0.50	ND 0.50	NT	NT	ND 0.50	ND 0.50	ND 0.50
CHLORIDE	µg/l	200000	200000	NT	NT	200000	200000	190000
CHLOROBENZENE	µg/l	ND 0.50	ND 0.50	NT	NT	ND 0.50	ND 0.50	ND 0.50
CHLOROETHANE	µg/l	ND 1.0	ND 1.0	NT	NT	ND 1.0	ND 1.0	ND 1.0
CHLOROFORM	µg/l	8.7	8.6	NT	NT	16	16	8.3
CHLOROMETHANE	µg/l	ND 1.0	ND 1.0	NT	NT	ND 1.0	ND 1.0	ND 1.0
cis-1,2-DICHLOROETHENE	µg/l	ND 0.50	ND 0.50	NT	NT	ND 0.50	ND 0.50	ND 0.50
cis-1,3-DICHLOROPROPENE	µg/l	ND 0.50	ND 0.50	NT	NT	ND 0.50	ND 0.50	ND 0.50
CUMENE	µg/l	NT	NT	NT	NT	NT	NT	NT
CYANIDE	µg/l	ND 10	ND 10	NT	NT	NT	ND 10	NT
Di-isopropyl ether	µg/l	NT	NT	NT	NT	NT	NT	NT
DIBROMOACETIC ACID	µg/l	ND 1.0	ND 1.0	NT	NT	ND 1.0	ND 1.0	0.43
DIBROMOCHLOROMETHANE	µg/l	4.9	4.6	NT	NT	6.1	6.3	3.9
DIBROMOMETHANE	µg/l	NT	NT	NT	NT	NT	NT	NT
DICHLOROACETIC ACID	µg/l	1.4	1.4	NT	NT	3.3	3.9	0.56
DICHLORODIFLUOROMETHANE	µg/l	NT	NT	NT	NT	NT	NT	NT

Notes:

ND - denotes result was below the detection limit

NT - sample not tested for the given parameter

Project sample associated with field duplicate sample included for comparison

Locus TECHNOLOGIES

TABLE III-4-3
QA/QC ANALYTICAL DATA
IDT PILOT STUDY
6024 SILVER CREEK VALLEY ROAD, SAN JOSE, CA

	Location	IDT Source	IDT Source	IDT Source	IDT Source	IDT Source	IDT Source	IDT Source
	Date	12/15/2008	12/15/2008	1/5/2009	1/5/2009	7/13/2009	7/13/2009	3/1/2010
	Sample Purpose	FD	REG	FD	REG	FD	REG	FD
Parameter	Units							
DISSOLVED ORGANIC CARBON	µg/l	6100	6200 T	NT	NT	6800	6800	5000
E. COLI, TOTAL	MPN/100ml	ND 2.0	ND 2.0	NT	NT	2.0	ND 2.0	ND 2.0
Ethyl tert-butyl ether	µg/l	NT	NT	NT	NT	NT	NT	NT
ETHYLBENZENE	µg/l	ND 0.50	ND 0.50	NT	NT	ND 0.50	ND 0.50	ND 0.50
ethylenediaminetetraacetic acid (EDTA)	µg/l	ND 100	ND 100	NT	NT	NT	ND 100	NT
FECAL COLIFORM	MPN/100ml	ND 2.0	ND 2.0	NT	NT	8.0	2.0	ND 2.0
FREON 113	µg/l	ND 5.0	ND 5.0	NT	NT	ND 5.0	ND 5.0	ND 2.0
HAA5, Total	µg/l	1.4	1.4	NT	NT	9.3	11	NT
HETEROTROPHIC PLATE COUNT (HPC)	CFU/ml	6600	6300	NT	NT	17000	15000	1000
HEXACHLOROBUTADIENE	µg/l	NT	NT	NT	NT	NT	NT	NT
m,p-Xylenes	µg/l	ND 0.50 mp	ND 0.50 mp	NT	NT	ND 0.50 mp	ND 0.50 mp	ND 0.50 mp
MAGNESIUM	µg/l	24000	26000	NT	NT	26000	25000	30000
METHYL tert-BUTYL ETHER	µg/l	NT	NT	NT	NT	NT	NT	ND 0.50
METHYLENE CHLORIDE	µg/l	ND 5.0	ND 5.0	NT	NT	ND 5.0	ND 5.0	ND 20
MONOBROMOACETIC ACID	µg/l	ND 1.0	ND 1.0	NT	NT	ND 1.0	ND 1.0	ND 0.99
n-BUTYLBENZENE	µg/l	NT	NT	NT	NT	NT	NT	NT
N-Nitrosodimethylamine	µg/l	0.46	0.38	NT	NT	0.24	0.35 D	0.33
n-PROPYLBENZENE	µg/l	NT	NT	NT	NT	NT	NT	NT
NAPHTHALENE	µg/l	NT	NT	NT	NT	NT	NT	NT
NITRATE	µg/l	10000	10000	NT	NT	12000	12000	7700
Nitrilotriacetic acid (NTA)	µg/l	NT	NT	NT	NT	NT	NT	NT
NITRITE	µg/l	130	140	NT	NT	110	130	660
o-CHLOROTOLUENE	µg/l	NT	NT	NT	NT	NT	NT	NT
ORTHOPHOSPHATE as P	µg/l	NT	NT	NT	NT	NT	NT	NT
p-CHLOROTOLUENE	µg/l	NT	NT	NT	NT	NT	NT	NT
p-CYMENE	µg/l	NT	NT	NT	NT	NT	NT	NT
Perchlorate	µg/l	NT	NT	NT	NT	NT	NT	NT
Perfluorobutyric acid (PFBA)	µg/l	ND 0.020	ND 0.020	NT	NT	ND 0.020	ND 0.020	ND 0.010

Notes:

ND - denotes result was below the detection limit
NT - sample not tested for the given parameter
Project sample associated with field duplicate sample included for comparison

TABLE III-4-3
QA/QC ANALYTICAL DATA
IDT PILOT STUDY
6024 SILVER CREEK VALLEY ROAD, SAN JOSE, CA

	Location	IDT Source	IDT Source	IDT Source	IDT Source	IDT Source	IDT Source	IDT Source
	Date	12/15/2008	12/15/2008	1/5/2009	1/5/2009	7/13/2009	7/13/2009	3/1/2010
	Sample Purpose	FD	REG	FD	REG	FD	REG	FD
Parameter	Units							
Perfluorooctanesulfonic acid (PFOS)	µg/l	0.044	0.067 D	NT	NT	0.060	0.046 D	0.046
Perfluorooctanoic acid (PFOA)	µg/l	0.043	0.065 D	NT	NT	0.051	0.041	0.062
Phosphate	µg/l	250	260	NT	NT	550	530	200
POTASSIUM	µg/l	13000	14000	NT	NT	12000	13000	12000
sec-BUTYLBENZENE	µg/l	NT	NT	NT	NT	NT	NT	NT
sec-DICHLOROPROPANE	µg/l	NT	NT	NT	NT	NT	NT	NT
SODIUM	µg/l	120000	130000	NT	NT	140000	140000 T	120000
STYRENE	µg/l	NT	NT	NT	NT	NT	NT	NT
SULFATE	µg/l	89000	89000	NT	NT	94000	94000	100000
SURFACTANTS (MBAS)	µg/l	ND 200	ND 200	NT	NT	NT	ND 200	NT
Terbuthylazine	µg/l	ND 0.10	ND 0.10	NT	NT	NT	ND 0.10	NT
Tert-amyl methyl ether	µg/l	NT	NT	NT	NT	NT	NT	NT
tert-BUTYLBENZENE	µg/l	NT	NT	NT	NT	NT	NT	NT
TETRACHLOROETHENE	µg/l	ND 0.50	ND 0.50	NT	NT	ND 0.50	ND 0.50	ND 0.50
TOLUENE	µg/l	ND 0.50	ND 0.50	NT	NT	ND 0.50	ND 0.50	ND 0.50
TOTAL COLIFORMS	MPN/100ml	14	24	NT	NT	46	24	ND 2.0
Total Dissolved Solids	µg/l	700000	700000	NT	NT	730000	740000	720000
TOTAL ORGANIC CARBON	µg/l	5800	5900	NT	NT	6800	6700	6300
trans-1,2-DICHLOROETHENE	µg/l	ND 0.50	ND 0.50	NT	NT	ND 0.50	ND 0.50	ND 0.50
trans-1,3-DICHLOROPROPENE	µg/l	ND 0.50	ND 0.50	NT	NT	ND 0.50	ND 0.50	ND 0.50
TRICHLOROACETIC ACID	µg/l	ND 1.0	ND 1.0	NT	NT	6.0	6.8	ND 0.99
TRICHLOROETHENE	µg/l	ND 0.50	ND 0.50	NT	NT	ND 0.50	ND 0.50	ND 0.50
TRICHLOROFLUOROMETHANE	µg/l	ND 1.0	ND 1.0	NT	NT	ND 1.0	ND 1.0	ND 1.0
VINYL CHLORIDE	µg/l	ND 0.50	ND 0.50	NT	NT	ND 0.50	ND 0.50	ND 0.50
Xylenes (Total)	µg/l	NT	NT	NT	NT	NT	NT	NT

Notes:

ND - denotes result was below the detection limit

NT - sample not tested for the given parameter

Project sample associated with field duplicate sample included for comparison

Locus TECHNOLOGIES

TABLE III-4-3
QA/QC ANALYTICAL DATA
IDT PILOT STUDY
6024 SILVER CREEK VALLEY ROAD, SAN JOSE, CA

	Location	IDT Source	Rinseate Blank	SJSC Plant	SJSC Plant	Travel Blank	Travel Blank	Travel Blank
	Date	3/1/2010	2/2/2009	5/19/2008	5/19/2008	5/19/2008	12/15/2008	7/13/2009
	Sample Purpose	REG	RB	FD	REG	TB	TB	TB
Parameter	Units							
1,1,1,2-TETRACHLOROETHANE	µg/l	NT	NT	ND 0.50	ND 0.50	ND 0.50	NT	NT
1,1,1-TRICHLOROETHANE	µg/l	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50
1,1,2,2-TETRACHLOROETHANE	µg/l	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50
1,1,2-TRICHLOROETHANE	µg/l	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50
1,1-DICHLOROETHANE	µg/l	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50
1,1-DICHLOROETHENE	µg/l	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50
1,1-DICHLOROPROPENE	µg/l	NT	NT	ND 0.50	ND 0.50	ND 0.50	NT	NT
1,2,3-TRICHLOROBENZENE	µg/l	NT	NT	ND 0.50	ND 0.50	ND 0.50	NT	NT
1,2,3-TRICHLOROPROPANE	µg/l	NT	NT	ND 0.50	ND 0.50	ND 0.50	NT	NT
1,2,4-TRICHLOROBENZENE	µg/l	NT	NT	ND 0.50	ND 0.50	ND 0.50	NT	NT
1,2-DICHLOROBENZENE	µg/l	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50
1,2-DICHLOROETHANE	µg/l	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50
1,2-DICHLOROPROPANE	µg/l	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50
1,2-DIMETHYLBENZENE	µg/l	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50
1,3 Dichloropropene (Total)	µg/l	NT	NT	ND 0.50	ND 0.50	ND 0.50	NT	NT
1,3-DICHLOROBENZENE	µg/l	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50
1,3-DICHLOROPROPANE	µg/l	NT	NT	ND 0.50	ND 0.50	ND 0.50	NT	NT
1,4-DICHLOROBENZENE	µg/l	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50
2-BUTANONE	µg/l	NT	NT	ND 5.0	ND 5.0	ND 5.0	NT	NT
2-CHLOROETHYL VINYL ETHER	µg/l	NT	ND 1.0	ND 1.0	ND 1.0	ND 1.0	ND 1.0	ND 1.0
2-HEXANONE	µg/l	NT	NT	ND 5.0	ND 5.0	ND 5.0	NT	NT
4-METHYL-2-PENTANONE	µg/l	NT	NT	ND 5.0	ND 5.0	ND 5.0	NT	NT
ACETIC ACID, CHLORO-	µg/l	ND 2.0	NT	ND 2.0	ND 2.0	ND 2.0	ND 2.0	ND 2.0
Alkalinity Total, as CaCO3	µg/l	210000	NT	190000	190000	ND 2000	ND 1000	2100
Alkalinity, Bicarbonate as CaCO3	µg/l	210000	NT	NT	NT	NT	ND 1000	ND 1000
Alkalinity, Bicarbonate as HCO3	mg/l	NT	NT	230	230	ND 2.0	NT	NT
Alkalinity, Carbonate as CaCO3	µg/l	ND 6700	NT	ND 2000	ND 2000	ND 2000	ND 1000	ND 1000
Alkalinity, Hydroxide as CaCO3	µg/l	ND 6700	NT	ND 2000	ND 2000	ND 2000	ND 1000	ND 1000

Notes:

ND - denotes result was below the detection limit

NT - sample not tested for the given parameter

Project sample associated with field duplicate sample included for comparison

TABLE III-4-3
QA/QC ANALYTICAL DATA
IDT PILOT STUDY
6024 SILVER CREEK VALLEY ROAD, SAN JOSE, CA

	Location	IDT Source	Rinseate Blank	SJSC Plant	SJSC Plant	Travel Blank	Travel Blank	Travel Blank
	Date	3/1/2010	2/2/2009	5/19/2008	5/19/2008	5/19/2008	12/15/2008	7/13/2009
	Sample Purpose	REG	RB	FD	REG	TB	TB	TB
Parameter	Units							
BENZENE, 1,2,4-TRIMETHYL	µg/l	NT	NT	ND 0.50	ND 0.50	ND 0.50	NT	NT
BENZENE, 1,3,5-TRIMETHYL-	µg/l	NT	NT	ND 0.50	ND 0.50	ND 0.50	NT	NT
BENZENE	µg/l	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50
BORON	µg/l	390	NT	480	480	ND 10	ND 100	ND 100
BROMIDE	µg/l	280	NT	ND 500	ND 500	ND 500	NT	ND 50
BROMOBENZENE	µg/l	NT	NT	ND 0.50	ND 0.50	ND 0.50	NT	NT
BROMOCHLOROACETIC ACID	µg/l	ND 0.99	NT	10	9.6	ND 1.0	ND 1.0	ND 1.0
BROMOCHLOROMETHANE	µg/l	NT	NT	ND 0.50	ND 0.50	ND 0.50	NT	NT
BROMODICHLOROMETHANE	µg/l	8.6	ND 0.50	16	15	ND 0.50	ND 0.50	ND 0.50
BROMOFORM	µg/l	0.80	ND 0.50	1.3	1.3	ND 0.50	ND 0.50	ND 0.50
BROMOMETHANE	µg/l	ND 1.0	ND 1.0	ND 0.50	ND 0.50	ND 0.50	ND 1.0	ND 1.0
CALCIUM	µg/l	52000	NT	53000	54000	ND 100	ND 500	ND 500
CARBON TETRACHLORIDE	µg/l	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50
CHLORIDE	µg/l	190000	NT	190000	190000	ND 500	ND 200	ND 200
CHLOROBENZENE	µg/l	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50
CHLOROETHANE	µg/l	ND 1.0	ND 1.0	ND 0.50	ND 0.50	ND 0.50	ND 1.0	ND 1.0
CHLOROFORM	µg/l	8.8	ND 0.50	13	12	ND 0.50	ND 0.50	ND 0.50
CHLOROMETHANE	µg/l	ND 1.0	ND 1.0	ND 0.50	ND 0.50	ND 0.50	ND 1.0	ND 1.0
cis-1,2-DICHLOROETHENE	µg/l	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50
cis-1,3-DICHLOROPROPENE	µg/l	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50
CUMENE	µg/l	NT	NT	ND 0.50	ND 0.50	ND 0.50	NT	NT
CYANIDE	µg/l	20	NT	ND 5.0	ND 5.0	ND 5.0	ND 10	NT
Di-isopropyl ether	µg/l	NT	NT	ND 3.0	ND 3.0	ND 3.0	NT	NT
DIBROMOACETIC ACID	µg/l	0.37	NT	3.3	3.4	ND 1.0	ND 1.0	ND 1.0
DIBROMOCHLOROMETHANE	µg/l	4.2	ND 0.50	7.8	7.1	ND 0.50	ND 0.50	ND 0.50
DIBROMOMETHANE	µg/l	NT	NT	ND 0.50	ND 0.50	ND 0.50	NT	NT
DICHLOROACETIC ACID	µg/l	0.57	NT	15	14	ND 1.0	ND 1.0	ND 1.0
DICHLORODIFLUOROMETHANE	µg/l	NT	NT	ND 0.50	ND 0.50	ND 0.50	NT	NT

Notes:

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NT - sample not tested for the given parameter

Project sample associated with field duplicate sample included for comparison

TABLE III-4-3
QA/QC ANALYTICAL DATA
IDT PILOT STUDY
6024 SILVER CREEK VALLEY ROAD, SAN JOSE, CA

	Location	IDT Source	Rinseate Blank	SJSC Plant	SJSC Plant	Travel Blank	Travel Blank	Travel Blank
	Date	3/1/2010	2/2/2009	5/19/2008	5/19/2008	5/19/2008	12/15/2008	7/13/2009
	Sample Purpose	REG	RB	FD	REG	TB	TB	TB
Parameter	Units							
DISSOLVED ORGANIC CARBON	µg/l	4800	NT	7000	6800	ND 300	1700	ND 1000
E. COLI, TOTAL	MPN/100ml	ND 2.0	NT	ND 2.0	ND 2.0	ND 2.0	ND 2.0	ND 2.0
Ethyl tert-butyl ether	µg/l	NT	NT	ND 3.0	ND 3.0	ND 3.0	NT	NT
ETHYLBENZENE	µg/l	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50
ethylenediaminetetraacetic acid (EDTA)	µg/l	ND 100	NT	ND 100	ND 100	ND 100	ND 100	NT
FECAL COLIFORM	MPN/100ml	ND 2.0	NT	ND 2.0	ND 2.0	ND 2.0	ND 2.0	ND 2.0
FREON 113	µg/l	ND 2.0	ND 5.0	ND 5.0	ND 5.0	ND 5.0	ND 5.0	ND 5.0
HAA5, Total	µg/l	NT	NT	29	27	ND 5.0	ND 1.0	ND 1.0
HETEROTROPHIC PLATE COUNT (HPC)	CFU/ml	3100 T D	NT	6.0	2.0	NT	ND 1.0	ND 1.0
HEXACHLOROBUTADIENE	µg/l	NT	NT	ND 0.50	ND 0.50	ND 0.50	NT	NT
m,p-Xylenes	µg/l	ND 0.50 mp	ND 0.50 mp	ND 1.0	ND 1.0	ND 1.0	ND 0.50 mp	ND 0.50 mp
MAGNESIUM	µg/l	29000	NT	29000	30000	ND 100	ND 500	ND 500
METHYL tert-BUTYL ETHER	µg/l	ND 0.50	NT	ND 3.0	ND 3.0	ND 3.0	NT	NT
METHYLENE CHLORIDE	µg/l	ND 20	ND 5.0	ND 0.50	ND 0.50	1.3	ND 5.0	ND 5.0
MONOBROMOACETIC ACID	µg/l	ND 0.99	NT	ND 1.0	ND 1.0	ND 1.0	ND 1.0	ND 1.0
n-BUTYLBENZENE	µg/l	NT	NT	ND 0.50	ND 0.50	ND 0.50	NT	NT
N-Nitrosodimethylamine	µg/l	0.32	NT	0.12	0.11	ND 0.0020	ND 0.0020	ND 0.0020
n-PROPYLBENZENE	µg/l	NT	NT	ND 0.50	ND 0.50	ND 0.50	NT	NT
NAPHTHALENE	µg/l	NT	NT	ND 0.50	ND 0.50	ND 0.50	NT	NT
NITRATE	µg/l	7700	NT	9300 O-09	9600 O-09	ND 110 O-09	ND 50	ND 50
Nitrilotriacetic acid (NTA)	µg/l	NT	NT	ND 100	ND 100	ND 100	NT	NT
NITRITE	µg/l	650	NT	ND 150 O-09	ND 150 O-09	ND 150 O-09	ND 50	ND 50
o-CHLOROTOLUENE	µg/l	NT	NT	ND 0.50	ND 0.50	ND 0.50	NT	NT
ORTHOPHOSPHATE as P	µg/l	NT	NT	175	168 T	76	NT	NT
p-CHLOROTOLUENE	µg/l	NT	NT	ND 0.50	ND 0.50	ND 0.50	NT	NT
p-CYMENE	µg/l	NT	NT	ND 0.50	ND 0.50	ND 0.50	NT	NT
Perchlorate	µg/l	NT	NT	ND 4.0	ND 4.0	ND 4.0	NT	NT
Perfluorobutyric acid (PFBA)	µg/l	0.012	NT	ND 0.050	ND 0.050	ND 0.050	ND 0.020	ND 0.020

Notes:

ND - denotes result was below the detection limit
NT - sample not tested for the given parameter
Project sample associated with field duplicate sample included for comparison

Locus TECHNOLOGIES

TABLE III-4-3
QA/QC ANALYTICAL DATA
IDT PILOT STUDY
6024 SILVER CREEK VALLEY ROAD, SAN JOSE, CA

	Location	IDT Source	Rinseate Blank	SJSC Plant	SJSC Plant	Travel Blank	Travel Blank	Travel Blank
	Date	3/1/2010	2/2/2009	5/19/2008	5/19/2008	5/19/2008	12/15/2008	7/13/2009
	Sample Purpose	REG	RB	FD	REG	TB	TB	TB
Parameter	Units							
Perfluorooctanesulfonic acid (PFOS)	µg/l	0.051	NT	ND 0.050	ND 0.050	ND 0.050	ND 0.0050	ND 0.0050
Perfluorooctanoic acid (PFOA)	µg/l	0.070	NT	0.029	ND 0.020 D	ND 0.020	ND 0.0050	ND 0.0050
Phosphate	µg/l	210	NT	NT	NT	NT	ND 30	ND 30
POTASSIUM	µg/l	12000	NT	15000	16000	ND 100	ND 500	ND 500
sec-BUTYLBENZENE	µg/l	NT	NT	ND 0.50	ND 0.50	ND 0.50	NT	NT
sec-DICHLOROPROPANE	µg/l	NT	NT	ND 0.50	ND 0.50	ND 0.50	NT	NT
SODIUM	µg/l	120000	NT	130000	130000	ND 500	ND 500	530
STYRENE	µg/l	NT	NT	ND 0.50	ND 0.50	ND 0.50	NT	NT
SULFATE	µg/l	100000	NT	96000	94000	ND 500	ND 500	ND 500
SURFACTANTS (MBAS)	µg/l	ND 200	NT	180	210	ND 100	ND 200	NT
Terbuthylazine	µg/l	ND 0.10	NT	ND 0.10 Q5	ND 0.10 Q5	ND 0.10	ND 0.10	NT
Tert-amyl methyl ether	µg/l	NT	NT	ND 3.0	ND 3.0	ND 3.0	NT	NT
tert-BUTYLBENZENE	µg/l	NT	NT	ND 0.50	ND 0.50	ND 0.50	NT	NT
TETRACHLOROETHENE	µg/l	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50
TOLUENE	µg/l	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50
TOTAL COLIFORMS	MPN/100ml	ND 2.0	NT	ND 2.0	ND 2.0	ND 2.0	ND 2.0	ND 2.0
Total Dissolved Solids	µg/l	740000	NT	680000	690000	ND 10000	ND 10000	ND 10000
TOTAL ORGANIC CARBON	µg/l	6200	NT	6900	6900	ND 300	ND 500	ND 500
trans-1,2-DICHLOROETHENE	µg/l	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50
trans-1,3-DICHLOROPROPENE	µg/l	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50
TRICHLOROACETIC ACID	µg/l	ND 0.99	NT	11	9.7	ND 1.0	ND 1.0	ND 1.0
TRICHLOROETHENE	µg/l	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50
TRICHLOROFLUOROMETHANE	µg/l	ND 1.0	ND 1.0	ND 5.0	ND 5.0	ND 5.0	ND 1.0	ND 1.0
VINYL CHLORIDE	µg/l	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50	ND 0.50
Xylenes (Total)	µg/l	NT	NT	ND 0.50	ND 0.50	ND 0.50	NT	NT

Notes:

ND - denotes result was below the detection limit
NT - sample not tested for the given parameter
Project sample associated with field duplicate sample included for comparison

TABLE III-4-3
QA/QC ANALYTICAL DATA
IDT PILOT STUDY
6024 SILVER CREEK VALLEY ROAD, SAN JOSE, CA

	Location	Travel Blank
	Date	3/1/2010
	Sample Purpose	TB
Parameter	Units	
1,1,1,2-TETRACHLOROETHANE	µg/l	NT
1,1,1-TRICHLOROETHANE	µg/l	ND 0.50
1,1,2,2-TETRACHLOROETHANE	µg/l	ND 0.50
1,1,2-TRICHLOROETHANE	µg/l	ND 0.50
1,1-DICHLOROETHANE	µg/l	ND 0.50
1,1-DICHLOROETHENE	µg/l	ND 0.50
1,1-DICHLOROPROPENE	µg/l	NT
1,2,3-TRICHLOROBENZENE	µg/l	NT
1,2,3-TRICHLOROPROPANE	µg/l	NT
1,2,4-TRICHLOROBENZENE	µg/l	NT
1,2-DICHLOROBENZENE	µg/l	ND 0.50
1,2-DICHLOROETHANE	µg/l	ND 0.50
1,2-DICHLOROPROPANE	µg/l	ND 0.50
1,2-DIMETHYLBENZENE	µg/l	ND 0.50
1,3 Dichloropropene (Total)	µg/l	NT
1,3-DICHLOROBENZENE	µg/l	ND 0.50
1,3-DICHLOROPROPANE	µg/l	NT
1,4-DICHLOROBENZENE	µg/l	ND 0.50
2-BUTANONE	µg/l	NT
2-CHLOROETHYL VINYL ETHER	µg/l	NT
2-HEXANONE	µg/l	NT
4-METHYL-2-PENTANONE	µg/l	NT
ACETIC ACID, CHLORO-	µg/l	ND 2.0
Alkalinity Total, as CaCO3	µg/l	ND 1000
Alkalinity, Bicarbonate as CaCO3	µg/l	ND 1000
Alkalinity, Bicarbonate as HCO3	mg/l	NT
Alkalinity, Carbonate as CaCO3	µg/l	ND 1000
Alkalinity, Hydroxide as CaCO3	µg/l	ND 1000

Notes:

ND - denotes result was below the detection limit
NT - sample not tested for the given parameter
Project sample associated with field duplicate sample included for comparison

TABLE III-4-3
QA/QC ANALYTICAL DATA
IDT PILOT STUDY
6024 SILVER CREEK VALLEY ROAD, SAN JOSE, CA

	Location	Travel Blank
	Date	3/1/2010
	Sample Purpose	TB
Parameter	Units	
BENZENE, 1,2,4-TRIMETHYL	µg/l	NT
BENZENE, 1,3,5-TRIMETHYL-	µg/l	NT
BENZENE	µg/l	ND 0.50
BORON	µg/l	ND 100
BROMIDE	µg/l	ND 50
BROMOBENZENE	µg/l	NT
BROMOCHLOROACETIC ACID	µg/l	ND 1.0
BROMOCHLOROMETHANE	µg/l	NT
BROMODICHLOROMETHANE	µg/l	ND 0.50
BROMOFORM	µg/l	ND 0.50
BROMOMETHANE	µg/l	ND 1.0
CALCIUM	µg/l	ND 500
CARBON TETRACHLORIDE	µg/l	ND 0.50
CHLORIDE	µg/l	ND 200
CHLOROBENZENE	µg/l	ND 0.50
CHLOROETHANE	µg/l	ND 1.0
CHLOROFORM	µg/l	ND 0.50
CHLOROMETHANE	µg/l	ND 1.0
cis-1,2-DICHLOROETHENE	µg/l	ND 0.50
cis-1,3-DICHLOROPROPENE	µg/l	ND 0.50
CUMENE	µg/l	NT
CYANIDE	µg/l	NT
Di-isopropyl ether	µg/l	NT
DIBROMOACETIC ACID	µg/l	ND 1.0
DIBROMOCHLOROMETHANE	µg/l	ND 0.50
DIBROMOMETHANE	µg/l	NT
DICHLOROACETIC ACID	µg/l	ND 1.0
DICHLORODIFLUOROMETHANE	µg/l	NT

Notes:

ND - denotes result was below the detection limit
NT - sample not tested for the given parameter
Project sample associated with field duplicate sample included for comparison

TABLE III-4-3
QA/QC ANALYTICAL DATA
IDT PILOT STUDY
6024 SILVER CREEK VALLEY ROAD, SAN JOSE, CA

	Location	Travel Blank
	Date	3/1/2010
	Sample Purpose	TB
Parameter	Units	
DISSOLVED ORGANIC CARBON	µg/l	ND 1000
E. COLI, TOTAL	MPN/100ml	ND 2.0
Ethyl tert-butyl ether	µg/l	NT
ETHYLBENZENE	µg/l	ND 0.50
ethylenediaminetetraacetic acid (EDTA)	µg/l	NT
FECAL COLIFORM	MPN/100ml	ND 2.0
FREON 113	µg/l	ND 2.0
HAA5, Total	µg/l	NT
HETEROTROPHIC PLATE COUNT (HPC)	CFU/ml	980
HEXACHLOROBUTADIENE	µg/l	NT
m,p-Xylenes	µg/l	ND 0.50 mp
MAGNESIUM	µg/l	ND 500
METHYL tert-BUTYL ETHER	µg/l	ND 0.50
METHYLENE CHLORIDE	µg/l	ND 20
MONOBROMOACETIC ACID	µg/l	ND 1.0
n-BUTYLBENZENE	µg/l	NT
N-Nitrosodimethylamine	µg/l	ND 0.0020
n-PROPYLBENZENE	µg/l	NT
NAPHTHALENE	µg/l	NT
NITRATE	µg/l	ND 50
Nitrilotriacetic acid (NTA)	µg/l	NT
NITRITE	µg/l	ND 50
o-CHLOROTOLUENE	µg/l	NT
ORTHOPHOSPHATE as P	µg/l	NT
p-CHLOROTOLUENE	µg/l	NT
p-CYMENE	µg/l	NT
Perchlorate	µg/l	NT
Perfluorobutyric acid (PFBA)	µg/l	ND 0.010

Notes:

ND - denotes result was below the detection limit
NT - sample not tested for the given parameter
Project sample associated with field duplicate sample included for comparison

TABLE III-4-3
QA/QC ANALYTICAL DATA
IDT PILOT STUDY
6024 SILVER CREEK VALLEY ROAD, SAN JOSE, CA

	Location	Travel Blank
	Date	3/1/2010
	Sample Purpose	TB
Parameter	Units	
Perfluorooctanesulfonic acid (PFOS)	µg/l	ND 0.0050
Perfluorooctanoic acid (PFOA)	µg/l	ND 0.0050
Phosphate	µg/l	ND 30
POTASSIUM	µg/l	ND 500
sec-BUTYLBENZENE	µg/l	NT
sec-DICHLOROPROPANE	µg/l	NT
SODIUM	µg/l	ND 500
STYRENE	µg/l	NT
SULFATE	µg/l	ND 500
SURFACTANTS (MBAS)	µg/l	NT
Terbuthylazine	µg/l	NT
Tert-amyl methyl ether	µg/l	NT
tert-BUTYLBENZENE	µg/l	NT
TETRACHLOROETHENE	µg/l	ND 0.50
TOLUENE	µg/l	ND 0.50
TOTAL COLIFORMS	MPN/100ml	ND 2.0
Total Dissolved Solids	µg/l	ND 10000
TOTAL ORGANIC CARBON	µg/l	ND 500
trans-1,2-DICHLOROETHENE	µg/l	ND 0.50
trans-1,3-DICHLOROPROPENE	µg/l	ND 0.50
TRICHLOROACETIC ACID	µg/l	ND 1.0
TRICHLOROETHENE	µg/l	ND 0.50
TRICHLOROFLUOROMETHANE	µg/l	ND 1.0
VINYL CHLORIDE	µg/l	ND 0.50
Xylenes (Total)	µg/l	NT

Notes:

ND - denotes result was below the detection limit
NT - sample not tested for the given parameter
Project sample associated with field duplicate sample included for comparison

Locus TECHNOLOGIES

TABLE III-4-4
MANN-KENDALL TREND ANALYSIS
PILOT STUDY
RECYCLED WATER STUDY

Parameter Name	Location ID	No Of Records	No Of Positive Differences	No Of Negative Differences	No Of Ties	No Of NonDetects	Mann Kendall Stat (S)	Probability	Trend
Alkalinity Total, as CaCO3	IDT Source	11	25	8	22	0	17	0.218	None
	L10-COMP	8	16	11	1	0	5	0.634	None
	L5-COMP	8	17	10	1	0	7	0.474	None
	MW-1	8	14	13	1	0	1	1	None
	MW-2	8	6	16	6	0	-10	0.276	None
	MW-3	8	19	9	0	0	10	0.276	None
	MW-4	8	8	19	1	0	-11	0.228	None
Alkalinity, Bicarbonate as CaCO3	IDT Source	11	25	8	22	0	17	0.218	None
	L10-COMP	8	16	10	2	0	6	0.548	None
	L5-COMP	8	17	9	2	0	8	0.398	None
	MW-1	8	14	13	1	0	1	1	None
	MW-2	8	6	16	6	0	-10	0.276	None
	MW-3	8	19	9	0	0	10	0.276	None
	MW-4	8	8	19	1	0	-11	0.228	None
Boron	IDT Source	11	15	34	6	0	-19	0.164	None
	L10-COMP	8	7	20	1	0	-13	0.142	None
	L5-COMP	8	7	20	1	0	-13	0.142	None
	MW-1	9	13	18	5	0	-5	0.686	None
	MW-2	9	9	21	6	0	-12	0.26	None
	MW-3	9	10	19	7	0	-9	0.418	None
	MW-4	9	11	21	4	0	-10	0.358	None
Bromide	IDT Source	11	28	21	6	0	7	0.648	None
	L10-COMP	8	26	2	0	0	24	0.002	Up
	L5-COMP	7	7	13	1	0	-6	0.472	None
	MW-1	9	22	13	1	2	9	0.418	None
	MW-2	9	23	12	1	2	11	0.31	None
	MW-3	9	24	11	1	2	13	0.22	None
	MW-4	9	22	13	1	2	9	0.418	None
Bromochloroacetic acid	IDT Source	11	16	34	5	5	-18	0.191	None
	L10-COMP	8	0	0	0	8	0	1	None - All Ties
	L5-COMP	8	0	0	0	8	0	1	None - All Ties
	MW-1	9	2	6	28	9	-4	0.762	None
	MW-2	9	0	0	0	9	0	1	None - All Ties
	MW-3	9	2	12	22	9	-10	0.358	None
	MW-4	9	0	8	28	9	-8	0.476	None
Bromodichloromethane	IDT Source	11	31	20	4	0	11	0.446	None
	L10-COMP	8	5	2	21	7	3	0.812	None
	L5-COMP	8	4	9	15	7	-5	0.634	None
	MW-1	9	0	0	0	9	0	1	None - All Ties
	MW-2	9	0	0	0	9	0	1	None - All Ties
	MW-3	9	0	0	0	9	0	1	None - All Ties
	MW-4	9	0	0	0	9	0	1	None - All Ties
Bromoform	IDT Source	11	20	32	3	0	-12	0.402	None
	L10-COMP	8	0	0	0	8	0	1	None - All Ties
	L5-COMP	8	0	7	21	8	-7	0.474	None
	MW-1	9	0	0	0	9	0	1	None - All Ties
	MW-2	9	0	0	0	9	0	1	None - All Ties
	MW-3	9	0	0	0	9	0	1	None - All Ties
	MW-4	9	0	0	0	9	0	1	None - All Ties
Calcium	IDT Source	11	21	30	4	0	-9	0.542	None
	L10-COMP	8	4	20	4	0	-16	0.062	None
	L5-COMP	8	3	22	3	0	-19	0.022	Down
	MW-1	9	12	24	0	0	-12	0.26	None
	MW-2	9	9	26	1	0	-17	0.098	None
	MW-3	9	18	17	1	0	1	1	None
	MW-4	9	8	18	10	0	-10	0.358	None
Carbon Tetrachloride	IDT Source	11	0	0	0	11	0	1	None - All Ties
	L10-COMP	8	0	0	0	8	0	1	None - All Ties
	L5-COMP	8	0	7	21	8	-7	0.474	None
	MW-1	9	0	0	0	9	0	1	None - All Ties
	MW-2	9	0	0	0	9	0	1	None - All Ties
	MW-3	9	0	0	0	9	0	1	None - All Ties
	MW-4	9	0	0	0	9	0	1	None - All Ties
Chloride	IDT Source	11	9	34	12	0	-25	0.06	None
	L10-COMP	8	24	3	1	0	21	0.01	Up
	L5-COMP	8	25	3	0	0	22	0.006	Up
	MW-1	9	17	15	4	0	2	0.92	None
	MW-2	9	18	16	2	0	2	0.92	None
	MW-3	9	29	6	1	0	23	0.018	Up
	MW-4	9	27	8	1	0	19	0.06	None
Chloroacetic acid	IDT Source	11	7	3	45	10	4	0.821	None
	L10-COMP	8	0	13	15	6	-13	0.142	None
	L5-COMP	8	12	1	15	6	11	0.228	None
	MW-1	9	0	0	0	9	0	1	None - All Ties
	MW-2	9	0	8	28	8	-8	0.476	None
	MW-3	9	0	0	0	9	0	1	None - All Ties
	MW-4	9	0	0	0	9	0	1	None - All Ties
Chloroform	IDT Source	11	36	16	3	0	20	0.142	None
	L10-COMP	8	5	2	21	7	3	0.812	None
	L5-COMP	8	4	9	15	7	-5	0.634	None
	MW-1	9	6	2	28	9	4	0.762	None
	MW-2	9	6	2	28	9	4	0.762	None
	MW-3	9	6	2	28	9	4	0.762	None
	MW-4	9	6	2	28	9	4	0.762	None
Cyanide	IDT Source	9	14	9	13	5	5	0.686	None
Dibromoacetic acid	IDT Source	11	3	36	16	7	-33	0.01	Down
	L10-COMP	8	5	2	21	7	3	0.812	None
	L5-COMP	8	2	5	21	7	-3	0.812	None
	MW-1	9	2	6	28	9	-4	0.762	None
	MW-2	9	0	0	0	9	0	1	None - All Ties
	MW-3	9	2	12	22	9	-10	0.358	None
	MW-4	9	0	8	28	9	-8	0.476	None

Notes:

Non detects treated at the reporting limit.
5% Significance level used.

TABLE III-4-4
MANN-KENDALL TREND ANALYSIS
PILOT STUDY
RECYCLED WATER STUDY

Parameter Name	Location ID	No Of Records	No Of Positive Differences	No Of Negative Differences	No Of Ties	No Of NonDetects	Mann Kendall Stat (S)	Probability	Trend
Dibromochloromethane	IDT Source	11	27	24	4	0	3	0.88	None
	L10-COMP	8	5	2	21	7	3	0.812	None
	L5-COMP	8	4	9	15	7	-5	0.634	None
	MW-1	9	0	0	0	9	0	1	None - All Ties
	MW-2	9	0	0	0	9	0	1	None - All Ties
	MW-3	9	0	0	0	9	0	1	None - All Ties
	MW-4	9	0	0	0	9	0	1	None - All Ties
Dichloroacetic acid	IDT Source	11	16	36	3	1	-20	0.142	None
	L10-COMP	8	3	10	15	6	-7	0.474	None
	L5-COMP	8	3	10	15	6	-7	0.474	None
	MW-1	9	2	6	28	9	-4	0.762	None
	MW-2	9	0	0	0	9	0	1	None - All Ties
	MW-3	9	2	12	22	9	-10	0.358	None
	MW-4	9	0	8	28	9	-8	0.476	None
Dissolved Organic Carbon	IDT Source	11	11	41	3	0	-30	0.021	Down
	L10-COMP	8	11	17	0	0	-6	0.548	None
	L5-COMP	8	9	18	1	0	-9	0.336	None
	MW-1	9	0	8	28	8	-8	0.476	None
	MW-2	9	12	3	21	7	9	0.418	None
	MW-3	9	8	0	28	8	8	0.476	None
	MW-4	9	0	8	28	8	-8	0.476	None
E. Coli, total	IDT Source	11	8	10	37	9	-2	0.94	None
	L10-COMP	8	0	0	0	8	0	1	None - All Ties
	L5-COMP	8	0	0	0	8	0	1	None - All Ties
	MW-1	9	0	0	0	9	0	1	None - All Ties
	MW-2	9	0	0	0	9	0	1	None - All Ties
	MW-3	9	0	0	0	9	0	1	None - All Ties
	MW-4	9	0	0	0	9	0	1	None - All Ties
Ethylenediaminetetraacetic acid (edta)	IDT Source	9	0	0	0	9	0	1	None - All Ties
Fecal coliform	IDT Source	11	12	25	18	7	-13	0.358	None
	L10-COMP	8	0	0	0	8	0	1	None - All Ties
	L5-COMP	8	5	2	21	7	3	0.812	None
	MW-1	9	0	0	0	9	0	1	None - All Ties
	MW-2	9	0	0	0	9	0	1	None - All Ties
	MW-3	9	0	0	0	9	0	1	None - All Ties
	MW-4	9	0	0	0	9	0	1	None - All Ties
Heterotrophic plate count (HPC)	IDT Source	11	28	21	6	0	7	0.648	None
	L10-COMP	8	8	19	1	1	-11	0.228	None
	L5-COMP	8	6	21	1	0	-15	0.086	None
	MW-1	9	18	18	0	0	0	1	None
	MW-2	9	23	13	0	0	10	0.358	None
	MW-3	9	18	18	0	0	0	1	None
	MW-4	9	8	27	1	0	-19	0.06	None
m,p-Xylenes	IDT Source	11	0	0	0	11	0	1	None - All Ties
	L10-COMP	8	0	0	0	8	0	1	None - All Ties
	L5-COMP	8	0	7	21	8	-7	0.474	None
	MW-1	8	0	0	0	8	0	1	None - All Ties
	MW-2	8	0	0	0	8	0	1	None - All Ties
	MW-3	8	0	0	0	8	0	1	None - All Ties
	MW-4	8	0	0	0	8	0	1	None - All Ties
Magnesium	IDT Source	11	22	27	6	0	-5	0.762	None
	L10-COMP	8	7	17	4	0	-10	0.276	None
	L5-COMP	8	6	22	0	0	-16	0.062	None
	MW-1	9	12	23	1	0	-11	0.31	None
	MW-2	9	11	23	2	0	-12	0.26	None
	MW-3	9	14	21	1	0	-7	0.544	None
	MW-4	9	11	24	1	0	-13	0.22	None
Monobromoacetic acid	IDT Source	11	0	24	31	11	-24	0.073	None
	L10-COMP	8	0	0	0	8	0	1	None - All Ties
	L5-COMP	8	0	0	0	8	0	1	None - All Ties
	MW-1	9	2	6	28	9	-4	0.762	None
	MW-2	9	0	0	0	9	0	1	None - All Ties
	MW-3	9	2	12	22	9	-10	0.358	None
	MW-4	9	0	8	28	9	-8	0.476	None
N-Nitrosodimethylamine	IDT Source	11	13	37	5	0	-24	0.073	None
	L10-COMP	8	3	24	1	2	-21	0.01	Down
	L5-COMP	8	0	13	15	6	-13	0.142	None
	MW-1	9	23	3	10	5	20	0.044	Up
	MW-2	9	15	0	21	7	15	0.15	None
	MW-3	9	0	0	0	9	0	1	None - All Ties
	MW-4	9	19	2	15	6	17	0.098	None
Nitrate as N	IDT Source	11	12	33	10	0	-21	0.12	None
	L10-COMP	8	24	4	0	0	20	0.014	Up
	L5-COMP	8	20	7	1	2	13	0.142	None
	MW-1	9	11	23	2	0	-12	0.26	None
	MW-2	9	4	31	1	0	-27	0.004	Down
	MW-3	9	22	14	0	0	8	0.476	None
	MW-4	9	9	26	1	0	-17	0.098	None
Nitrite as N	IDT Source	11	23	28	4	1	-5	0.762	None
	L10-COMP	8	2	5	21	8	-3	0.812	None
	L5-COMP	8	0	19	9	8	-19	0.022	Down
	MW-1	9	2	13	21	8	-11	0.31	None
	MW-2	9	0	8	28	9	-8	0.476	None
	MW-3	9	0	8	28	9	-8	0.476	None
	MW-4	9	0	8	28	9	-8	0.476	None
Perfluorobutyric acid (PFBA)	IDT Source	11	15	11	29	10	4	0.821	None
	L10-COMP	8	0	13	15	7	-13	0.142	None
	L5-COMP	8	3	22	3	4	-19	0.022	Down
	MW-1	9	0	15	21	9	-15	0.15	None
	MW-2	9	0	15	21	9	-15	0.15	None
	MW-3	9	0	15	21	9	-15	0.15	None
	MW-4	9	0	15	21	9	-15	0.15	None

Notes:

Non detects treated at the reporting limit.

5% Significance level used.

TABLE III-4-4
MANN-KENDALL TREND ANALYSIS
PILOT STUDY
RECYCLED WATER STUDY

Parameter Name	Location ID	No Of Records	No Of Positive Differences	No Of Negative Differences	No Of Ties	No Of NonDetects	Mann Kendall Stat (S)	Probability	Trend
Perfluorooctanesulfonic acid (PFOS)	IDT Source	11	29	22	4	0	7	0.648	None
	L10-COMP	8	5	2	21	7	3	0.812	None
	L5-COMP	8	6	1	21	7	5	0.634	None
	MW-1	9	5	10	21	8	-5	0.686	None
	MW-2	9	0	8	28	9	-8	0.476	None
	MW-3	9	0	8	28	9	-8	0.476	None
	MW-4	9	1	14	21	8	-13	0.22	None
Perfluorooctanoic acid (PFOA)	IDT Source	11	29	21	5	0	8	0.595	None
	L10-COMP	8	3	10	15	6	-7	0.474	None
	L5-COMP	8	7	15	6	4	-8	0.398	None
	MW-1	9	0	8	28	9	-8	0.476	None
	MW-2	9	5	16	15	7	-11	0.31	None
	MW-3	9	4	11	21	8	-7	0.544	None
	MW-4	9	5	10	21	8	-5	0.686	None
Phosphate, Total as P	IDT Source	11	21	31	3	0	-10	0.494	None
	L10-COMP	8	15	12	1	1	3	0.812	None
	L5-COMP	9	23	13	0	1	10	0.358	None
	MW-1	8	22	5	1	0	17	0.05	None
	MW-2	8	8	20	0	0	-12	0.178	None
	MW-3	8	12	16	0	0	-4	0.72	None
	MW-4	8	6	19	3	3	-13	0.142	None
Potassium	IDT Source	11	11	36	8	0	-25	0.06	None
	L10-COMP	8	3	24	1	0	-21	0.01	Down
	L5-COMP	8	8	19	1	0	-11	0.228	None
	MW-1	9	16	20	0	0	-4	0.762	None
	MW-2	9	15	21	0	0	-6	0.612	None
	MW-3	9	11	15	10	5	-4	0.762	None
	MW-4	9	1	14	21	7	-13	0.22	None
Sodium	IDT Source	11	18	29	8	0	-11	0.446	None
	L10-COMP	8	6	21	1	0	-15	0.086	None
	L5-COMP	8	11	16	1	0	-5	0.634	None
	MW-1	9	10	23	3	0	-13	0.22	None
	MW-2	9	11	22	3	0	-11	0.31	None
	MW-3	9	15	20	1	0	-5	0.686	None
	MW-4	9	9	24	3	0	-15	0.15	None
Sulfate	IDT Source	11	30	18	7	0	12	0.402	None
	L10-COMP	8	0	28	0	0	-28	0	Down
	L5-COMP	8	3	25	0	0	-22	0.006	Down
	MW-1	9	14	22	0	0	-8	0.476	None
	MW-2	9	11	23	2	0	-12	0.26	None
	MW-3	9	22	14	0	0	8	0.476	None
	MW-4	9	14	22	0	0	-8	0.476	None
Surfactants (MBAS)	IDT Source	9	0	0	0	9	0	1	None - All Ties
Terbuthylazine	IDT Source	9	0	8	28	8	-8	0.476	None
Total Coliforms	IDT Source	11	18	26	11	3	-8	0.595	None
	L10-COMP	8	10	12	6	4	-2	0.904	None
	L5-COMP	8	14	10	4	3	4	0.72	None
	MW-1	9	14	15	7	4	-1	1	None
	MW-2	9	12	17	7	4	-5	0.686	None
	MW-3	9	15	10	11	5	5	0.686	None
	MW-4	9	10	15	11	5	-5	0.686	None
Total Dissolved Solids	IDT Source	11	21	29	5	0	-8	0.595	None
	L10-COMP	8	3	24	1	0	-21	0.01	Down
	L5-COMP	8	5	23	0	0	-18	0.032	Down
	MW-1	9	16	18	2	0	-2	0.92	None
	MW-2	9	14	20	2	0	-6	0.612	None
	MW-3	9	23	12	1	0	11	0.31	None
	MW-4	9	10	23	3	0	-13	0.22	None
Total Organic Carbon	IDT Source	11	23	28	4	0	-5	0.762	None
	L10-COMP	8	9	18	1	0	-9	0.336	None
	L5-COMP	8	11	17	0	0	-6	0.548	None
	MW-1	9	19	16	1	2	3	0.84	None
	MW-2	9	15	14	7	4	1	1	None
	MW-3	9	14	19	3	3	-5	0.686	None
	MW-4	9	8	27	1	2	-19	0.06	None
Trichloroacetic acid	IDT Source	11	18	30	7	6	-12	0.402	None
	L10-COMP	8	0	0	0	8	0	1	None - All Ties
	L5-COMP	8	0	0	0	8	0	1	None - All Ties
	MW-1	9	2	6	28	9	-4	0.762	None
	MW-2	9	0	0	0	9	0	1	None - All Ties
	MW-3	9	2	12	22	9	-10	0.358	None
	MW-4	9	0	8	28	9	-8	0.476	None
Conductivity	IDT Source	7	9	12	0	0	-3	0.772	None
	L10-COMP	8	13	15	0	0	-2	0.904	None
	L5-COMP	8	9	19	0	0	-10	0.276	None
	MW-1	8	12	16	0	0	-4	0.72	None
	MW-2	8	17	11	0	0	6	0.548	None
	MW-3	8	19	9	0	0	10	0.276	None
	MW-4	8	0	28	0	0	-28	0	Down
Dissolved Oxygen	IDT Source	7	11	10	0	0	1	1	None
	L10-COMP	8	16	12	0	0	4	0.72	None
	L5-COMP	8	16	12	0	0	4	0.72	None
	MW-1	8	9	18	1	0	-9	0.336	None
	MW-2	8	22	6	0	0	16	0.062	None
	MW-3	8	18	10	0	0	8	0.398	None
	MW-4	8	19	8	1	0	11	0.228	None
Oxidation Reduction Potential	IDT Source	7	11	10	0	0	1	1	None
	L10-COMP	8	20	8	0	0	12	0.178	None
	L5-COMP	8	19	9	0	0	10	0.276	None
	MW-1	8	16	12	0	0	4	0.72	None
	MW-2	8	10	18	0	0	-8	0.398	None
	MW-3	8	2	25	1	0	-23	0.002	Down

Notes:

Non detects treated at the reporting limit.

5% Significance level used.

TABLE III-4-4
MANN-KENDALL TREND ANALYSIS
PILOT STUDY
RECYCLED WATER STUDY

Parameter Name	Location ID	No Of Records	No Of Positive Differences	No Of Negative Differences	No Of Ties	No Of NonDetects	Mann Kendall Stat (S)	Probability	Trend
Oxidation Reduction Potential	MW-4	8	18	9	1	0	9	0.336	None
pH	IDT Source	7	14	7	0	0	7	0.382	None
	L10-COMP	8	15	13	0	0	2	0.904	None
	L5-COMP	8	22	5	1	0	17	0.05	None
	MW-1	8	10	18	0	0	-8	0.398	None
	MW-2	8	15	12	1	0	3	0.812	None
	MW-3	8	6	22	0	0	-16	0.062	None
	MW-4	8	10	18	0	0	-8	0.398	None
Residual Chlorine	IDT Source	7	10	11	0	0	-1	1	None
	L10-COMP	8	19	9	0	0	10	0.276	None
	L5-COMP	8	14	14	0	0	0	1	None
	MW-1	8	2	26	0	0	-24	0.002	Down
	MW-2	8	0	18	10	0	-18	0.032	Down
	MW-3	8	20	8	0	0	12	0.178	None
	MW-4	8	7	21	0	0	-14	0.108	None
Sodium Adorption Ratio	IDT Source	9	16	20	0	0	-4	0.762	None
	L10-COMP	8	8	20	0	0	-12	0.178	None
	L5-COMP	8	17	11	0	0	6	0.548	None
	MW-1	9	15	21	0	0	-6	0.612	None
	MW-2	9	15	21	0	0	-6	0.612	None
	MW-3	9	16	20	0	0	-4	0.762	None
	MW-4	9	10	26	0	0	-16	0.12	None

Notes:

Non detects treated at the reporting limit.
5% Significance level used.

Volume IV
Evaluation of Potential Impacts

Recycled Water Irrigation and Groundwater Study
Santa Clara and Llagas Groundwater Subbasins
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LIST OF ACRONYMS AND ABBREVIATIONS

ACRONYM	**DESCRIPTION**
GIS	geographic information system
IDT	Integrated Device Technology
Locus	Locus Technologies
mg/L	milligrams per liter
PARWQCP	Palo Alto Regional Water Quality Control Plant
PFOA	perfluoro octanoic acid
PFOS	perfluoro octanesulfonate
SAT	soil aquifer treatment
SCRWA	South County Regional Wastewater Authority
SCVWD	Santa Clara Valley Water District
SJ/SC WPCP	San Jose/Santa Clara Water Pollution Control Plant
SWPCP	Sunnyvale Water Pollution Control Plant

EXECUTIVE SUMMARY

Volume IV of this report assesses the soil aquifer treatment (SAT) capacity and groundwater degradation potential from expanded use of recycled water in the Santa Clara and Llagas Groundwater Subbasins. The goal of Volume IV is to geographically rate the SAT capacity and groundwater degradation potential throughout the study area. The evaluation relies on findings from the bench test and pilot study to calibrate the evaluation specific to the study area. To assess a rating in a geographical manner, the study utilizes AutoCAD Map 3D software to analyze multiple layers of geographic information system (GIS) data.

Soil Aquifer Treatment Capacity

SAT capacity is defined as the ability of the soil and aquifer to naturally treat contaminants. For this study, the focus is contaminants found in recycled water. The approach to delineating SAT capacity in the study area utilizes the hydrogeological characteristics of the given area including the depth to groundwater ("D"), the type of shallow soil media ("S") and the type of vadose zone media ("I"). The methodology for determining SAT capacity is an adaptation of EPA's DRASTIC system created for evaluating the relative groundwater pollution potential using hydrogeologic settings (USEPA, 1987). SAT capacity is determined by a weighted average of the rating of each input ("D", "S", and "I").

Depth to groundwater ("D") is the physical distance the water travels from the surface to reach the groundwater in the target aquifer. The target aquifer of concern is the principal aquifer which is the confined aquifer where a confining layer exists and the shallowest aquifer for unconfined areas. The rating for the depth to groundwater is calibrated on depth-specific results from the pilot study. The majority of the depth to water in the Santa Clara Subbasin in the confined areas was over 100 feet bgs. In the unconfined areas for the Santa Clara Subbasin, depth to groundwater ranged between 0 and 100 feet. Very few areas were below five feet bgs. In the Llagas Subbasin, the majority of the depth to groundwater in the confined area was more than 100 ft bgs. In the unconfined portions of the Llagas Subbasin, depth to groundwater ranged from 0 to 100 feet bgs. The weighting of the depth groundwater relative to the other input parameters is 49%. The weighting is calibrated from the soil attenuation model which examined the relative importance between each input.

Soil media ("S") refers to the first several feet of soil below the ground surface. This is taken to be approximately six feet or less. The soil in this depth range is generally characterized by a high amount of organic matter. Major attenuative processes that occur in the soil media include biodegradation, filtration, volatilization, and sorption. Rating for the soil media is calibrated on results from the bench test which examined constituent removal from a range of soil cores with different grain size distributions. The majority of the Santa Clara Subbasin has a soil media classified as sandy loam or clay loam. The soil media in the northern section of the Santa Clara Subbasin is dominated by clay. For the Llagas Subbasin the major soil media is sandy loam followed by clay loam and silty loam. The weighting of the soil media relative to the other input parameters is 25%. The weighting is calibrated from the soil attenuation model which examined the relative importance between each input.

Impact of vadose zone media ("I") refers to the depth above the water table in the unsaturated or partially saturated zone. The vadose zone is significant because it provides attenuation through biodegradation, filtration, volatilization, dispersion, and chemical reaction. Within the study area, the vadose zone media can be variable over depth. For unconfined areas, the representative vadose zone media for each area is determined by using the net hydraulic conductivity for the vadose zone soil profile. For areas with confined aquifers, the layer that controls the attenuation processes is the confining layer. Therefore, a value for the confining layer is assigned to confined areas. Rating for the vadose zone media is calibrated on results from the bench test which examined constituent removal from a range of soil cores with different grain size distributions. The vadose zone media in the Santa Clara and Llagas Subbasins in the confined area is the confining layer. The dominant vadose zone media in the Santa Clara Subbasin in the unconfined area is the clay. For the Llagas Subbasin, the dominant vadose zone media in the unconfined area is clay followed by silt. The weighting of the soil media relative to the other input parameters is 26%. The weighting is calibrated from the soil attenuation model which examined the relative importance between each input.

Soil Aquifer Treatment (SAT) capacity maps are found in Figure IV-2-11 and IV-2-12 for the Santa Clara and Llagas Subbasin respectively. Based on a relative scale, the SAT rating ranges from 1 to 10 (high to least capacity). The confined areas of both subbasins were determined to have relatively high SAT capacity due to the confining layer and deep depth to groundwater. The unconfined areas were largely of good or average capacity. Only a few areas in the unconfined area were regarded as having relatively marginal capacity and even fewer areas were regarded as least capacity. Areas with a lower rating tended to be characterized with shallow depth to water and a coarse grain size distribution in the vadose zone.

Groundwater Degradation Potential

Groundwater degradation potential is defined as the potential for groundwater to be impacted by recycled water used in irrigation. Groundwater is regarded as impacted when the quality is worse than current groundwater quality, with the consideration of the available assimilative capacity. For the purpose of this study, the available assimilative capacity is determined by comparing current groundwater quality with applicable water quality standards, and calculating 20% of the difference between those two values. For constituents where the current groundwater concentration exceeds the water quality standard, there is zero available assimilative capacity for that constituent.

The approach to delineating groundwater degradation potential in the study area is dependent on (1) the hydrogeological characteristics (SAT capacity) and (2) the quality of the recycled water applied for a given area. Compared to the additive approach in evaluating SAT capacity, the input parameters for the groundwater degradation potential are more appropriately evaluated in a multiplicative method. The maximum score for groundwater degradation potential is 100.

SAT capacity rating can range from 1 to 10, such that 10 is indicative of poor SAT capacity and 1 is indicative of high SAT capacity. The recycled water quality rating also ranges from 1 to 10, such that 10 is indicative of relatively poor recycled water quality (generally higher constituent concentrations), and 1 is indicative of relatively high recycled water quality (generally lower constituent concentrations).

The recycled water quality rating is dependent on (1) the concentration of the recycled water applied, (2) the threat of each constituent determined in Volume III of this study, and (3) representative groundwater quality in the study area. The recycled water quality is evaluated based on an aggregate index method using multiple subindices. In this case, the subindices refer to the constituents. The aggregate index is normalized to a scale from 1 to 10. A rating of 10 is indicative of relatively low recycled water quality (maximum recycled water concentrations) and a rating of 1 is indicative of relatively high recycled water quality (recycled water concentrations equal to groundwater concentrations).

Groundwater degradation potential maps are found in IV-3-3 and IV-3-4 for the Santa Clara and Llagas Subbasin respectively. Groundwater degradation potential in the Santa Clara Subbasin is largely of lowest to average potential with a few areas regarded as high or highest. The rating in the Santa Clara Subbasin ranges from 8 to 96. Groundwater degradation potential in the Llagas Subbasin is largely of lowest to average potential and with a few areas regarded as high. The evaluation did not find any areas of the highest potential in the Llagas Subbasin. In the Llagas Subbasin, the groundwater degradation potential rating ranges from 11 to 70. Comparatively, the Santa Clara and Llagas Subbasins share a similar distribution in groundwater degradation potential with a majority of lowest and low potential found in the confined areas and more average potential in the unconfined areas.

VOLUME IV
EVALUATION OF POTENTIAL IMPACTS
RECYCLED WATER STUDY

1. INTRODUCTION

This report was prepared by Locus Technologies (Locus) on behalf of the Santa Clara Valley Water District (SCVWD) for the Recycled Water Irrigation and Groundwater Study (Study). Volume IV assesses the soil aquifer treatment capacity and potential to degrade groundwater quality across the project study area.

This document provides a qualitative screening approach that employs the best professional judgment to extrapolate data from the findings of the previous phases of this study to the entire study area. Previous phases of this study are the literature review and data analysis (Volume I), the soil attenuation model and bench test (Volume II), and the pilot study (Volume III). These earlier phases compiled and reported information that was used to prepare the analysis discussed in Volume IV.

1.1. Purpose

This volume reports the findings from the evaluation of soil aquifer treatment capacity and groundwater degradation potential in the Santa Clara and Llagas Subbasins. The results of the evaluation serve as a tool for determining what quality of recycled water is needed to prevent groundwater quality impacts in specific geographic areas. The findings from this evaluation are important towards determining recycled water screening levels, best management practices, and monitoring recommendation discussed in Volume V. The following goals were identified for the evaluation:

- Provide a comparative evaluation for soil aquifer treatment capacity, specific to recycled water as an irrigation source, for any given location in the project study area.
- Provide a comparative evaluation for the groundwater degradation potential for any given location using the local recycled water sources in the project study area.

The focus of this phase of the study is chemical constituents, including those of anthropogenic and non-anthropogenic origins that have been evaluated in the previous phases of the study (Volumes I to III). A few constituents of concern are biological.

Soil aquifer treatment capacity is defined as the ability of the soil and aquifer to naturally treat contaminants. The study's focus is on contaminants found in recycled water. Mechanisms to lower the concentrations of contaminants include but are not exclusive to volatilization, dispersion, diffusion, sorption, precipitation, ion exchange, oxidation-reduction, transformation, and filtration. Soil aquifer treatment capacity is established from the hydrogeological characteristics of a given area.

Groundwater degradation potential is defined as the potential for groundwater to be impacted by recycled water used in irrigation. Groundwater is regarded as impacted when the quality is worse than current groundwater quality, with the consideration of the available assimilative capacity. Groundwater degradation potential is not only determined by the hydrogeological characteristics of a given area but is also dependent on the quality of the recycled water applied.

1.2. Approach

To determine regional zones for soil aquifer treatment capacity and groundwater degradation potential, AutoCAD Map 3D software was used to compile and evaluate the criteria discussed. AutoCAD Map 3D is a mapping software tool for visualizing, managing, creating and analyzing geographic information system (GIS) data. Multiple sets of geographic data are used to determine relative soil aquifer treatment capacity and groundwater degradation potential.

The methodology used in this document is an adaptation of EPA's DRASTIC system, adapted to the use of recycled water for irrigation using the findings from the pilot study, bench test, soil attenuation model, and literature review. DRASTIC was published in 1987 and lays out an established methodology for evaluating groundwater pollution potential using hydrogeologic settings (USEPA, 1987).

The core of DRASTIC's evaluation system is a weighting and rating system of several factors. The methodology used in this document is an adaptation of the DRASTIC evaluation system using a rating from one to ten and a weighted average of each of the factors. The criteria incorporate a range of hydrogeological factors from the surface and subsurface. Hydrogeological factors at the surface include the topography area and the amount of recharge entering the system. In the subsurface, hydrogeological factors include the depth to groundwater, the type of soils in the subsurface, and the hydraulic conductivity of the aquifer. The adapted evaluation utilizes a subset of these factors which were found to be relevant to the evaluation of recycled water irrigation's potential effect on groundwater. Each criterion is weighted, by a percentage, which depend on the level of relevance. The sum of all the weighting from each criterion is equal to 100%. The numerical evaluation allows for a comparison of different areas of the relative risk of degradation from the use of recycled water use in irrigation.

The values for each criterion are ranked (up to 10), reflecting the criterion's impact on soil treatment capacity or groundwater degradation potential. A higher rating denotes lower soil treatment capacity and consequently greater groundwater degradation potential. For example, areas with a greater depth to groundwater would have greater soil attenuation capacity and would be assigned a low rating. Areas with a shallow depth to groundwater (i.e. high water table) would have less soil attenuation capacity and would be therefore given the highest rating for this input.

2. SOIL AQUIFER TREATMENT CAPACITY

Soil aquifer treatment capacity is the ability of the soil and aquifer to naturally remove contaminants. The unsaturated or vadose zone acts as a natural filter and can lower the concentration of constituents found in recycled water. Additional reduction is achieved in the aquifer from residence time in the aquifer before extraction for beneficial use. Mechanisms to lower the concentrations of contaminants of concern include volatilization, dispersion, diffusion, sorption, precipitation, ion exchange, oxidation-reduction, transformation, and filtration. For the purpose of this study, general physical parameters of the soil are used to help evaluate the combined potential for soil aquifer treatment rather than attempting to quantify each mechanism separately. Findings from the previous phases of the study, namely the literature review, data analysis, soil modeling, bench test and pilot test, were used to support a comparative evaluation of soil aquifer treatment capacity.

For this study, the soil aquifer treatment capacity focuses on attenuation that is achieved before reaching groundwater. Attenuation that is potentially achieved in the aquifer is not considered part of the soil aquifer treatment capacity for this study. Assimilative capacity differs from soil aquifer treatment capacity, in that assimilative capacity refers to the capacity of the groundwater to degrade without affecting beneficial use. Soil aquifer treatment capacity in this study refers to the capacity of the subsurface to remove contaminants before reaching groundwater.

2.1. Methodology

2.1.1. DRASTIC

DRASTIC was published in 1987 by the EPA. DRASTIC lays out a methodology for evaluating groundwater pollution potential using hydrogeologic settings (USEPA, 1987). DRASTIC is a system of weighted ratings. The name, DRASTIC, is an acronym for the seven major factors in the rating system that includes depth to water (“D”), net recharge (“R”), aquifer media (“A”), soil media (“S”), topography (“T”), impact of the vadose zone media (“I”), and hydraulic conductivity of the aquifer (“C”) (USEPA, 1987). Using the DRASTIC method as a starting point, the values and relative importance of these inputs were adapted using data collected from previous phases of this study, as discussed below for each input.

2.1.2. Evaluation Assumptions

Assumptions in this evaluation are

1) The contaminant is introduced at the ground surface through application of recycled water. The study is concerned with recycled water as an irrigation source, which is applied at the surface. Typically, irrigation is applied at the surface; however recycled water can also be introduced using buried drip irrigation systems with buried emitters. Buried irrigation systems are still located close to the surface, where the root zone is located. Therefore, the assumption of surface application is still appropriate.

2) The contaminant is flushed and moved advectively toward groundwater by precipitation and irrigation. If attenuative processes were not present, the fate of a contaminant would be towards the groundwater. The assumption also implies that there is no runoff. By regulation, no volume of recycled water is allowed as runoff, and irrigation systems should be maintained and adjusted so that no runoff occurs.

3) For areas with both a confined and unconfined aquifer, the groundwater of concern for the purpose of this evaluation is in the confined aquifer. In portions of the study area, an unconfined aquifer lies atop a confined aquifer. The groundwater that is used in these areas is typically from the confined aquifer which is considered to be the principal groundwater supply aquifer. Therefore, the input parameters for the confined areas relate to the deep, confined zone rather than the shallow unconfined zone. This evaluation may not be protective for shallow unconfined groundwater where a confined deeper aquifer is also present.

4) Percolation is not short circuited by fractures. The evaluation assumes that preferential flow paths from fractures or other vertical conduits (e.g. abandoned wells) are not present. Percolation occurs through the pores of the soil matrix.

2.1.3. GIS Tool

To determine regional zones for soil aquifer treatment capacity and groundwater degradation potential, AutoCAD Map 3D software was used to compile and evaluate the factors discussed. AutoCAD Map 3D is a mapping software tool for visualizing, managing, creating and analyzing geographic information system (GIS) data. Multiple sets of geographic data are factored into determining soil aquifer treatment capacity.

2.2. Evaluation Criteria

2.2.1. Depth to Water

The depth to groundwater is the vertical distance water must travel from the surface to reach groundwater. In general, a longer distance allows for more contact time through the soil for attenuation processes to occur. As discussed in Section 2.1.1, the target aquifer of concern is the confined aquifer where the principal groundwater supply aquifer is protected by a confining layer, and the shallowest aquifer for all unconfined areas. Values for this input are based on this assumption, so that the depth to the top of the aquifer is used for confined areas, and the depth to the water table is used for unconfined areas.

In the Santa Clara Subbasin, depth to shallow groundwater ranges from 0 to over 100 feet bgs (SCVWD, 2004). The principal aquifer depth in confined areas of the Santa Clara Subbasin was over 100 feet bgs. In the Llagas Subbasin, the depth to shallow groundwater varies from 10 to 100 feet bgs in the northeast region of the basin to less than five feet bgs to the south. The principal aquifer depth in confined areas of the Llagas Subbasin ranges from 50 ft bgs to over 100 ft bgs.

2.2.1.1. Derivation of Ratings

Ratings for the Depth to Water input were derived and calibrated using results from the pilot study in Volume III, as shown in Table IV-2-1. The pilot study included sampling of recycled water constituents in the irrigation source water and also in the subsurface at five feet, at ten feet, and in the groundwater (approximately 30 feet bgs).

From the pilot study, the percentage of removal of total haloacetic acids (HAA6) was used as the indicator for the attenuation capacity at different depths. HAA6 was selected for this purpose because (1) it was consistently quantifiable in the recycled water sources and in the subsurface, (2) this constituent is the sum of six analytical constituents and therefore less prone to analytical variability, and (3) within the pilot study, the only origin of this constituent is from recycled water. The concentration of HAA6 in the recycled water source was calculated as the average total HAA6 concentration for all eight sampling events, to represent the net contribution of this constituent over the entire duration of the pilot study. The concentration of HAA6 in the subsurface was calculated as the average of the last two events of the pilot study, so that long-term conditions can be represented without relying entirely on a single sampling event.

Removal percentages of HAA6 were calculated by comparing the concentrations at 5 feet, 10 feet, and 30 feet to the concentration in the recycled water used for irrigation. The percentage removal at 10 feet and 30 feet were then compared to the percentage removal at 5 feet. This ratio represents the increased attenuation capacity at depths of 10 feet and 30 feet compared to 5 feet. From this analysis, there was 1.14 times more attenuation capacity at 10 feet, and 1.31 times more attenuation capacity at 30 feet, compared to 5 feet. The Depth to Water rating for 5 feet (DRASTIC default of 10) is then adjusted by these factors to obtain Depth to Water ratings for 10 feet and 30 feet. Values for other depths were extrapolated from the calibrated values using a trend line as shown in Figure IV-2-1 and can be expressed as

$$[\text{Depth to Water Rating}] = 12.544 \times [\text{Depth to Water}]^{-0.1483}$$

A geometric trend was used to fit the data because the rate of removal is expected to be constant over depth for a given soil type.

Depth to Water		
Weighting: 49%		
Range (ft)	Default DRASTIC Rating	Customized Rating
0-5	10	10
5-15	9	8.4
15-30	7	7.6
30-50	5	7.0
50-75	3	6.6
75-100	2	6.3
100+	1	6.0

Compared to the default DRASTIC rating, the customized rating has a shorter range (6 to 10).

2.2.1.1.1.Sensitivity Analysis

A sensitivity analysis was done on the derivation using haloacetic acid data due to the limited data in the groundwater. Results of the sensitivity analysis are also included in Table IV-2-1. For the haloacetic acid data in groundwater, there was one detected value which was qualified (“J” flag). Specifically, this value is 0.26 J µg/L for the monochloroacetic acid in MW-2 in the eighth sampling event. The “J” flag indicates that the value is an estimate between the method detection limit and the laboratory reporting limit. Estimates in this range are at a lower confidence than detection at or above the reporting limit. Because of the reliance on this one data point, the sensitivity of the results using this value was tested by substituting the value for zero (Scenario 1) and for the reporting limit (2 µg/L) (Scenario 2).

The resulting ratings from the sensitivity analysis did not reveal significant changes to the DRASTIC ratings. In scenario 1, the ratings did not change from the base scenario. There was a slightly higher percentage removal at 30 feet but the change was not prominent enough to affect the depth to water rating. In scenario 2, the ratings did not change significantly from the base scenario. There was a lower percentage removal at 30 feet and this translated into a slightly higher depth to water rating at 30 feet (7.9 as opposed to 7.6). Overall, the derivation for the depth to water rating was determined to have low sensitivity to the specified groundwater data point within the range between 0 and 2 µg/L.

2.2.1.2. Data and Calculation

GIS data for the depth to water was supplied from the SCVWD website and from *Groundwater Vulnerability Study, Santa Clara County, California* (SCVWD, 2010). Geographic data for depth to water was determined by two different sources of data: one set for confined areas, and another for unconfined areas. For the unconfined areas in the Santa Clara and Llagas Subbasins, data was derived from the SCVWD using minimum depth to water measurements at fuel leak sites. Data from fuel leak sites for the coverage spanned from 1980 to just prior to the publication date (October 15, 2003) of the geographic data. For unconfined areas, the depth to water is the distance from the ground surface to the water table.

For confined areas, the depth to groundwater is the distance from the ground surface to top of the confined aquifer. Data for this is defined using the depth to the top of the first well screen of public water supply wells. Data for depth to groundwater for confined aquifers was obtained from *Groundwater Vulnerability Study, Santa Clara County, California* (SCVWD, 2010).

The depth to water ratings for Santa Clara and Llagas Groundwater Subbasins, as calculated from the depth to water data, are shown on Figures IV-2-2 and IV-2-3. Depth to water is given a weighting factor of 49%. The weighting factor is determined using a calibration method with the soil attenuation model. Section 2.4 describes in detail the procedure for establishing the weighting factor.

2.2.2. Soil Media

The soil media refers to the first several feet of soil from the land surface, commonly an average of six feet or less. The soil in this zone is generally characterized by a high amount of organic matter. Organic matter is composed of undecayed plant and animal tissue, charcoal and humic substances. Humic substances are largely responsible for adsorption and complexation processes in the soil. Soil provides attenuation of recycled water contaminants through biodegradation, filtration, volatilization, and sorption. Biodegradation and volatilization, as well as organic content, decrease with depth. Coverage of soil media was determined from a previous DRASTIC analysis of the study area conducted by the SCVWD (SCVWD, 1999). The coverage used a soil map developed by the United States Soil Conservation Service. The soil classifications were analyzed and assigned for each area.

Soil media was found to be a significant factor in how well a recycled water constituent was attenuated. In the soil attenuation model and bench test, the study verified that constituents generally attenuate better in fine grain soils, followed by semifine and coarse soils.

2.2.2.1. Derivation of Ratings

Ratings for the soil media input were calibrated using results from the bench test in Volume II, as shown in Table IV-2-2. The bench test included eight soil cores, which were irrigated with recycled water. The soil cores were selected to represent different soil types observed within the study area. The recycled water used in the bench test was obtained from the SJ/SC WPCP and the SCRWA Plant in Gilroy. Five of the eight soil cores irrigated with recycled water from the bench test yielded sufficient effluent for chemical analysis. These cores are listed in Table IV-2-2, with the soil characterization of each core as originally documented, and also as would be classified for the DRASTIC soil media input.

From the bench test, the percentage of removal of total trihalomethanes was used as the indicator for the attenuation capacity of the varying soil types. Total trihalomethanes were selected for this purpose because (1) they were consistently quantifiable in the recycled water sources and in the effluent from each of the soil cores, (2) this constituent is the sum of four analytical constituents and therefore less prone to analytical variability, and (3) within the bench test, trihalomethanes can be uniquely attributed to the recycled water source. Removal percentages of total trihalomethanes were calculated by comparing the final effluent sample from each core to the initial recycled water influent sample for each core. The final effluent sample was used to better represent long-term conditions, and the initial influent sample was used to account for the estimated travel time through the soil cores.

Because the soil cores varied in length, the percentage removals for the four-foot soil cores were normalized to one foot. This calculation was done assuming a constant percentage removal over each foot of the four-foot soil cores, using the following equation:

$$[\text{1-ft Removal}] = 1 - (1 - [\text{4-ft Removal}])^{1/4}$$

Once normalized, the percentage removal of total trihalomethanes from each soil core was compared to the percentage removal through sand. This ratio represents the increased attenuation capacity for silt and clay compared to sand. From this analysis, the silt core had 1.70 times more attenuation capacity than sand, and the clay cores had 3.63 to 3.86 times more attenuation capacity than sand. The soil media rating for sand (DRASTIC default of 7) is then adjusted by these factors to obtain soil media ratings for silt and clay. Values for soil types not included in the bench test were interpolated from the calibrated values for sand, silty loam, and massive clay.

Soil media is ranked in the following categories:

Soil Media		
Weighting: 25%		
Range	Default DRASTIC Rating	Customized Rating
Sand Loam to Sand	7	7
Sandy Loam	6	6
Silty Loam	4	4
Clay Loam	3	3
Massive Clay	1	2

2.2.2.2. Data and Calculations

Soil media data were obtained from *Groundwater Vulnerability Study, Santa Clara County, California* (SCVWD, 2010). Soil media in the study area include sand loam to sand, sandy loam, silty loam, clay loam, and massive clay. Soil media rating is determined accordingly with grain size which affects the hydraulic conductivity. Soils with high clay content have lower hydraulic conductivity which slows the transport of constituents and increases the time for filtration and other attenuative processes. Shrinking/aggregated clays are characterized by their significant capacity to expand and contract. Montmorillonite and smectite are examples of expansive clays.

The soil media ratings for Santa Clara and Llagas Groundwater Subbasins are shown on Figures IV-2-4 and IV-2-5. Soil media is given a weighting factor of 25%. The weighting factor is determined using a calibration method with the soil attenuation model. Section 2.4 of this volume describes in detail the procedure for establishing the weighting factor.

2.2.3. Impact of the Vadose Zone Media

The impact of the vadose media refers to the depth above the water table in the unsaturated or partially saturated zone. For confined aquifers, the vadose zone includes the aquitard and the unconfined aquifer above the top of the aquifer and below the soil. The vadose zone provides attenuation of recycled water contaminants through biodegradation, filtration, volatilization, dispersion, and chemical reaction. Biodegradation and volatilization decrease with depth.

Categories for the vadose zone media depend on whether the aquifer is confined or unconfined. Following DRASTIC procedure, the lithologic layer that most significantly controls the attenuation potential for each area is used to represent the vadose zone. For areas with a confined aquifer the appropriate vadose zone medium is the confining layer, since the presence of a confining layer controls the attenuation and transport through the vadose zone. For unconfined areas, the representative vadose zone medium is determined by calculating the net hydraulic conductivity through the entire vadose zone, and assigning the vadose zone medium that best represents that hydraulic conductivity.

2.2.3.1. Derivation of Ratings

The attenuation capacity for the vadose zone can be evaluated using the same approach used for the soil media described in Section 2.2.2. Therefore, the calibration of this input follows a similar procedure, with the ratio of total trihalomethane removal being used to derive vadose zone media ratings for silt and clay from the rating for sand (default of 6 for the sand end of the range). The derivation of these ratings is shown on Table IV-2-2, and the results are summarized below.

Impact of the Vadose Zone Media			
Weighting: 26%			
Range	DRASTIC Default Rating	DRASTIC Default Typical Rating	Customized Rating
Confining Layer	1	1	1
Clay	2-6	3	2
Silt	2-6	3	3
Loam	4-8	6	4
Sand	6-9	8	6
Gravel	6-9	8	9

2.2.3.2. *Data and Calculations*

GIS data for the vadose zone media was calculated using SCVWD's database of lithology data for wells, and the GIS depth to water data discussed in Section 2.2.1. First, the depth to water values were extracted from the GIS data at each well where lithology data were available. The lithology data set was then filtered to remove data below the depth to water, so that only lithology data for the unsaturated vadose zone remained. The lithology information at each location was then categorized and assigned hydraulic conductivity values using values from Fetter (1994) as shown in Table IV-2-3. For soil types that include multiple grain sizes, the category was selected based on the best representation of hydraulic conductivity, which generally corresponds to the fine-grained material.

Net vertical hydraulic conductivity at each location was then calculated using the following equation (Fetter, 1994):

$$\left[\text{net hydraulic conductivity}\right] = \frac{\sum_{m=1}^{n}\left[\text{layer thickness}\right]_m}{\sum_{m=1}^{n}\frac{\left[\text{layer thickness}\right]_m}{\left[\text{layer hydraulic conductivity}\right]_m}}$$

This equation combines the hydraulic conductivities for each lithologic layer into a single value at each location. The net hydraulic conductivities were then converted back into a soil type using the value ranges listed in Table IV-2-3. Those values were then developed into a data set for the entire study area using thiessen polygons. The net result is a distribution of soil types that adequately characterize the vadose zone over the study area. In all confined areas, the vadose zone rating was set to 1, because the confining layer controls this input for those areas.

The impact to vadose ratings for Santa Clara and Llagas Groundwater Subbasins are shown on Figures IV-2-6 and IV-2-7. Impact of vadose zone media is given a weighting factor of 26%. The weighting factor is determined using a calibration method with the soil attenuation model. Section 2.4 describes in detail the procedure for establishing the weighting factor.

2.3. Omitted Evaluation Criteria

Several input factors that are included as part of the standard DRASTIC evaluation process were not included in the adapted version for this study. Those factors and the rationale for their omission from this study are discussed below.

2.3.1. Net Recharge

Net recharge is the amount of water per unit area that percolates from the surface to the groundwater and is typically represented by precipitation. In this study, irrigation serves as an additional source of recharge. Recharge water is the main vehicle for leaching and transporting contaminants downward. The greater the net recharge, the greater the potential for transport of contaminants to groundwater.

Net recharge is not included in this evaluation. Net recharge for this study is predominantly water from irrigation rather than precipitation. In the pilot study, nearly 80% of water at the surface was from irrigation. The remaining 20% was from precipitation. Geographically, the water needs for similar types of vegetation are not expected to vary greatly across the Santa Clara and Llagas Subbasins. This is because reference evapotranspiration rates, associated with irrigation rates, are the same throughout the study area (CIMIS, 1999). In addition, the landscaping and irrigation rates may be modified at any time by property owners, making it inappropriate to set a fixed value for net recharge at any location. Annual precipitation rates in the Santa Clara and Llagas Subbasins, from 1961 to 1990, approximately range from 5 to 25 inches per year (Natural Resources Conservation Services, 1961 to 1990). Precipitation can vary within the study area but the variation is minimized by the larger contribution from irrigation.

2.3.2. Topography

Topography in DRASTIC is the land surface's slope and slope variability. A pollutant is less likely to infiltrate into the soil when the land surface is more sloped. Steeper slopes also generally signify higher groundwater velocity.

Topography is not included in this evaluation. Topography in DRASTIC refers to slope and slope variability on a large scale of a regional area, which can influence the overall infiltration rate. But for this study, recycled water infiltration is more affected by local topography of each landscaped site. Higher infiltration of recycled water occurs in small-scale low points in the site topography. However, this level of detail for topography is not available as GIS data, nor is it practical to assemble data at this scale. Topography at this level can also be modified by property owners during construction activities, so it cannot be considered constant.

In addition, Title 22 regulations for recycled water use prohibit any runoff of recycled water from the recycled water use area, unless the runoff does not pose a public health threat and is authorized by the regulatory agency (Title 22, §60310 (e)). Therefore, large-scale topography would not have a significant impact on recycled water infiltration.

2.3.3. Aquifer Media and Hydraulic Conductivity of Aquifer

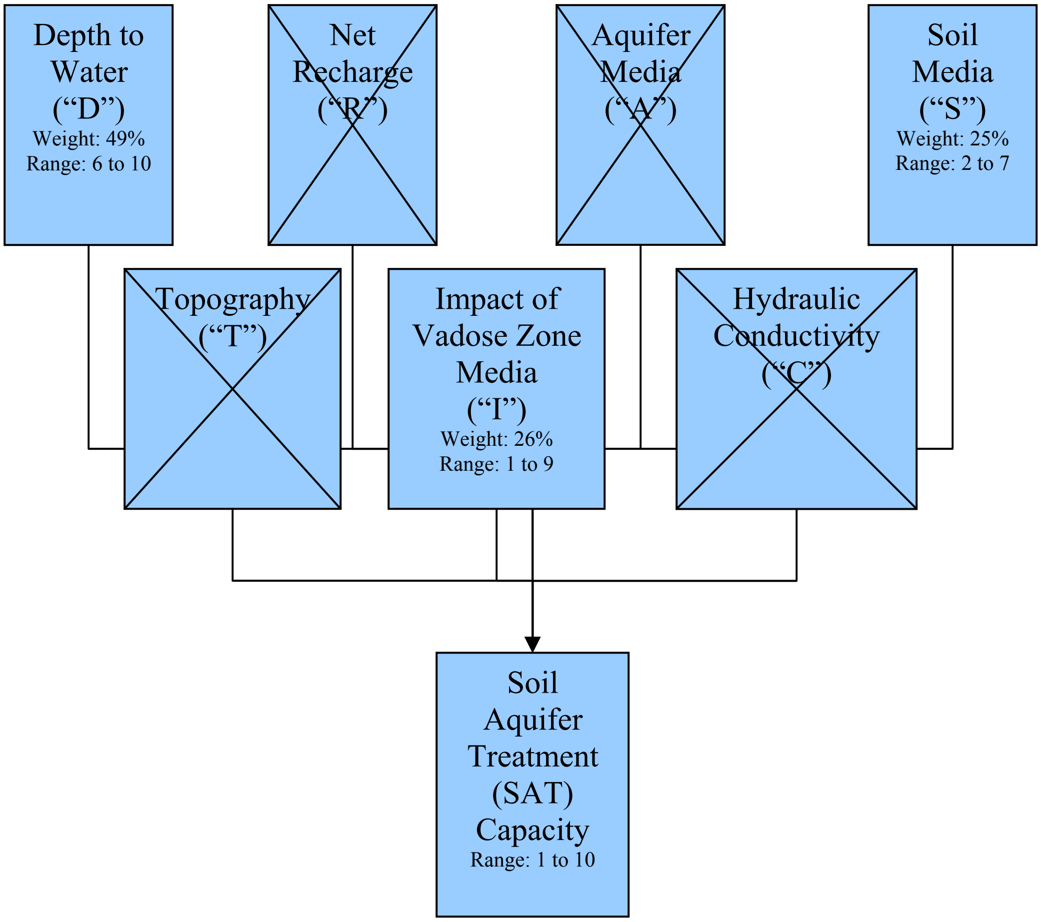
The aquifer media refers to the consistency of the porous material comprising the aquifer. Attenuative processes that can take place in the aquifer include sorption, transformation, and dispersion. The media of the aquifer determines the flow path and path length which in turn determines amount of time for attenuation. Larger grain sizes of the aquifer media correspond with higher porosity, which generally leads to higher permeability. Aquifers with high permeability are associated with lower attenuation capacity due to the decrease in soil contact time, which reduces any potential attenuation and increases potential for a contaminant to migrate quickly. Aquifer media also influences attenuation due to the effective surface area of the media.

The hydraulic conductivity of the aquifer refers to the permeability of the aquifer. For a given hydraulic gradient and hydraulic conductivity, the groundwater flow rate can be determined. Higher values of hydraulic conductivity are associated with lesser soil aquifer treatment capacity due to less time within the aquifer for attenuative processes to occur and greater potential for contaminants to travel. Attenuative processes that can take place in the aquifer include sorption, transformation and dispersion.

Aquifer media and hydraulic conductivity of aquifer are not included in this evaluation. Both of these inputs are criteria associated with treatment within the aquifer. Since the focus of this evaluation is the attenuative capacity before reaching groundwater, aquifer-related attenuation is not considered.

2.4. Weighting and Rating System Flowchart

The evaluation system comprises three factors each assigned a rating which can range from 1 to 10. Each factor is also weighted by a percentage based on the importance of the factor evaluated. The numerical evaluation allows for comparison of different areas for recycled water use in irrigation. Below is a flow chart of the variables used to determine SAT capacity.



Notes:
1) The seven factors above are the original DRASTIC inputs. Four of these factors are crossed indicating that they are not used in evaluating the SAT capacity.
2) Weight is the weighting or contribution assigned to the factor in determining the SAT capacity.
3) Range is the set of values that are valid for the factor or SAT capacity.

2.5. Calibration of Input Weightings

To determine the weighting of each input into the modified DRASTIC evaluation, the soil attenuation model from Volume II was used. A baseline scenario was used in the model to represent average conditions observed within the study area. Modifications were made individually to one of the evaluated model inputs (depth to water, soil media, and vadose zone media) to determine the net effect of that input on the modeled groundwater concentrations.

For the baseline scenario, the depth to groundwater was 40 feet (12.2 meters), with the first 6.6 feet (2 meters) defined as the soil media and the remaining soil profile as the vadose zone. The depth to groundwater of 40 feet is a median value for the study area, where it ranges from 0 to 100 feet. Silt was used as the baseline soil type for soil media and vadose zone. Silt is also a median value given the range of soil types observed in the study area. Attenuation levels were evaluated at the 40 foot depth and at the 50-year time frame. Chloroform was used as the constituent modeled. Chloroform, as seen in the soil attenuation model in Volume II, behaved in a manner that was consistent with the bench test and pilot study findings.

Using the base conditions as a starting point, the model inputs were then adjusted to determine differences in attenuation resulting from those changes. The core concept of this calibration is that relative to each factor, the weighting is proportional to the change in attenuation per unit change in rating. An alternative way this can be stated is the weighted change in rating per unit change in attenuation from each input contributes equally to the soil aquifer treatment capacity. Mathematically, this can be expressed as:

$$\frac{W_D \times \Delta \text{Rating}_D}{\Delta \text{Attenuation}_D} = \frac{W_S \times \Delta \text{Rating}_S}{\Delta \text{Attenuation}_S} = \frac{W_I \times \Delta \text{Rating}_I}{\Delta \text{Attenuation}_I}$$

and

$$W_D + W_S + W_I = 100\%$$

Where:
W = percent weight of input.
ΔRating = change in rating of input.
ΔAttenuation = change in attenuation of input.
D = depth to groundwater input. (discussed in Section 2.2.1)
S = soil media input. (discussed in Section 2.2.4)
I = impact of vadose zone media input. (discussed in Section 2.2.6)

Following these equations, the weighting of each input was determined using the modeled changes in attenuation caused by fixed changes in inputs. For the depth to groundwater input, the calibration used the attenuation difference from the 40 foot depth to the 5 foot depth. For the soil media, the calibration used the attenuation differences from silt to clay. For the impact of vadose zone media, the calibration used the attenuation differences from silt (silt loam was the appropriate category for this input) to clay.

The calibration determined the relative weighting of depth to groundwater, soil media, and impact to vadose zone to be 49%, 25%, and 26% respectively. Calculations and results of the calibration are displayed in Table IV-2-4. Graphs from the soil attenuation model used to determine the attenuation achieved are displayed in Figures IV-2-8 to IV-2-10.

2.6. Soil Aquifer Treatment Capacity Zones

Using the ratings and weighting factors discussed above, the relative soil aquifer treatment capacity is calculated as follows:

$$\begin{aligned}\left[\text{Soil Aquifer Treatment Capacity}\right] = {} & \left[\text{Weighting Factor for Depth to Water}\right] \times \left[\text{Depth to Water Rating}\right] + \\ & \left[\text{Weighting Factor for Soil Media}\right] \times \left[\text{Soil Media Rating}\right] + \\ & \left[\text{Weighting Factor for Impact to Vadose Zone}\right] \times \left[\text{Impact to Vadose Zone Rating}\right]\end{aligned}$$

After the calculation using the above equation, the values are rescaled such that the worst capacity found in the study area is set to 10 and the best capacity found in the study area is set 1. The unscaled range was found to be from 3.7 to 8.21. The net distribution of soil aquifer treatment capacity for the Santa Clara and Llagas Groundwater Subbasins are shown on Figures IV-2-11 and IV-2-12. The following is a description of the rating of the soil aquifer treatment capacity.

1 to 2 – High Capacity

A rating of 1 or 2 denotes areas with the highest capacity to attenuate constituents of recycled water relative to the range of hydrogeological conditions in the evaluation. These areas contain physical characteristics that are most ideal for the application of recycled water and protection of groundwater sources.

3 to 4 – Good Capacity

A rating of 3 or 4 denotes areas with good capacity to attenuate constituents of recycled water relative to the range of hydrogeological conditions in the evaluation. These areas contain physical characteristics that provide reasonably good capacity for soil aquifer treatment of recycled water constituents.

5 to 6 - Average Capacity

A rating of 5 or 6 denotes areas with average capacity to attenuate constituents of recycled water relative to the range of hydrogeological conditions in the evaluation. These areas contain physical characteristics that may provide some capacity for soil aquifer treatment of recycled water constituents.

7 to 8 - Marginal Capacity

A rating of 7 or 8 denotes areas with marginal capacity to attenuate constituents of recycled water relative to the range of hydrogeological conditions in the evaluation. These areas contain physical characteristics that have less capacity for soil aquifer treatment of recycled water constituents.

9 to 10 - Least Capacity

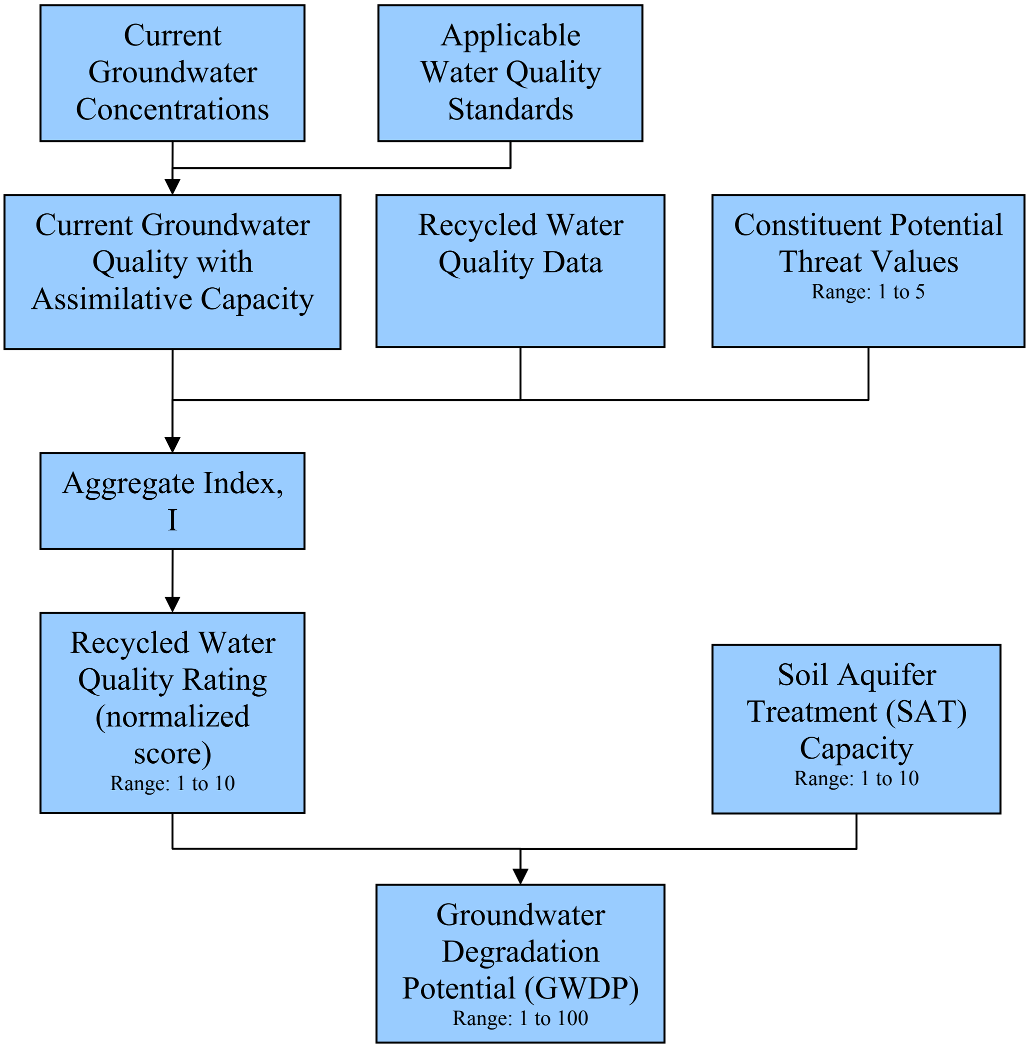
A rating of 9 or 10 denotes areas with the least capacity to attenuate constituents of recycled water relative to the range of hydrogeological conditions in the evaluation. These areas contain physical characteristics that are least ideal for soil aquifer treatment of recycled water constituents.

3. POTENTIAL TO DEGRADE GROUNDWATER QUALITY

Chapter 3 describes the methodology to determine the potential for recycled water as an irrigation source to degrade groundwater quality. The evaluation to determine the potential to degrade groundwater quality is directly related to the soil aquifer treatment capacity but also includes consideration of the quality of the recycled water.

3.1. Methodology

Methodology for determining groundwater degradation potential is a multiplicative rather than an additive approach of ratings from two evaluation criteria. The evaluation incorporates two inputs: 1) the soil aquifer treatment capacity, discussed in Chapter 2, and 2) the quality of the recycled water used for irrigation. The multiplication of these two ratings provides a range of the groundwater degradation potential up to maximum value of 100. This potential is calculated by multiplying the ratings so that a low rating in either input (meaning either excellent soil aquifer treatment capacity or very high quality recycled water), would result in relatively low groundwater degradation potential. Conversely, higher ratings for both inputs would cause a synergistic effect with significantly increased degradation potential if soil aquifer treatment capacity and recycled water quality are both low. Below is a flow chart of the variables used to determine the groundwater degradation potential.



3.2. Evaluation Criteria

3.2.1. Soil Aquifer Treatment Capacity

Soil aquifer treatment capacity was determined from Chapter 2 of this volume. SAT capacity incorporates hydrogeological parameters to rate the ability to attenuate recycled water constituents. Soil aquifer capacity rating ranges from one to ten, ten being the worst in terms of soil aquifer treatment capacity. The soil aquifer treatment capacity is a key input for evaluating the potential for recycled water to degrade groundwater quality.

3.2.2. Recycled Water Quality Rating

The recycled water quality is a necessary input for determining the groundwater degradation potential. Soil aquifer treatment capacity does not include consideration of the quality of the recycled water applied. Quality is dependent on the concentrations of the constituents found in the recycled water. Generally, the higher the quality of water of a given source is, the less potential for groundwater to be degraded. Groundwater is regarded as degraded when the quality becomes worse than the current groundwater quality, with consideration of assimilative capacity. For the constituents evaluated in this study, this would occur if the concentrations in groundwater increase from current values beyond the available assimilative capacity.

Because recycled water quality is represented by a range of constituents, there is a need to develop an aggregate water quality rating that can be calculated from the available concentration data for each recycled water source. The rating of the recycled water quality is determined using three types of information: 1) current groundwater quality in the study area, 2) the concentrations in recycled water, and 3) the relative threat of each constituent determined in Volume III of this study.

3.2.2.1. Current Groundwater Quality

Current groundwater quality is important in considering potential for groundwater degradation. For this study, mean groundwater concentration data and the assimilative capacity are used to represent the groundwater quality of the study area.

3.2.2.1.1.Groundwater Concentrations

Data used in this evaluation for groundwater quality was derived from SCVWD's database, and included data from 1973 to 2007. Additional data from the California Groundwater Ambient Monitoring and Assessment (GAMA) program (Ray et. al., 2009) and the pilot study baseline data from Volume III were also included to supplement SCVWD data. Statistics of the resulting dataset are found in Table IV-3-2.

For constituents with less than fifty available records in the SCVWD database, available data from the California GAMA program and pilot study were used. For the GAMA program, only data from wells located in the Santa Clara County were extracted. Where the accumulated data set is sufficient to quantify separate mean groundwater concentrations for Santa Clara and Llagas Groundwater Subbasins, the mean groundwater concentration is calculated separately for each subbasin. If the data set for a given constituent has less than 10 records for either groundwater subbasin, the mean groundwater concentration for the entire study area is used for both subbasins.

For the purpose of calculating mean groundwater concentrations, values below the reporting limit (nondetects) are taken as a value of zero. Using this approach, the mean concentration for a constituent may be less than the reporting limit. Where this occurs, the representative groundwater quality is taken to be the reporting limit. Table IV-3-2 contains the typical reporting limits, which are based on the data from the bench test and pilot study. The representative groundwater concentrations used for this evaluation are also listed on Table IV-3-2.

For biological parameters E. Coli, fecal, and total coliforms, the data is presented as frequency of detection rather than mean value. Frequency of detection was considered to be a more appropriate value for this evaluation than the mean value, because it is used frequently for water quality standards. Biological parameters are inherently different from the other constituents in recycled water and are evaluated in a different manner.

3.2.2.1.2.Assimilative Capacity

Assimilative capacity refers to the capacity of groundwater to receive pollutants without reducing the beneficial use (California SWRCB, 2009). For landscape irrigation projects using recycled water, the SWRCB states that the assimilative capacity is to be estimated by the project proponent and a salt and nutrient management plan is to be prepared. In the absence of a specific salt and nutrient management plan for the study area, the calculation of assimilative capacity for this study is as defined by SWRCB for groundwater recharge projects. Numerically, assimilative capacity for recharge projects is the difference between the mineral water quality objective and the average groundwater concentration of the subbasin, over the most recent five years of data available. The mineral water quality objectives are limits of acceptable water quality for beneficial use. If the current groundwater quality is better than the water quality objectives then there is assimilative capacity.

For this evaluation, water quality objectives are compiled using various regulatory standards and guidelines in the following order of priority:

- California Primary Maximum Contaminant Level (MCL)
- Federal Primary Maximum Contaminant Level (MCL)
- Federal Secondary Maximum Contaminant Level (MCL)
- Department of Public Health Notification Level
- Public Health Goal (CA OEHHA)
- EPA's Maximum Contaminant Level Goal
- EPA Health Advisory

These values for recycled water constituents are shown on Table IV-3-1. Where a limit for a given constituent is specified by multiple standards, the standard with the higher priority takes precedence. This means that the water quality objective is not necessarily the lowest limit found among the list of standards and guidelines. The calculation of assimilative capacity using the groundwater concentrations and water quality standards is shown on Table IV-3-1. Where the groundwater concentration is greater or equal to the water quality standard, the assimilative capacity is zero.

For consistency with the SWRCB Recycled Water Policy (SWRCB, 2009), this evaluation allows the use of up to 20 percent of the available assimilative capacity by multiple landscape irrigation projects. Calculations of representative groundwater concentrations with 20 percent of the available assimilative capacity are shown in Table IV-3-1.

3.2.2.2. Recycled Water Quality Data

Recycled water data is needed to measure the relative quality of the water against the representative groundwater quality. Water quality data of the recycled water from the four treatment plants can be found in the *Literature Review and Data Analysis* (Volume I of this report). Summarized data, ranging from 2001 to 2007, of the recycled water constituents from the four treatment plants are shown in Table IV-3-2. Mean data are calculated from sample sizes ranging from 1 to 21 samples. Appendix IV-A includes plot summaries of the available recycled water quality data and conveys the differences in recycled water quality between the four treatment plants. Data for the SJSC WPCP and SCRWA is also supplemented with data from the pilot study and bench test documented in Volume II and III. To be consistent with the calculation of representative groundwater concentration, as discussed in Section 3.2.2.1, nondetect values are evaluated as zero for the purpose of calculating mean recycled water concentrations.

The concentrations of recycled water constituents vary between different sources. Within the subbasins, recycled water is derived from four sources: the Palo Alto Regional Water Quality Control Plant (PARWQCP), Sunnyvale Water Pollution Control Plant (SWPCP), San Jose/Santa Clara Water Pollution Control Plant (SJ/SC WPCP), and the South County Regional Wastewater Authority (SCRWA). Current use of recycled water is geographically limited and thus recycled water is not used everywhere in the subbasins. To identify the potential for degradation throughout the subbasins, the study hypothetically assumes that recycled water is used everywhere in the subbasins. Because there are multiple sources of recycled water, the study uses city boundaries to distinguish which sources of recycled water could be applied in each area. SCRWA is hypothetically assumed to provide recycled water to the Llagas Subbasin which includes the cities of Gilroy and Morgan Hill and all unincorporated areas. Currently, SCRWA recycled water customers are within a small area of the Llagas Subbasin. In the Santa Clara Subbasin, recycled water is assumed to be largely derived from SJ/SC WPCP and to a lesser degree from PARWQCP and SWPCP. This evaluation assumes the city of Palo Alto and Stanford University receive recycled water from the PARWQCP. In Sunnyvale, Mountain View, Los Altos, and Los Altos Hills, recycled water is assumed to originate from SWPCP. Other cities within the Santa Clara Subbasin, including San Jose, Santa Clara, Milpitas, Campbell, Cupertino, Los Gatos, Saratoga, and Monte Sereno are assumed to receive recycled water from the SJ/SC WPCP. The assumed potential distribution of recycled water sources is shown on Figures IV-3-1 and IV-3-2 for both groundwater basins.

For the SWPCP and PARWQCP, not all constituent concentration data are available for these recycled water sources. Where this occurs, mean concentration values from the SJ/SC WPCP are used as a surrogate. While SJ/SC WPCP services a much larger area which includes more industrial activity than the area served by SWPCP and PARWQCP, the treatment trains at the three plants are similar. Therefore, the SJ/SC WPCP recycled water concentrations provide a reasonable surrogate for SWPCP and PARWQCP recycled water concentrations if actual concentration data are not available. Values should be replaced with actual measured concentrations if they become available. However, there are only a few constituents where this assumption needed to be applied, and the overall impact on the results of the evaluation is expected to be relatively minor. The values where this was applied can be seen in Table IV-3-2 where the count for the data is reported as zero.

3.2.2.3. Threat Values

The threat value for each constituent was determined in the *San Jose Pilot Study* (Volume III) and is displayed in Table IV-3-2. The threat to groundwater of each constituent of concern is based on the findings from the pilot study and the bench test. The threats range from 1 to 5, with 5 representing the highest relative threat. The criteria for assigning each threat are generally determined on the observed attenuation of the constituent in the pilot study and bench test, and the type of constituent. The type of constituent can range from general water quality parameters like alkalinity and DO, to emerging contaminants like NDMA and PFCs. The potential health impact of each constituent is also evaluated in assigning the threat. The threat assigned for each constituent below is a combination of these factors. For constituents where behavior was not well observed due to a low occurrence in the source water, a threat of three was assigned. This central value is selected to indicate that although the low occurrence in recycled water may result in lower potential to impact groundwater, the potential for this constituent to migrate to groundwater may be significant if present.

A low threat indicates that the given constituent has shown minimal potential to impact groundwater in the pilot study. A higher threat indicates that the constituent in recycled water has shown significant potential to impact groundwater and may need to be taken into consideration in future recycled water irrigation use.

Some monitored constituents were not consistently detected in the recycled water source during the pilot study or bench test; therefore the threat of these constituents was regarded as inconclusive. Constituents that fall into this category include E. Coli, nitrilotriacetic acid (NTA), perchlorate, cyanide, and terbuthylazine. For the evaluation purposes of determining recycled water quality in Volume IV, the constituents with inconclusive determinations are assigned a default threat of 3, which is an average value within the 1 to 5 threat range. This default value may be reassigned to a more appropriate value if further studies provide provide more information on the potential threat of a given constituent.

3.2.2.4. Calculation Method

The above three factors, current groundwater quality with assimilative capacity (Section 3.2.2.1), recycled water concentrations (Section 3.2.2.2), and threat (Section 3.2.2.3), are used to calculate the recycled water quality rating. The method for determining recycled water quality follows a published aggregation index method (Swamee and Tyagi, 2000 and 2007). The aggregation method aims to avoid ambiguity, eclipsing, and rigidity issues. Ambiguity issues occur when all subindices indicate acceptable water quality, but the aggregate index does not. Eclipsing issues occur when the aggregated index fails to reflect poor water quality of one or more of the water quality variables. Rigidity issues occur when the aggregation function does not allow for new variables to be added to the aggregated index. All of these issues are minimized by the applied aggregation method described below.

The aggregation index, I, can be expressed as:

$$I = \left(1 - N + \sum_{i=1}^{N} s_i^{-1/k}\right)^{-k}$$

Where:

I = Aggregate index of the recycled water quality.

N = Number of subindices considered. In this study, the number of subindices corresponds to the number of constituents evaluated in this method (N=39).
s = Subindex for the individual constituent (calculated as described below).
k = Aggregation exponent, derived as $k = \frac{1}{\log_2(N-1)}$ using an assigned central value for the aggregate index (Swamee, 2007).

The subindices are based on the constituent concentrations, and can be calculated using several methods. For subindices that monotonically decrease with their water quality concentrations, Swamee and Tyagi (2000) recommend the following equation. This equation is recommended as the most appropriate when water quality is consistently considered lower for higher concentrations.

$$s = \left(1 + \frac{q}{q_c}\right)^{-m}$$

Where:

q = Quality of the constituent, which is taken to be the difference between the constituent concentration in recycled water and q_c. q is set to zero if the recycled water concentration is lower than q_c.
q_c = Representative groundwater quality, which is the current groundwater concentration of the given subbasin with 20 percent of the available assimilative capacity as calculated in Table IV-3-1.
m = Subindex exponent.

The subindex exponent, m, varies for each constituent, and it reflects the contribution of the constituent subindex to the overall aggregate index, I. For the purpose of this study, the subindex exponents were correlated to the threat of each constituent, as determined in Volume III (see Section 3.2.2.3). The appropriate distribution for this value was determined to be a positively-correlated function (i.e. increasing threat values cause an increasing impact to the aggregate index). Constituents assigned a threat of 1 should have a negligible effect on the aggregate index. Constituents assigned a threat of 5 should have the most significant effect on the aggregate index.

Using a polynomial distribution, the following function is derived for the subindex exponent:

m = [threat] × ([threat] – 1) × [mscale].

Using this equation, the value for mscale was determined by maximizing the range in aggregate scores between the four recycled water sources. The aggregate indices converge to the same value for high or low values of mscale. For this evaluation, the difference between the aggregate indices was maximized in order to best demonstrate the quality differences between the recycled water sources. The optimized value for mscale was 0.021218. The derivation of this value is shown in Figure IV-3-5.

Per Swamee, the resulting aggregate index, I, ranges from 0 to 1 such that 1 is indicative of high quality water and 0 is indicative of poor water quality. To refit the index for the needs of this study, a modified aggregate index, 1-I (i.e. one minus the aggregate index) is used to represent higher water quality with a decreasing numerical value. The modified aggregate index is rescaled on a range from 1 to 10 using the modified aggregate index of the representative groundwater quality and maximum observed recycled water quality as the minimum and maximum boundary conditions.

Recycled water quality ratings are determined for the recycled water from the four treatment plants in the study area. The results of this calculation are summarized below. Table IV-3-3 summarizes the calculations and results with greater detail.

Parameter	PARWQCP	SCRWA	SJ/SC WPCP	SWPCP
Aggregate Index, I (per Swamee)	0.16	0.37	0.16	0.31
Modified Aggregate Index, 1 – I	0.84	0.63	0.84	0.69
Recycled Water Quality	9.61	7.45	9.63	8.08

Not all constituents were included in the calculation of the recycled water quality ratings. Total alkalinity, bicarbonate alkalinity, dissolved oxygen, total chlorine, oxidation reduction potential, and pH are general water quality parameters and are not included in the analysis. To avoid double counting, total dissolved solids (TDS) was not included in the analysis because TDS is the sum of other constituents that are already included in the evaluation. Heterotrophic plate count was excluded because the accuracy of that analysis makes use of those values unsuitable for quantifying comparisons between water sources.

3.3. Assumptions

Because the pilot study threat values were determined based on conditions at the IDT site (including the site's landscape irrigation), the groundwater degradation potential evaluation assumes similar conditions as the pilot study, including the irrigation rate. Irrigation for general landscape is assumed for this evaluation. General landscaping includes turf grass and small shrubs, which are most common through the study area. The rate of irrigation at the pilot study site was 38.7 inches per year and is similar to the recommended application rate for the site (ITAP, 2006). Landscaping that requires irrigation with a different annual application rate (i.e. vegetation that have greater or lesser water needs) may change the potential to degrade groundwater. Generally, less irrigation with recycled water means less potential for groundwater degradation and more irrigation with recycled water means more potential for groundwater degradation.

3.4. Zones

Groundwater degradation potential is calculated using the inputs described above as follows:

[Groundwater Degradation Potential] = [Soil Aquifer Treatment Capacity] × [Recycled Water Quality Rating]

The net distribution of the relative rating for groundwater degradation potential for the Santa Clara and Llagas Groundwater Subbasins are shown on Figures IV-3-3 and IV-3-4. The following is a description of the relative ratings of the groundwater degradation potential.

1 to 20 – Lowest Potential

A rating of 1 to 20 denotes areas with the least potential for recycled water application to degrade groundwater relative to the range of hydrogeological conditions and recycled water qualities in the study area. The combination of the area's physical characteristics and the local recycled water source is ideal for irrigation using recycled water.

21 to 40 – Low Potential

A rating of 21 to 40 denotes areas with low potential for recycled water application to degrade groundwater relative to the range of hydrogeological conditions and recycled water qualities in the study area. These areas contain characteristics that provide reasonably good capacity for soil aquifer treatment of recycled water constituents of the given local recycled water source. The potential for recycled water to impact groundwater in these areas is comparatively low.

41 to 60 - Average Potential

A rating of 41 to 60 denotes areas with average potential for recycled water application to degrade groundwater relative to the range of hydrogeological conditions and recycled water qualities in the study area. These areas contain characteristics that may provide some capacity for soil aquifer treatment of recycled water constituents of the local source. However, there is potential for groundwater to be impacted by some recycled water constituents.

61 to 80 – High Potential

A rating of 61 to 80 denotes areas with significant potential for recycled water application to degrade groundwater relative to the range of hydrogeological conditions and recycled water qualities in the study area. These areas contain characteristics that have relatively marginal capacity for soil aquifer treatment and/or a relatively high concentration of constituents of the local recycled water. There is likelihood of one or more recycled water constituents impacting groundwater in these areas.

81 to 100 – Highest Potential

A relative rating of 81 to 100 denotes areas with the greatest potential for recycled water application to degrade groundwater relative to the range of hydrogeological conditions and recycled water qualities in the study area. These areas contain characteristics that are least ideal for soil aquifer treatment and/or likely have a high concentration of constituents of the local recycled water. Potential for recycled water constituents to impact groundwater sources is regarded as highest.

3.5. Limitations

Development of the zones for the potential to degrade groundwater is specific to current recycled water quality from the PARWQCP, SWPCP, SJ/SC WPCP, and SCRWA treatment plants. With the exception of the data collected during this study, the current recycled water quality data span from 2001 to 2007. Changes in recycled water quality, whether improved or worsened, will affect the groundwater degradation potential of recycled water application. Changes in recycled water quality can be caused by a switch to a different local recycled water source, modification of the treatment plant process, or change in quality of the received wastewater.

Threat values for this study were determined for each recycled water constituent based on available data from the bench test and pilot study. Both of those investigations had limitations in how they represent various physical conditions and long-term fate and transport of recycled water constituents. Those limitations are discussed in Volumes II and III of this report. Additional long-term monitoring under other site conditions may reveal that some constituents are more or less of a threat compared to what was concluded from the bench test and pilot study. Revisions to the threat levels would affect the overall recycled water scores and hence the groundwater degradation potential.

Development of the potential groundwater degradation zones is reliant on constituents with current and available data and information. For constituents with only a handful of sample data, the evaluation can be strengthened with ongoing monitoring for either recycled water or groundwater. Both recycled water and groundwater concentrations are used to derive the recycled water scores. In addition, there is the possibility of new contaminants which are not yet identified. As new contaminants are discovered, this analysis can be updated to reflect the groundwater degradation potential introduced by the new contaminant.

4. DISCUSSION

4.1. Soil Aquifer Treatment Capacity

Soil Aquifer Treatment (SAT) capacity maps are found in Figure IV-2-11 and IV-2-12 for the Santa Clara and Llagas Subbasin respectively. Based on a relative scale, the SAT rating in the Santa Clara Subbasin ranges from 1 to 10 (high to least capacity). In the Llagas Subbasin, the SAT rating ranges from 1 to 9.4. In both subbasins, the confined areas were determined to have relatively high capacity due to the confining layer and deep depth to groundwater. The unconfined areas were largely of good or average capacity. Only a few areas in the unconfined areas were regarded as having relatively marginal capacity and even fewer areas were regarded as least capacity. Areas with a lower rating tended to be characterized with shallow depth to water and a coarse grain size distribution in the vadose zone.

The SAT capacity map (Figure IV-2-11) shows a value of 5 for the IDT site, which indicates average SAT capacity. For comparison, direct calculation of the SAT capacity at the IDT site using site-specific data gives a rating of 2.5, indicating relatively good treatment capacity, which corresponds well with the findings from the pilot study. IDT has an approximate depth to groundwater of 35 feet (D = 7.0). The soil media and vadose zone media at IDT site is uniformly clay (S = 2, I = 2). A SAT rating of 2.5 is regarded as good capacity where the physical characteristics of the area provide good capacity for attenuation of recycled water constituents. This corresponds with the pilot study findings, which showed that there was reasonably good attenuation across depth for several constituents during the pilot study period. However, there were a few recycled water constituents that showed low concentrations in the groundwater, indicating that conditions were not ideal for recycled water application. The pilot study findings support the SAT rating, verifying the appropriateness of the methodology. The SAT values calculated using site-specific data (2.5) and the regional averaged approach (5) do not match exactly because the SAT capacity maps used basin-wide data to evaluate areas on a larger scale. The SAT capacity maps may not capture site-specific detail, however they provide a general indication of the SAT capacity for the area. These maps can be refined to reflect site-specific information as more data becomes available.

4.2. Groundwater Degradation Potential

Groundwater degradation potential maps are found in Figures IV-3-3 and IV-3-4 for the Santa Clara and Llagas Subbasin respectively. Groundwater degradation potential in the Santa Clara Subbasin is largely of lowest to average potential with a few areas regarded as high or highest. The rating in the Santa Clara Subbasin ranges from 8 to 96. Groundwater degradation potential in the Llagas Subbasin is largely of lowest to average potential and with a few areas regarded as high. The evaluation did not find any areas of the highest groundwater degradation potential in the Llagas Subbasin. In the Llagas Subbasin, the groundwater degradation potential rating ranges from 11 to 70. Comparatively, the Santa Clara and Llagas Subbasins share a similar distribution in groundwater degradation potential with a majority of lowest and low potential found in the confined areas and more average potential in the unconfined areas.

The groundwater degradation potential map (Figure IV-3-3) shows a value of 48.9 for the IDT site, which indicates average groundwater degradation potential. For comparison, direct calculation of the groundwater degradation potential at the IDT site using site-specific data gives a rating of 24, which indicates low groundwater degradation potential and corresponds well with the findings from the pilot study. At the IDT site, the SAT capacity rating is calculated as 2.5 using site-specific data, indicating relatively good capacity. At the IDT site, the recycled water was derived from the SJ/SC WPCP which was determined to have a recycled water quality rating of 9.62. A groundwater degradation potential of 24 is regarded as low potential, but some potential exists for groundwater degradation. The rating agrees with the results of the pilot study. For the given recycled water quality from the SJ/SC WPCP, there was a significant number of constituents that appeared to exhibit removal with depth. However, a few constituents were observed in groundwater, indicating some potential to degrade groundwater long-term (18 months). Overall, the pilot study agrees with the rating of the groundwater degradation potential, verifying the appropriateness of the methodology. While the pilot study is complete, groundwater sampling at the pilot study site is ongoing. The evaluation made in this volume can be updated as ongoing monitoring yields new data.

Similar to SAT, the GWDP values calculated using site-specific data (24) and the regional averaged approach (48.9) do not match exactly.. The GWDP maps used basin-wide data to evaluate areas on a larger scale. The GWDP maps may not capture site-specific detail, however they provide a general indication of the GWDP for the area. As with the SAT maps, the GWDP maps can be refined to reflect site-specific information as more data becomes available.

4.3. Comparison to the Groundwater Vulnerability Study

While the goals of the Groundwater Vulnerability Study (SCVWD, 2010) and this study are uniquely different, there is some similarity in the approach and the input parameters. The vulnerability study examined the Santa Clara, Coyote, and Llagas Subbasins with the goal of evaluating the sensitivity and vulnerability of the groundwater. In the vulnerability study, groundwater sensitivity is defined as the relative ease with which a contaminant on or near the land surface can migrate to the aquifer of interest. Sensitivity is a function of the aquifer properties (i.e. hydraulic conductivity, porosity, and hydraulic gradient) and the associated sources of water and stresses to the groundwater system (i.e. recharge, travel through the unsaturated zone, and well pumping). Contrasting to the vulnerability study, the soil aquifer treatment capacity and groundwater degradation potential were evaluated in the context of expanding the use of recycled water for irrigation in the study area. The study looked specifically at constituents that are found in recycled water and irrigation was the main driver of vadose zone percolation.

The most similar evaluation to the SAT capacity is the sensitivity assessment from the vulnerability study. Input parameters for the sensitivity assessment included (1) soil media characteristics in the vadose zone, (2) groundwater recharge, (3) depth to top of the aquifer, and (4) annual groundwater production. The SAT capacity assessment presented in this report did not include groundwater recharge or annual groundwater production. Groundwater recharge was omitted in the SAT capacity assessment because for the purpose of determining SAT capacity with respect to recycled water use, the main contributor to groundwater recharge is irrigation of recycled water. In the vulnerability study, the groundwater recharge component included both managed recharge and precipitation. Annual groundwater production was not evaluated for SAT capacity because the value is intended to represent attenuation within the vadose zone, as opposed to within the vadose zone and aquifer.

For the sensitivity of the principal aquifer, the Groundwater Vulnerability Study determined that the sensitivity was nine and ten (high) in the majority of the Llagas Subbasin. In the Santa Clara Subbasin, the sensitivity ranged from one (low) to nine. The northern most section of the subbasin was regarded as low sensitivity. The most sensitive areas within the Santa Clara Subbasin are the western side of the confined area and portions of the unconfined areas. Comparing the two subbasins, the vulnerability study determined that the Llagas Subbasin was more sensitive than the Santa Clara Subbasin. The soil aquifer treatment map indicates the highest capacity for SAT in the confined areas in both subbasins. The Llagas subbasin generally did not have less SAT capacity than the Santa Clara Subbasin. Variation between the maps from the two studies may be attributed to the differences in the input parameters (i.e. groundwater recharge and groundwater production) used and the difference in the goal of the respective study. The Groundwater Vulnerability Study assessed general groundwater sensitivity to contaminants while the goal of this study is to assess the degradation potential of groundwater specifically from recycled water use as an irrigation source.

5. CONCLUSION

Using a developed and calibrated methodology, and data collected from previous phases of the study, values of soil aquifer treatment capacity and groundwater degradation potential were calculated for the entire study area.

Soil aquifer treatment in the Santa Clara and Llagas Subbasin ranged from least to high capacity. Areas with the highest relative SAT capacity were found to be in the confined areas in the Santa Clara Subbasin and in the Llagas Subbasin. The confining layer and deep depth to groundwater are characteristics of the best areas within the study area for soil aquifer treatment capacity.

Groundwater degradation potential in the Santa Clara and Llagas Subbasin ranged from lowest to highest potential. Groundwater degradation potential was found to be generally low or lowest in the confined areas. Groundwater degradation potential in the unconfined areas was found to be generally average with some areas regarded as high or highest.

REFERENCES

Aspeitia, Miguel A. ITAP Landscape Consultant, 2006, *Integrated Device Technology Inc., Landscape Irrigation Evaluation Report*, Landscape Meter Account #017545B, prepared for Santa Clara Valley Water District, 15 February.

California Irrigation Management Information System (CIMIS), 1999, *Reference Evapotranspiration*, Developed as a cooperative project between the Department of Land, Air and Water Resources University of California Davis and Water Use Efficiency Office California Department of Water Resources, Map prepared by David W. Jones.

California Regional Water Quality Control Board, 1995, Water Control Quality Plan, Santa Ana River Basin, Santa Anna Region, January 24, updated February 2008.

California State Water Resources Control Board, 2009, Recycled Water Policy, Section (9)(a)(1) Approved May 14 2009.

Fetter, C.W., 1994, Applied Hydrogeology, Macmillan College Publishing Company, New York, New York.

Natural Resources Conservation Service, 1961 to 1990, Average Annual Precipitation 1961-1990, available at http://www.nationalatlas.gov/mld/prism0p.html.

Ray, M.C., Kulongoski, J.T., Belitz, Kenneth, 2009, Groundwater Quality Data in the San Francisco Bay Study Unit, 2007: Results from the California GAMA program: US Geological Survey Data Series 396, 92 p. Available at http://pubs.usgs.gov/ds/396.

Santa Clara Valley Water District, 1999, *An Analysis of the Sensitivity to Contamination of the Santa Clara Valley Groundwater Aquifers Based on the USEPA Drastic Methodology,* by Pierno, R., December 1999.

Santa Clara Valley Water District, 2004, *Technical Documents, Technical Memoranda 1-6: Advanced Recycled Water Treatment (ARWT) Feasibility Project,* prepared by Black & Veatch Corporation.

Santa Clara Valley Water District, 2010, *Groundwater Vulnerability Study, Santa Clara County, California,* prepared by Todd Engineers and Kennedy/Jenks Consultants, written in September 2009, revised in 2010.

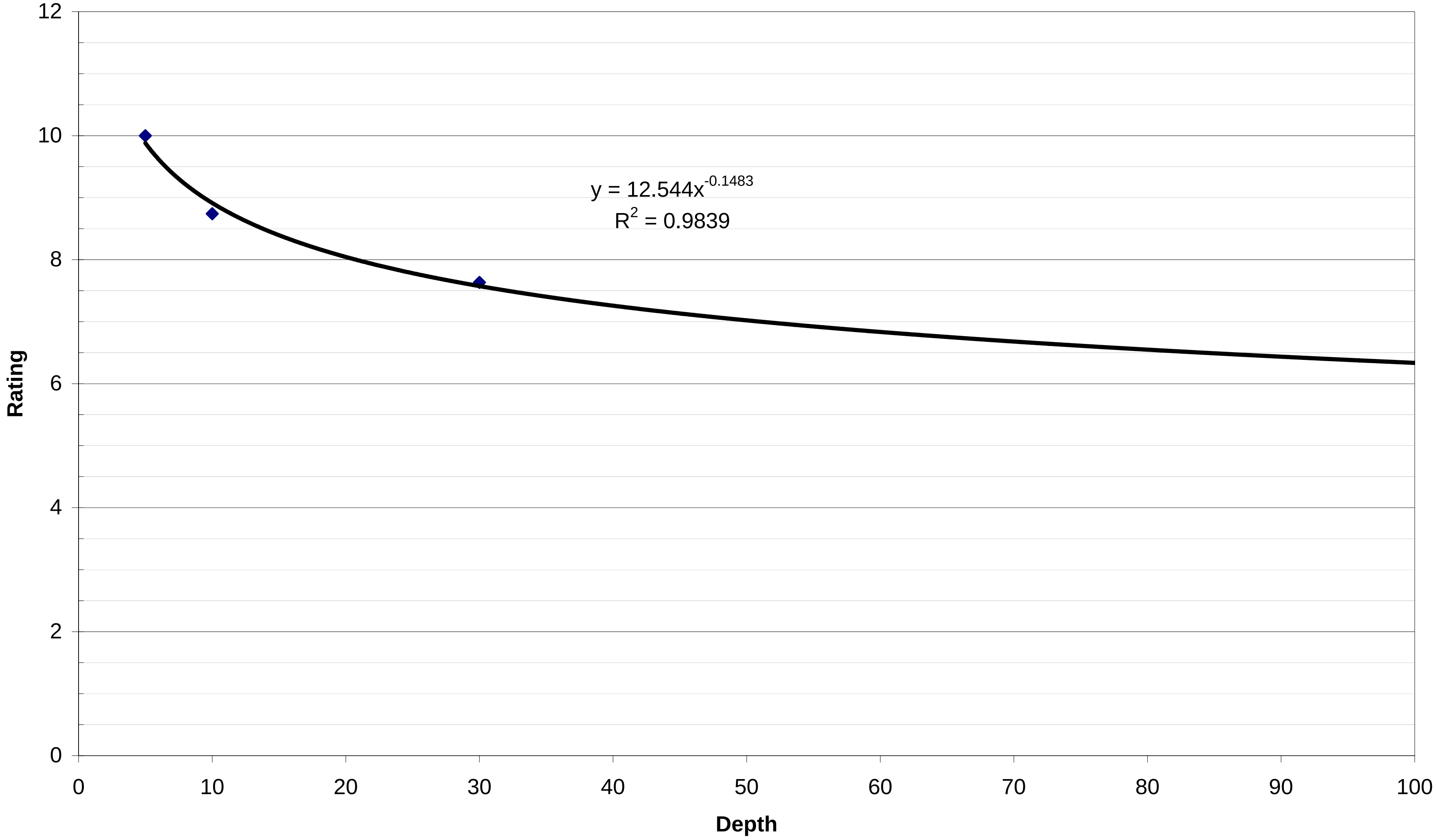
Swamee, P.K., Tyagi, A., 2000, *Describing Water Quality with Aggregate Index,* Journal of Environmental Engineering, ASCE, Vol. 126, No. 5, May.

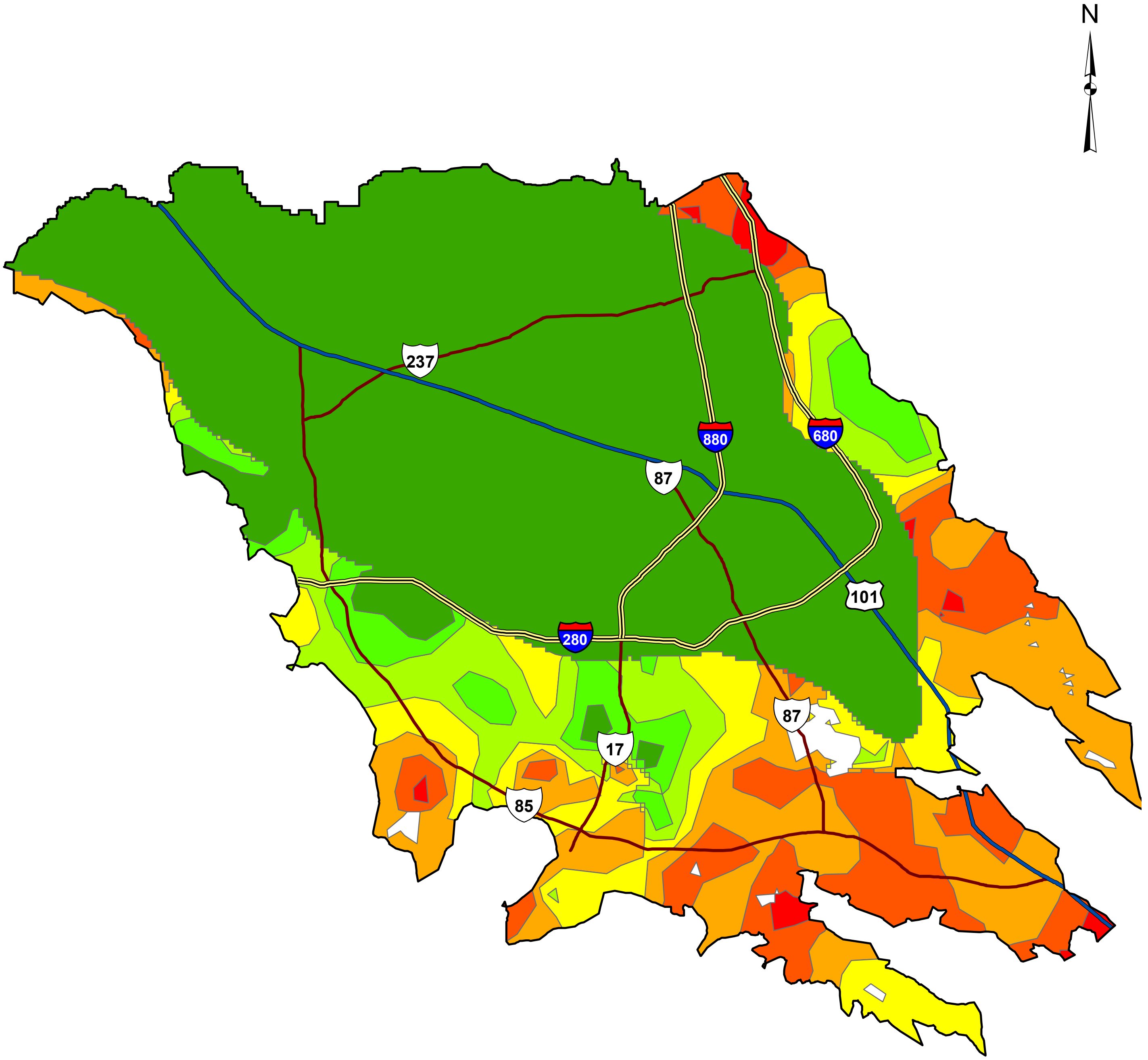
Swamee, P.K., Tyagi, A., 2007, *Improved Method for Aggregation of Water Quality Subindices,* Journal of Environmental Engineering, ASCE, 10.1061/(ASCE)0733-9372(2007)133:2(220).

US Environmental Protection Agency, 1987, *DRASTIC: A Standardized System for Evaluating Ground Water pollution Potential Using Hydrogeologic Settings*, EPA/600/2-87/035, June.

FIGURES

FIGURE IV-2-1
DERIVATION OFDEPTH TO WATER RATINGS





DEPTH TO WATER RATINGS

RATING. RANGE

- 🟩 **6, 100+ FEET**
- 🟩 **6.3, 75-100 FEET**
- 🟩 **6.6, 50-75 FEET**
- 🟨 **7, 30-50 FEET**
- 🟧 **7.6, 15-30 FEET**
- 🟧 **8.4, 5-15 FEET**
- 🟥 **10, 0-5 FEET**

ROADS

HWY_TYPE

- INTERSTATE
- US
- STATE
- ARTERIAL

REFERENCE:

1. BASE MAPPING INFORMATION FROM THE SANTA CLARA VALLEY WATER DISTRICT GIS DEPARTMENT.

DEPTH TO WATER RATINGS
SANTA CLARA GROUNDWATER SUBBASIN

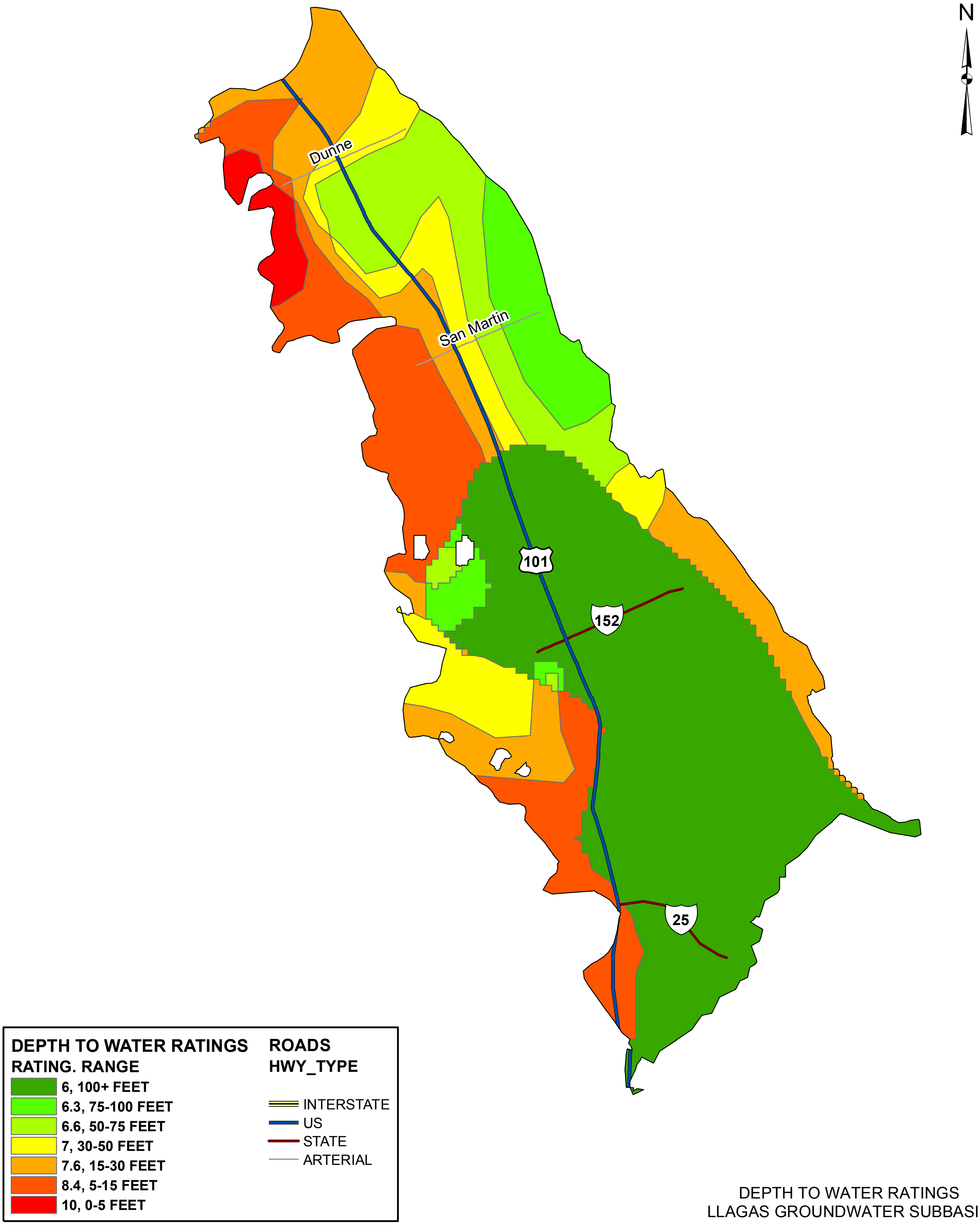
PREPARED FOR
SANTA CLARA VALLEY
WATER DISTRICT

△	08-19-11	ISSUED FOR REPORT	MS	NDW	NDW
NO.	DATE	ISSUE / REVISION	DWN. BY	CK'D BY	AP'D BY

Locus TECHNOLOGIES

0 0.5 1 2 3 4 Miles

Drawing Number	
Figure IV 2-2	



DEPTH TO WATER RATINGS
LLAGAS GROUNDWATER SUBBASIN

PREPARED FOR
SANTA CLARA VALLEY
WATER DISTRICT

REFERENCE:

1. BASE MAPPING INFORMATION FROM THE SANTA CLARA VALLEY WATER DISTRICT GIS DEPARTMENT.

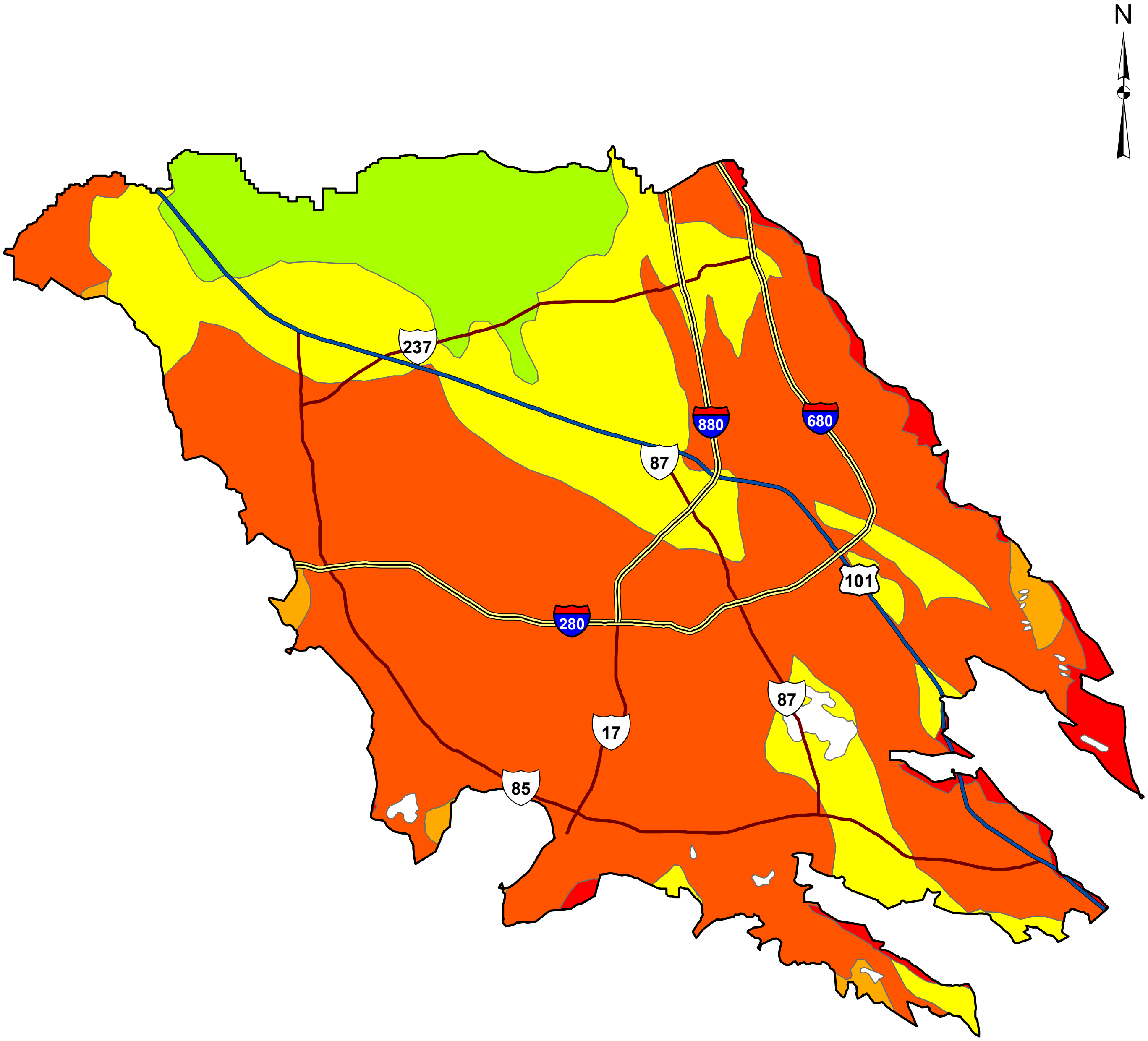
△	08-19-11	ISSUED FOR REPORT	MS	NDW	NDW
NO.	DATE	ISSUE / REVISION	DWN. BY	CK'D BY	AP'D BY

Locus TECHNOLOGIES

0 0.25 0.5 1 1.5 2 Miles

Drawing Number

Figure IV 2-3



Soil Media Ratings

Ratings, Range

🟩 **2, MASSIVE CLAY**
🟨 **3, CLAY LOAM**
🟧 **4, SILTY LOAM**
🟧 **6, SANDY LOAM**
🟥 **7, SAND LOAM TO SAND**

ROADS

HWY_TYPE

═ INTERSTATE
━ US
━ STATE
─ ARTERIAL

SOIL MEDIA RATINGS
SANTA CLARA GROUNDWATER SUBBASIN

PREPARED FOR
SANTA CLARA VALLEY
WATER DISTRICT

REFERENCE:

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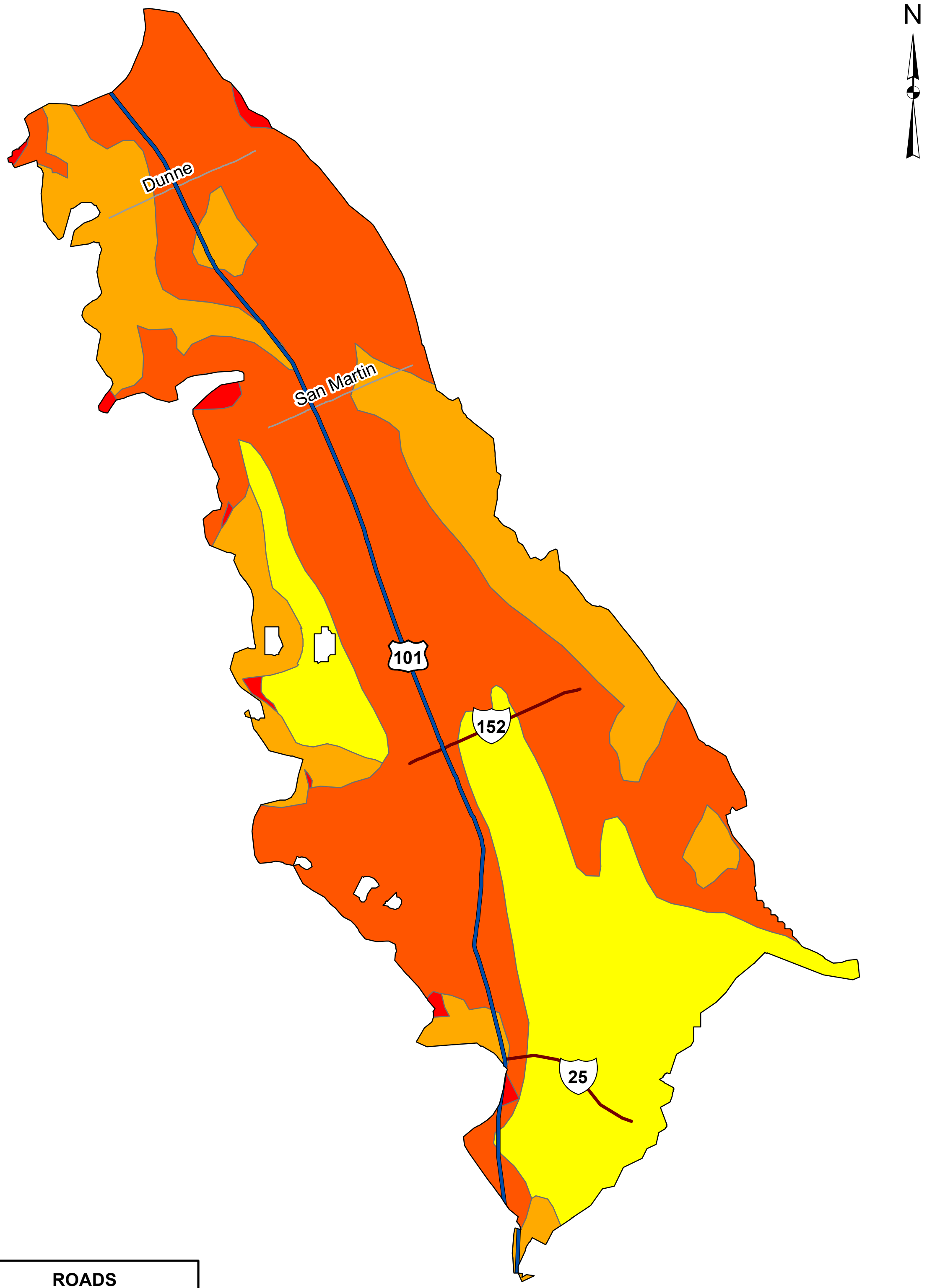
NO.	DATE	ISSUE / REVISION	DWN. BY	CK'D BY	AP'D BY
△	08-19-11	ISSUED FOR REPORT	MS	NDW	NDW

Locus
TECHNOLOGIES

0 0.5 1 2 3 4
Miles

Drawing Number	
Figure IV 2-4	



Soil Media Ratings

Ratings, Range

- 🟩 **2, MASSIVE CLAY**
- 🟨 **3, CLAY LOAM**
- 🟧 **4, SILTY LOAM**
- 🟧 **6, SANDY LOAM**
- 🟥 **7, SAND LOAM TO SAND**

ROADS

HWY_TYPE

- ═ INTERSTATE
- ━ US
- ━ STATE
- ─ ARTERIAL

SOIL MEDIA RATINGS
LLAGAS GROUNDWATER SUBBASIN

PREPARED FOR
SANTA CLARA VALLEY
WATER DISTRICT

REFERENCE:

1. BASE MAPPING INFORMATION FROM THE SANTA CLARA VALLEY WATER DISTRICT GIS DEPARTMENT.

△	08-19-11	ISSUED FOR REPORT	MS	NDW	NDW
NO.	DATE	ISSUE / REVISION	DWN. BY	CK'D BY	AP'D BY

Locus TECHNOLOGIES

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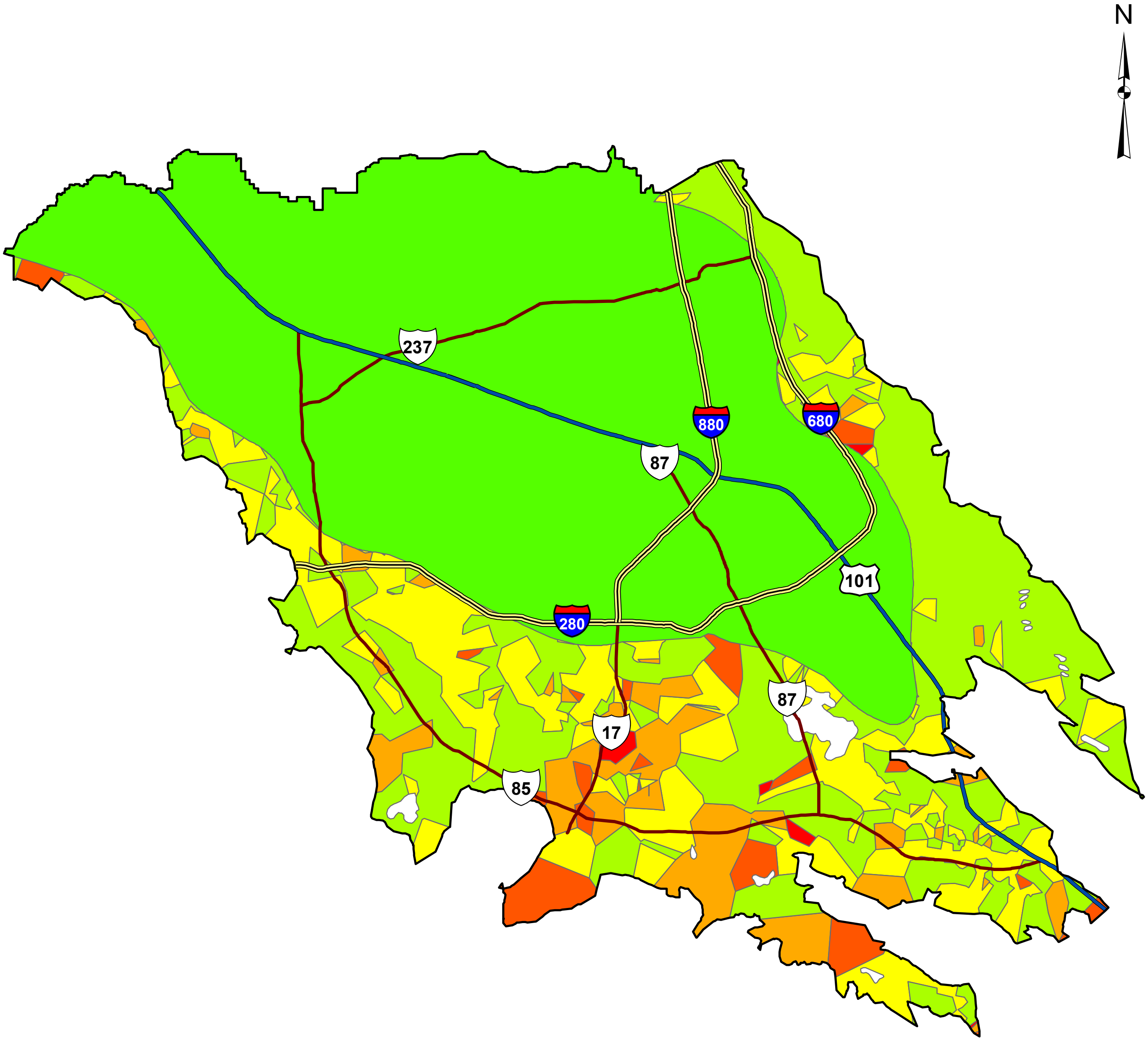
Drawing Number	
Figure IV 2-5	



IMPACT OF THE VADOZE ZONE MEDIA RATINGS

RATING, VALUE

🟩 **1, CONFINING LAYER**

🟩 **2, CLAY**

🟨 **3, SILT**

🟧 **4, LOAM**

🟧 **6, SAND**

🟥 **9, GRAVEL**

ROADS

HWY_TYPE

═ **INTERSTATE**

— **US**

— **STATE**

— **ARTERIAL**

IMPACT OF THE VADOSE MEDIA RATINGS
SANTA CLARA GROUNDWATER SUBBASIN

PREPARED FOR
SANTA CLARA VALLEY
WATER DISTRICT

REFERENCE:

1. BASE MAPPING INFORMATION FROM THE SANTA CLARA VALLEY WATER DISTRICT GIS DEPARTMENT.

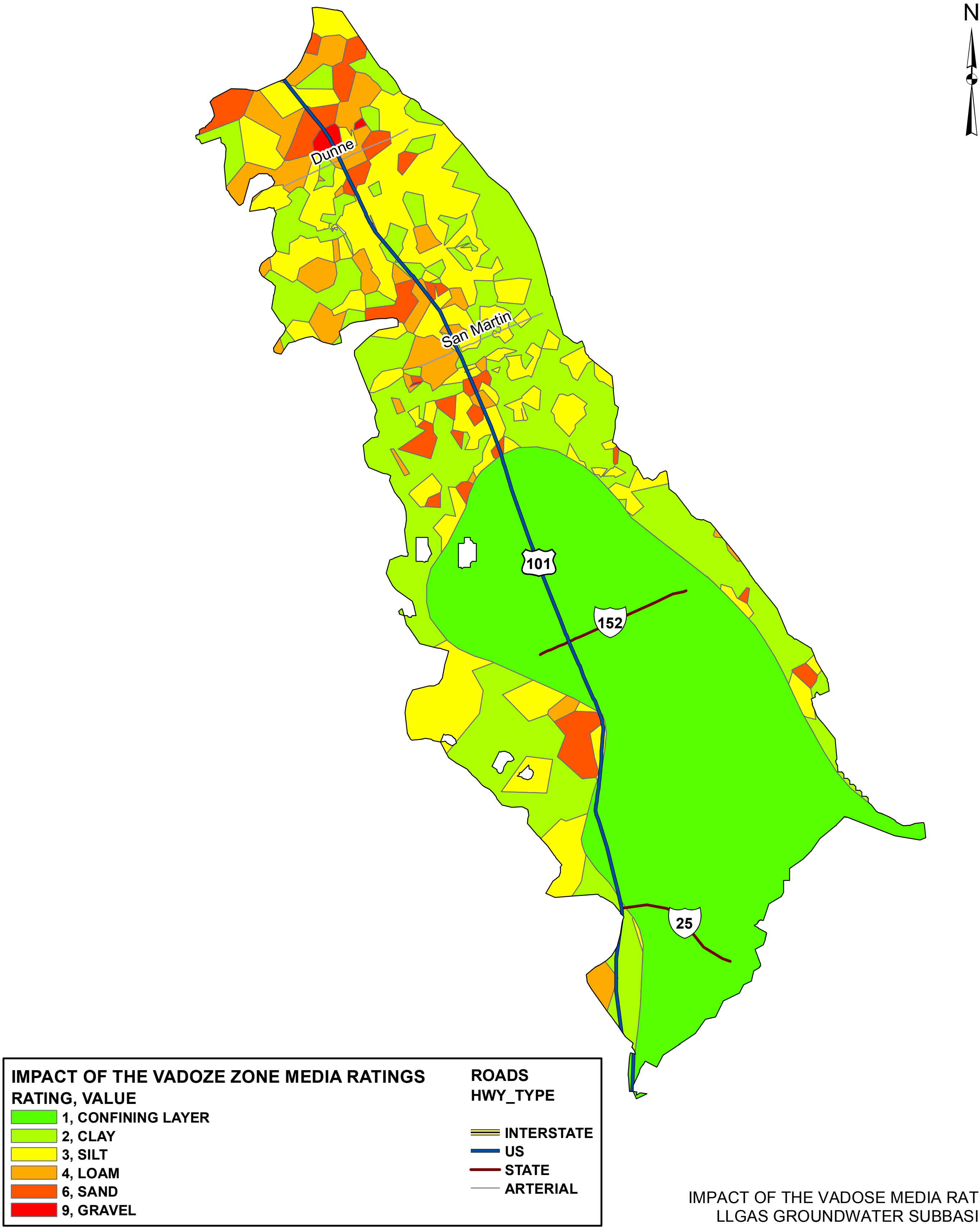
△	08-19-11	ISSUED FOR REPORT	MS	NDW	NDW
NO.	DATE	ISSUE / REVISION	DWN. BY	CK'D BY	AP'D BY

Locus TECHNOLOGIES

0 0.5 1 2 3 4 Miles

Drawing Number

Figure IV 2-6



IMPACT OF THE VADOZE ZONE MEDIA RATINGS

RATING, VALUE

- 🟩 **1, CONFINING LAYER**
- 🟩 **2, CLAY**
- 🟨 **3, SILT**
- 🟧 **4, LOAM**
- 🟥 **6, SAND**
- 🟥 **9, GRAVEL**

ROADS

HWY_TYPE

- **INTERSTATE**
- **US**
- **STATE**
- **ARTERIAL**

IMPACT OF THE VADOSE MEDIA RATINGS
LLGAS GROUNDWATER SUBBASIN

REFERENCE:

1. BASE MAPPING INFORMATION FROM THE SANTA CLARA VALLEY WATER DISTRICT GIS DEPARTMENT.

PREPARED FOR
SANTA CLARA VALLEY
WATER DISTRICT

NO.	DATE	ISSUE / REVISION	DWN. BY	CK'D BY	AP'D BY
△	08-19-11	ISSUED FOR REPORT	MS	NDW	NDW

Locus
TECHNOLOGIES

Drawing Number	
Figure IV 2-7	

FIGURE IV-2-8: BASELINE GRAPH
SOIL MEDIA: SILT, VADOSE ZONE MEDIA: SILT
TIME: 50 YEARS, CONSTITUENT: CHLOROFORM
EVALUATION OF POTENTIAL IMPACTS
RECYCLED WATER STUDY

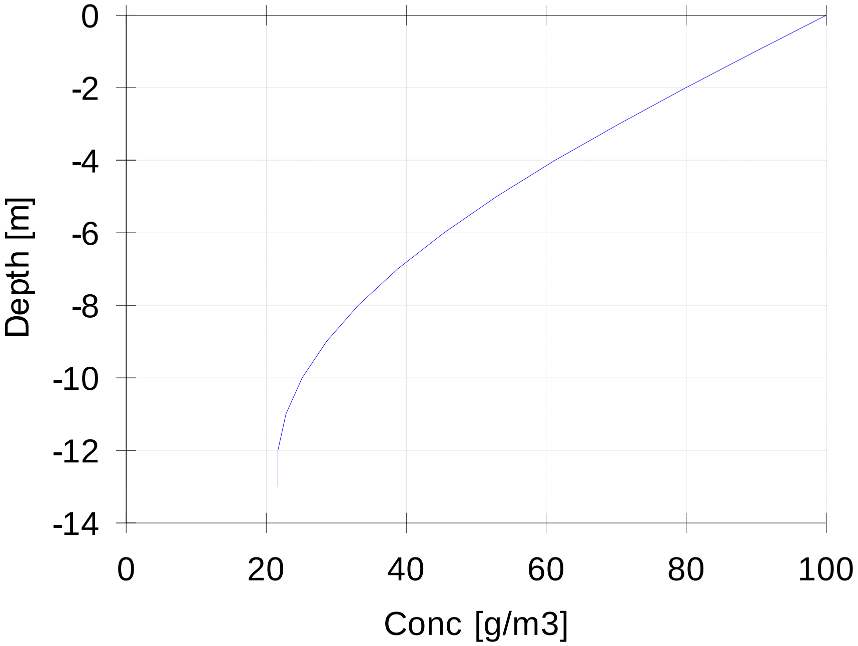


FIGURE IV-2-9: CALIBRATION GRAPH 1
SOIL MEDIA: CLAY, VADOSE ZONE MEDIA: SILT
TIME: 50 YEARS, CONSTITUENT: CHLOROFORM
EVALUATION OF POTENTIAL IMPACTS
RECYCLED WATER STUDY

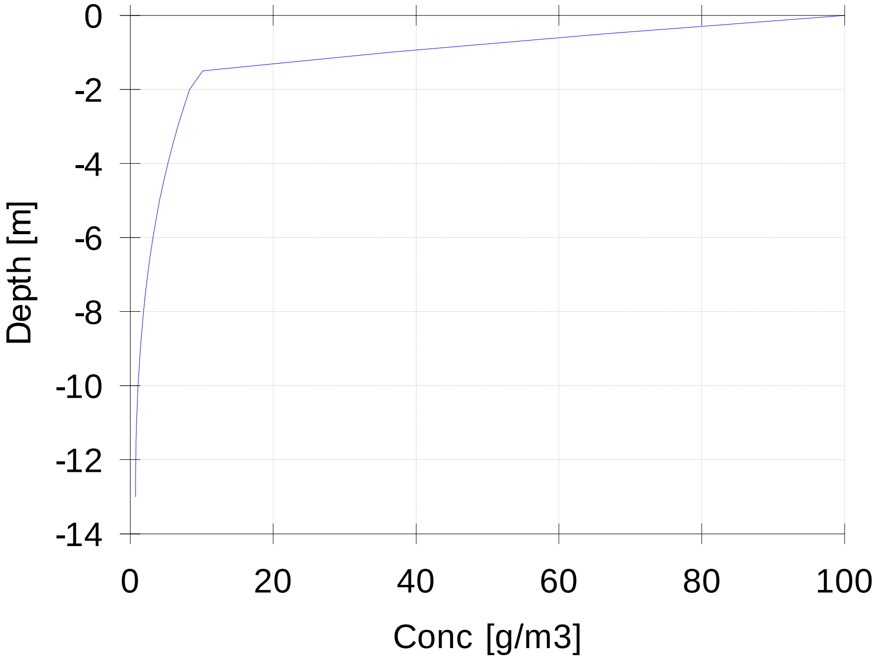
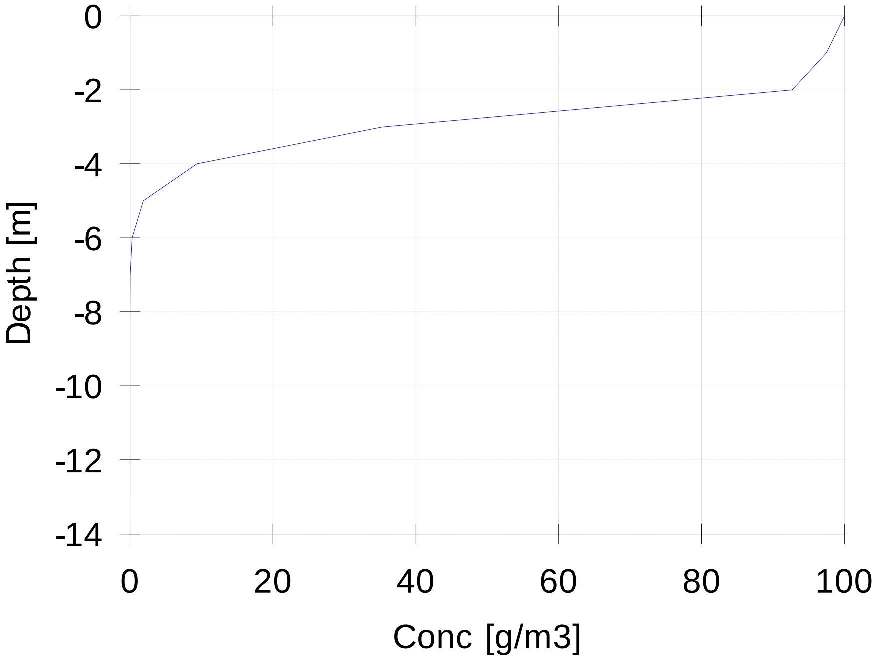
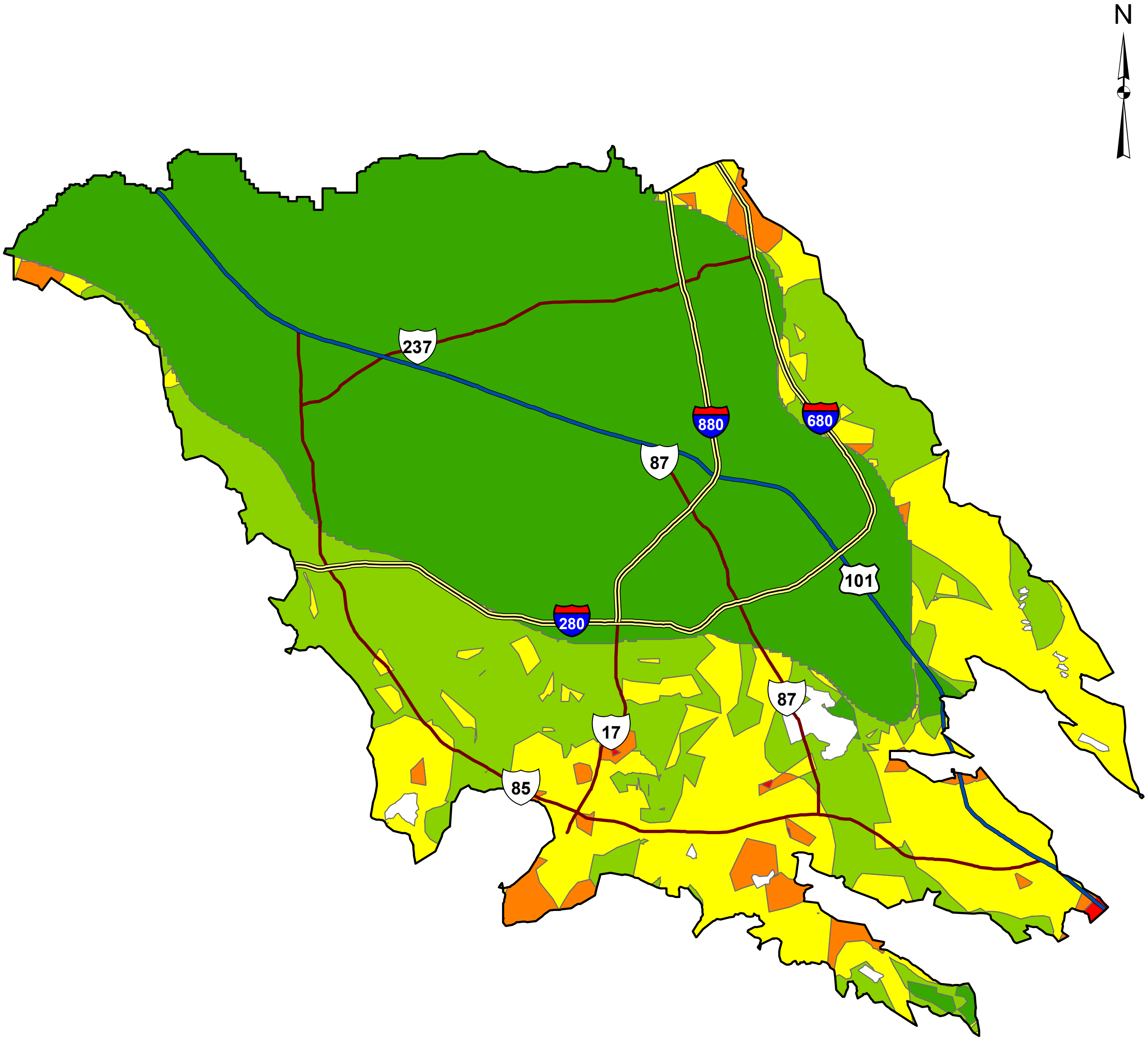


FIGURE IV-2-10: CALIBRATION GRAPH 2
SOIL MEDIA: SILT, VADOSE ZONE MEDIA: CLAY
TIME: 50 YEARS, CONSTITUENT: CHLOROFORM
EVALUATION OF POTENTIAL IMPACTS
RECYCLED WATER STUDY





SOIL AQUIFER TREATMENT CAPACITY RATINGS, RANGE

- 🟩 **1 To 2, HIGH CAPACITY**
- 🟩 **3 To 4, GOOD CAPACITY**
- 🟨 **5 To 6, AVERAGE CAPACITY**
- 🟧 **7 To 8, MARGINAL CAPACITY**
- 🟥 **9 To10, LEAST CAPACITY**

ROADS
HWY_TYPE

- ═ **INTERSTATE**
- ━ **US**
- ━ **STATE**
- ─ **ARTERIAL**

SOIL AQUIFER TREATMENT CAPACITY
SANTA CLARA GROUNDWATER SUBBASIN

PREPARED FOR
SANTA CLARA VALLEY
WATER DISTRICT

REFERENCE:

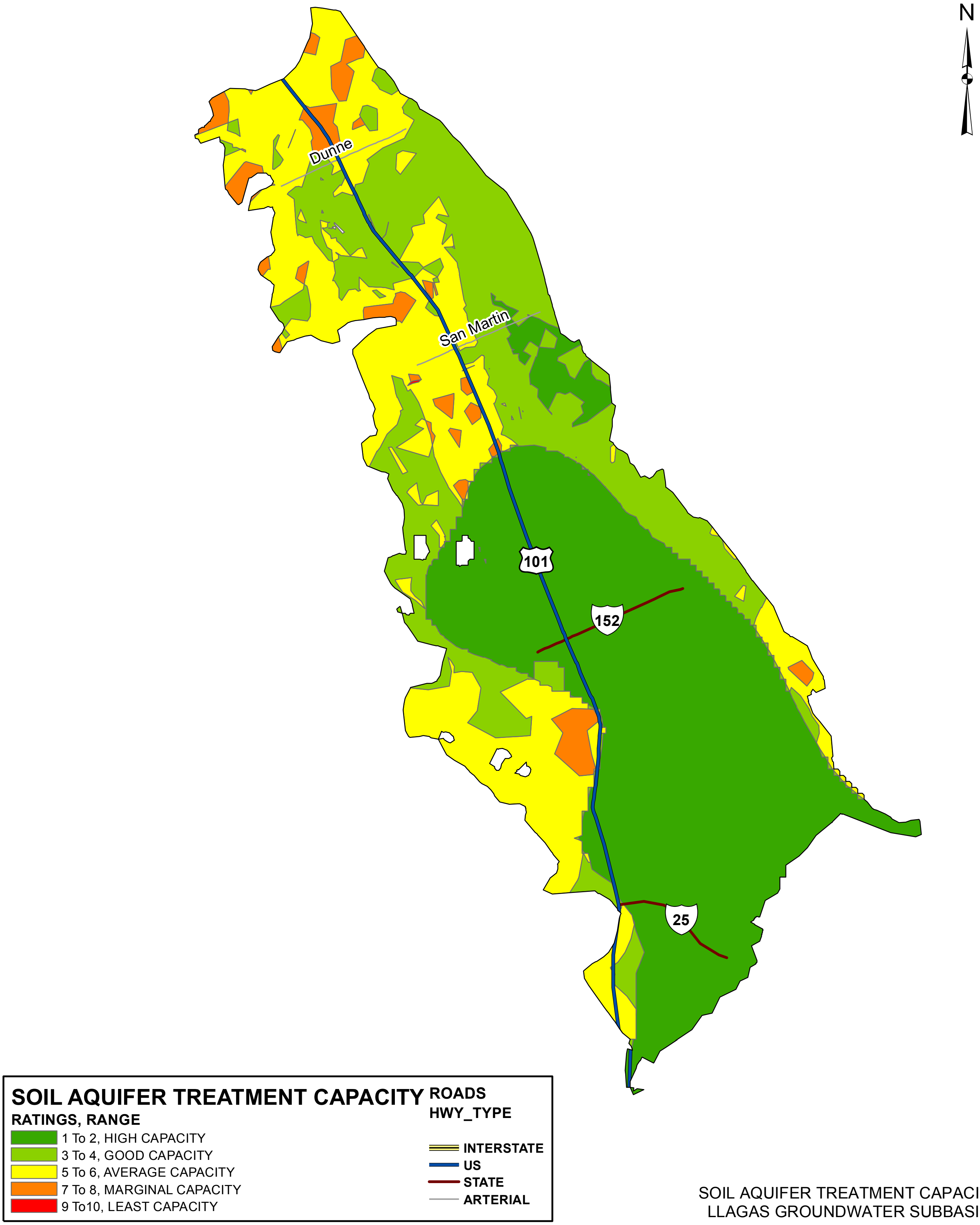
1. BASE MAPPING INFORMATION FROM THE SANTA CLARA VALLEY WATER DISTRICT GIS DEPARTMENT.

△	08-19-11	ISSUED FOR REPORT	MS	NDW	NDW
NO.	DATE	ISSUE / REVISION	DWN. BY	CK'D BY	AP'D BY

0 0.5 1 2 3 4 Miles

Drawing Number

Figure IV 2-11



SOIL AQUIFER TREATMENT CAPACITY
LLAGAS GROUNDWATER SUBBASIN

PREPARED FOR
SANTA CLARA VALLEY
WATER DISTRICT

REFERENCE:

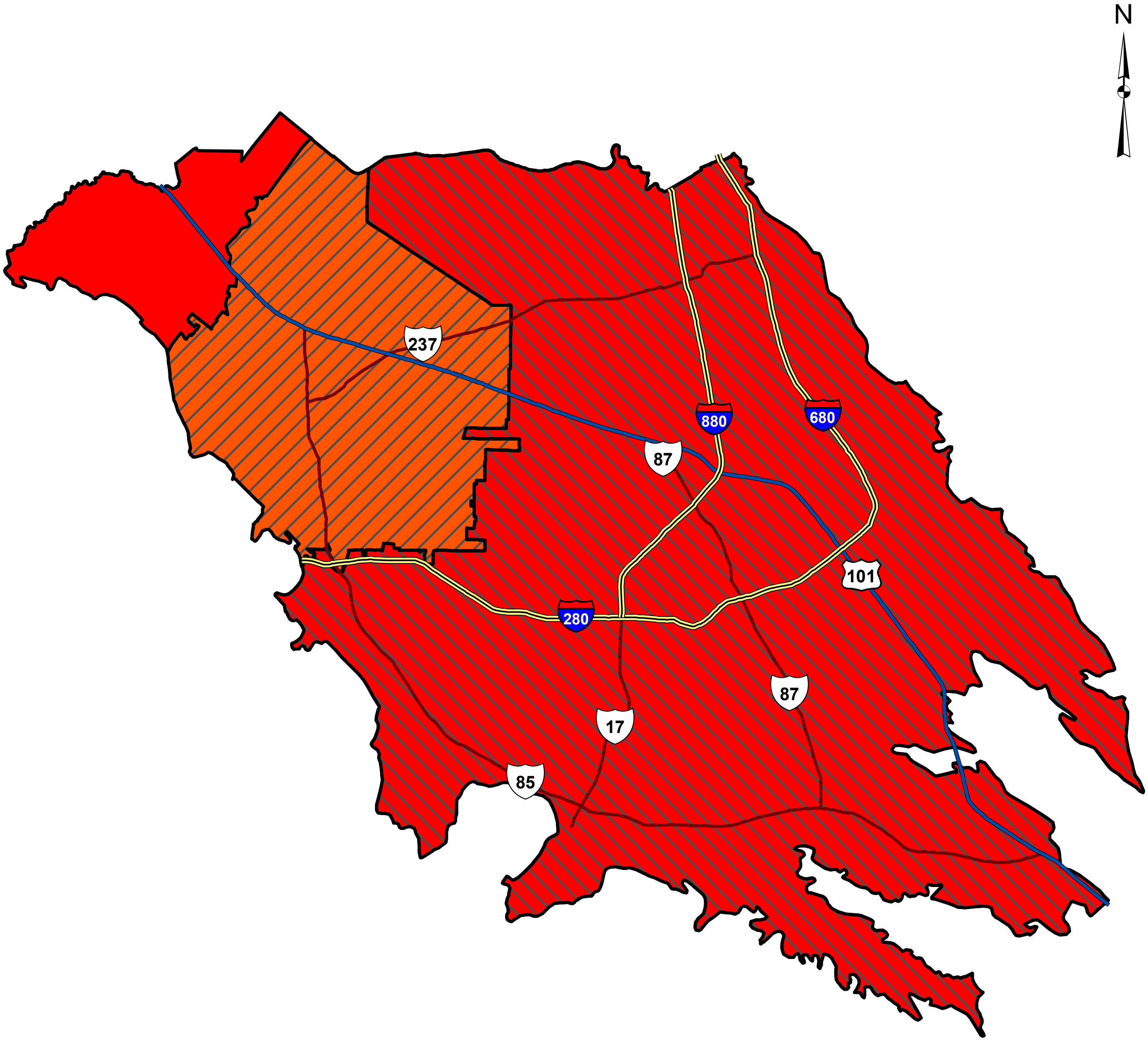
1. BASE MAPPING INFORMATION FROM THE SANTA CLARA VALLEY WATER DISTRICT GIS DEPARTMENT.

△	08-19-11	ISSUED FOR REPORT	MS	NDW	NDW
NO.	DATE	ISSUE / REVISION	DWN. BY	CK'D BY	AP'D BY

Locus
TECHNOLOGIES

0 0.25 0.5 1 1.5 2 Miles

Drawing Number	
Figure IV 2-12	



RECYCLED WATER QUALITY RATING

Rating, LOCUS_RWQ

- 🟧 **7.45, SCRWA**
- ▨ **8.08, SWPCP**
- 🟥 **9.61, PARQWCP**
- ▨ **9.63, SJ/SC WPCP**

ROADS

HWY_TYPE

- ═ **INTERSTATE**
- — **US**
- — **STATE**
- — **ARTERIAL**

REFERENCE:

1. BASE MAPPING INFORMATION FROM THE SANTA CLARA VALLEY WATER DISTRICT GIS DEPARTMENT.

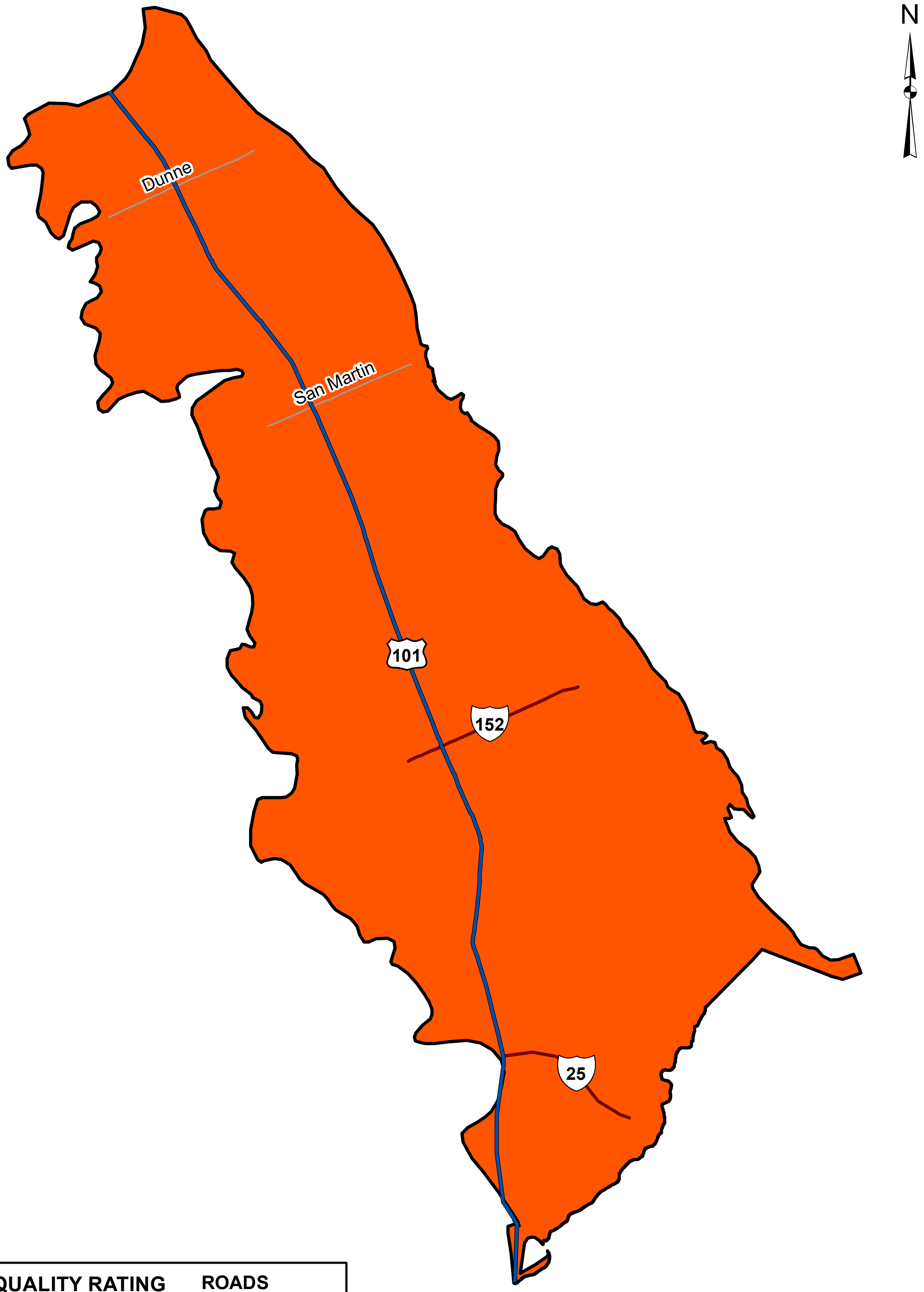
RECYCLED WATER QUALITY RATING
20% OF ASSIMILATIVE CAPACITY CONSIDERED
SANTA CLARA GROUNDWATER SUBBASIN
PREPARED FOR
SANTA CLARA VALLEY
WATER DISTRICT

△	08-19-11	ISSUED FOR REPORT	MS	NDW	NDW
NO.	DATE	ISSUE / REVISION	DWN. BY	CK'D BY	AP'D BY

0 0.5 1 2 3 4 Miles

Drawing Number

Figure IV 3-1



RECYCLED WATER QUALITY RATING

Rating, LOCUS_RWQ

- 🟧 **7.45, SCRWA**
- ▨ **8.08, SWPCP**
- 🟥 **9.61, PARQWCP**
- ▨ **9.63, SJ/SC WPCP**

ROADS

HWY_TYPE

- **INTERSTATE**
- **US**
- **STATE**
- **ARTERIAL**

RECYCLED WATER QUALITY RATING
20% OF ASSIMILATIVE CAPACITY CONSIDERED
LLAGAS GROUNDWATER SUBBASIN
PREPARED FOR
SANTA CLARA VALLEY
WATER DISTRICT

REFERENCE:

1. BASE MAPPING INFORMATION FROM THE SANTA CLARA VALLEY WATER DISTRICT GIS DEPARTMENT.

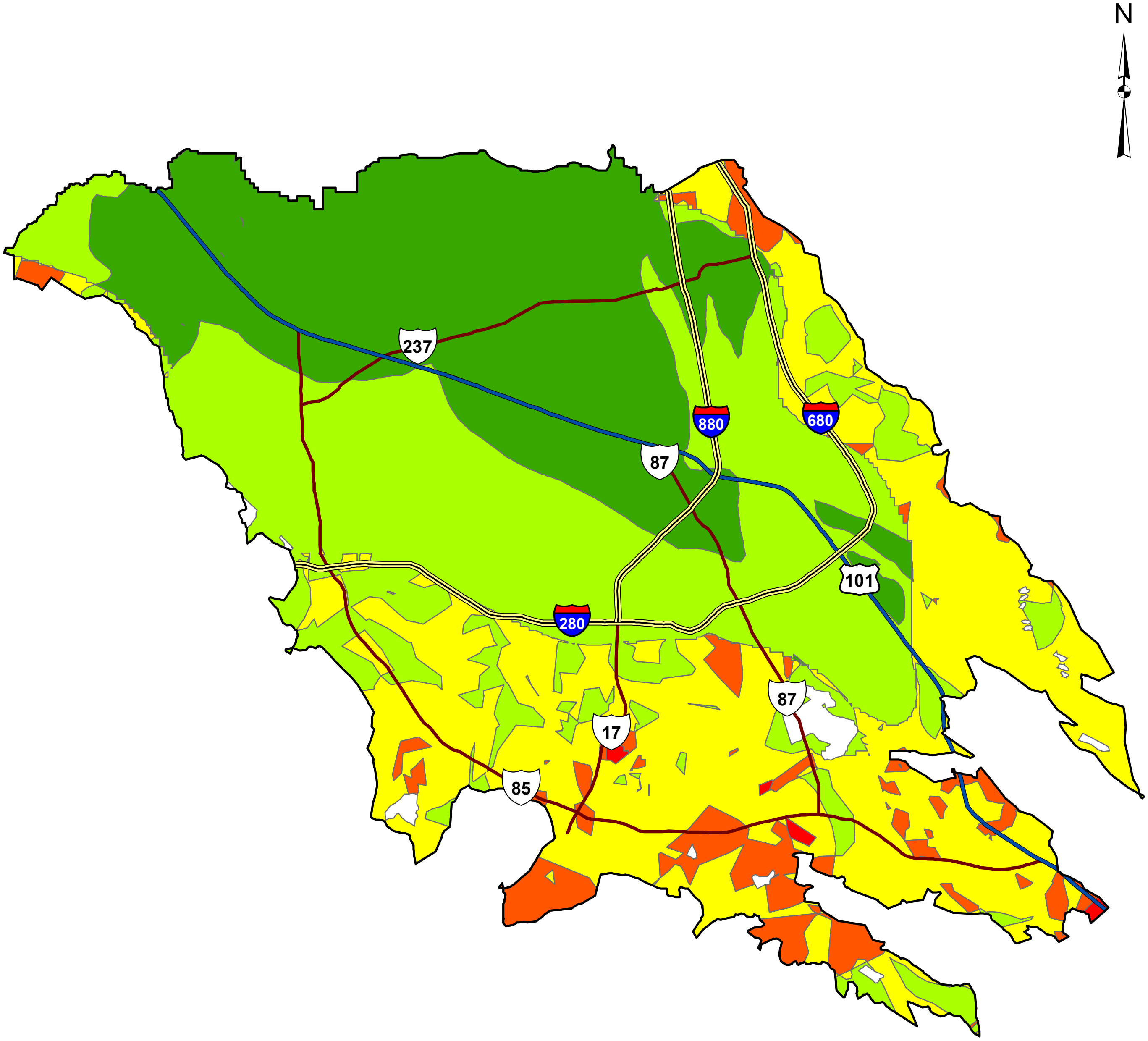
△	08-19-11	ISSUED FOR REPORT	MS	NDW	NDW
NO.	DATE	ISSUE / REVISION	DWN. BY	CK'D BY	AP'D BY

Locus
TECHNOLOGIES

0 0.25 0.5 1 1.5 2
Miles

Drawing Number

Figure IV 3-2



GW DEGRADATION POTENTIAL

Range

🟩 **1 To 20 Lowest Potential**
🟩 **21 To 40 Low Potential**
🟨 **41 To 60 Average Potential**
🟧 **61 To 80 High Potential**
🟥 **81 To 100 Highest Potential**

ROADS

HWY_TYPE

═ **INTERSTATE**
— **US**
— **STATE**
— **ARTERIAL**

REFERENCE:

1. BASE MAPPING INFORMATION FROM THE SANTA CLARA VALLEY WATER DISTRICT GIS DEPARTMENT.

△	08-19-11	ISSUED FOR REPORT	MS	NDW	NDW
NO.	DATE	ISSUE / REVISION	DWN. BY	CK'D BY	AP'D BY

GROUNDWATER DEGRADATION POTENTIAL
SANTA CLARA GROUNDWATER SUBBASIN

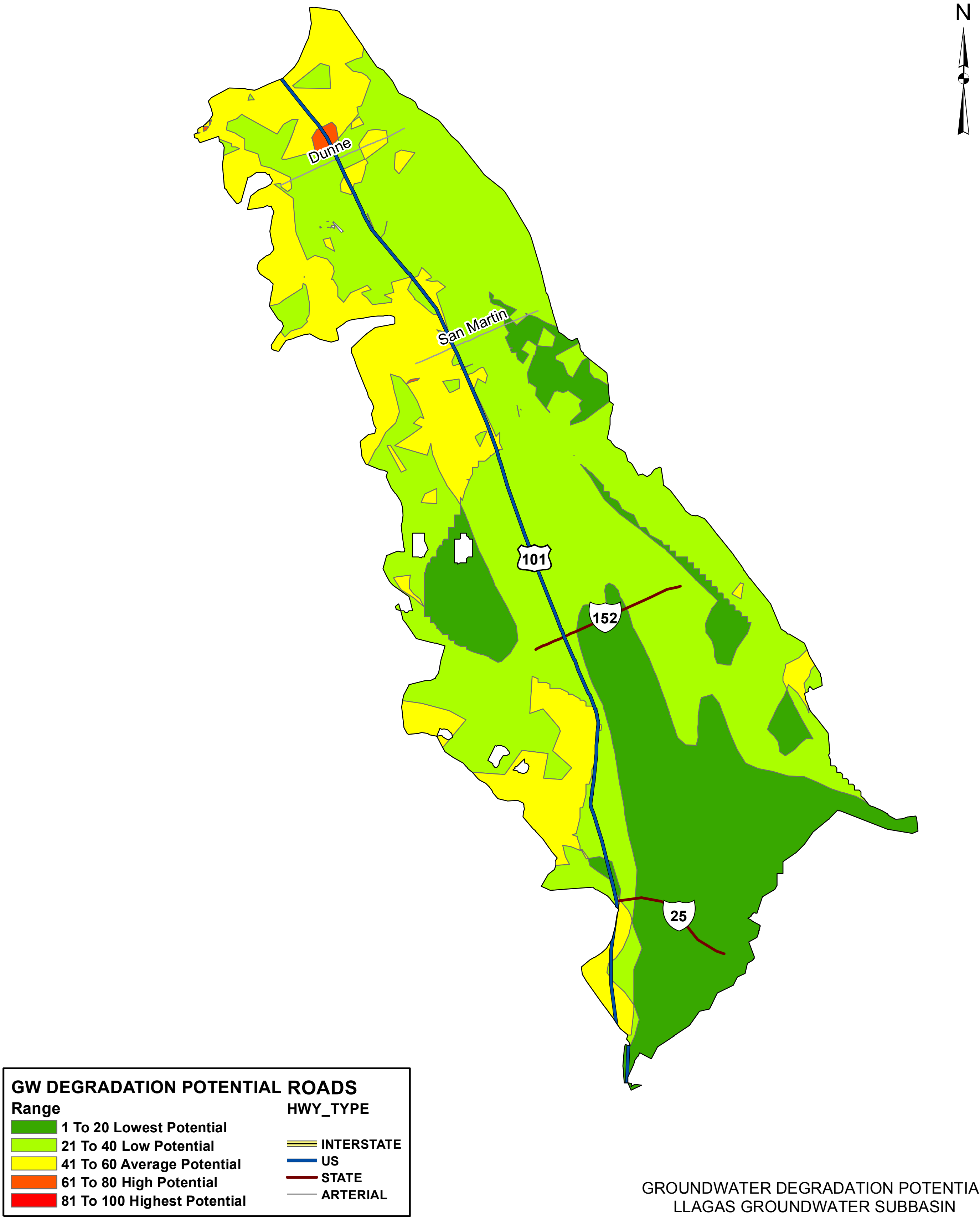
PREPARED FOR
SANTA CLARA VALLEY
WATER DISTRICT

Locus
TECHNOLOGIES

0 0.5 1 2 3 4
Miles

Drawing Number

Figure IV 3-3



REFERENCE:

1. BASE MAPPING INFORMATION FROM THE SANTA CLARA VALLEY WATER DISTRICT GIS DEPARTMENT.

GROUNDWATER DEGRADATION POTENTIAL
LLAGAS GROUNDWATER SUBBASIN

PREPARED FOR
SANTA CLARA VALLEY
WATER DISTRICT

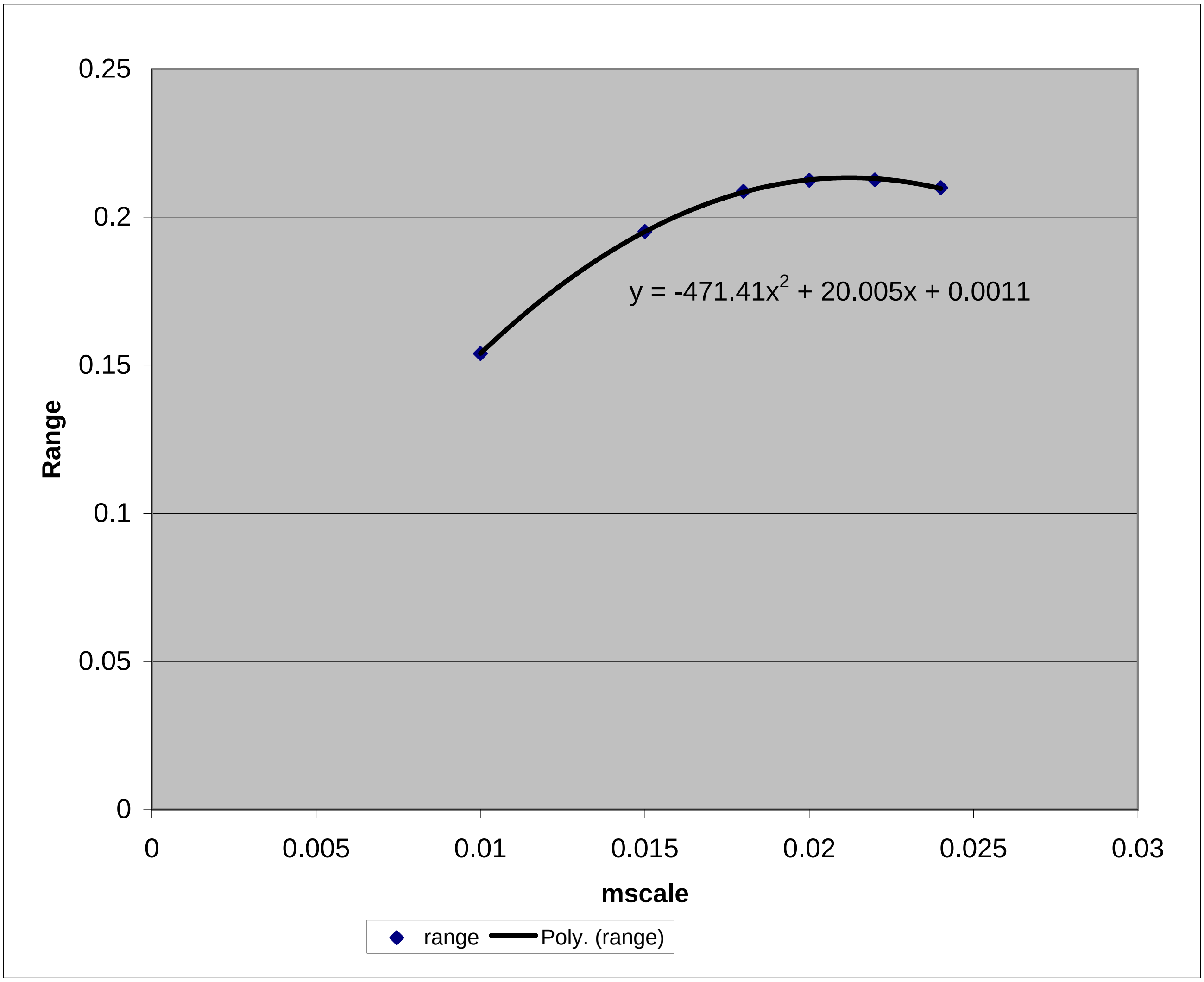
△	08-19-11	ISSUED FOR REPORT	MS	NDW	NDW
NO.	DATE	ISSUE / REVISION	DWN. BY	CK'D BY	AP'D BY

Locus
TECHNOLOGIES

Drawing Number

Figure IV 3-4

FIGURE IV-3-5
SUBINDEX EXPONENT DERIVATION



mscale value	Range in aggregate indices
0.01	0.153950982
0.015	0.195131597
0.018	0.20873943
0.02	0.212461682
0.022	0.212637299
0.024	0.209943724

Note:
The value of mscale was selected so that the difference between recycled water quality ratings (aggregate indices) would be maximized. The difference between the maximum and minimum aggregate indices was calculated for a range of mscale values as shown in the table above. With respect to mscale, the range varied according to a polynomial trend. The maximum range was observed at an mscale value of 0.021218.

TABLES

TABLE IV-2-1
DERIVATION OF RATINGS FOR DRASTIC DEPTH TO WATER INPUT

Parameter	Value	Comments
Total HAA6 concentration in Recycled Water Source	**6.35625** µg/L	Averaged over course of pilot study
Total HAA6 concentration at 5 feet	**1.53** µg/L	Average of two latest sampling events
Total HAA6 concentration at 10 feet	**0.835** µg/L	Average of two latest sampling events
Total HAA6 concentration at 30 feet	**0.0325** µg/L	Average of two latest sampling events
Percentage Removal at 5 feet	**75.9%**	
Percentage Removal at 10 feet	**86.9%**	
Percentage Removal at 30 feet	**99.5%**	
Ratio of 10-foot to 5-foot attenuation capacity	**1.144**	
Ratio of 30-foot to 5-foot attenuation capacity	**1.310**	
New DRASTIC Depth to Water Rating (5 feet)	**10**	
New DRASTIC Depth to Water Rating (10 feet)	**8.7**	
New DRASTIC Depth to Water Rating (30 feet)	**7.6**	

Sensitivity of Groundwater Data Point
[0.26 J ug/L for Monochloroacetic acid in MW-2 on the eighth sampling event]

Scenario 1: Substitute value for zero (0 ug/L)	Value	Comments
Total HAA6 concentration in Recycled Water Source	6.35625 µg/L	Averaged over course of pilot study
Total HAA6 concentration at 5 feet	1.53 µg/L	Average of two latest sampling events
Total HAA6 concentration at 10 feet	0.835 µg/L	Average of two latest sampling events
Total HAA6 concentration at 30 feet	**0** µg/L	Average of two latest sampling events
Percentage Removal at 5 feet	75.9%	
Percentage Removal at 10 feet	86.9%	
Percentage Removal at 30 feet	100.0%	
Ratio of 10-foot to 5-foot attenuation capacity	1.144	
Ratio of 30-foot to 5-foot attenuation capacity	1.317	
Scenario 1 DRASTIC Depth to Water Rating (5 feet)	10	No change in rating
Scenario 1 DRASTIC Depth to Water Rating (10 feet)	8.7	No change in rating
Scenario 1 DRASTIC Depth to Water Rating (30 feet)	7.6	No change in rating

Scenario 2: Substitute value for reporting limit (2 ug/L)	Value	Comments
Total HAA6 concentration in Recycled Water Source	6.35625 µg/L	Averaged over course of pilot study
Total HAA6 concentration at 5 feet	1.53 µg/L	Average of two latest sampling events
Total HAA6 concentration at 10 feet	0.835 µg/L	Average of two latest sampling events
Total HAA6 concentration at 30 feet	**0.25** µg/L	Average of two latest sampling events
Percentage Removal at 5 feet	75.9%	
Percentage Removal at 10 feet	86.9%	
Percentage Removal at 30 feet	96.1%	
Ratio of 10-foot to 5-foot attenuation capacity	1.144	
Ratio of 30-foot to 5-foot attenuation capacity	1.265	
Scenario 2 DRASTIC Depth to Water Rating (5 feet)	10	No change in rating
Scenario 2 DRASTIC Depth to Water Rating (10 feet)	8.7	No change in rating
Scenario 2 DRASTIC Depth to Water Rating (30 feet)	**7.9**	Slight increase in rating

Notes:

For the purpose of totalling HAA6 concentrations, haloacetic acid concentrations below detection were assumed to be zero.

TABLE IV-2-2
DERIVATION OF RATINGS FOR SOIL MEDIA AND IMPACT OF THE VADOSE ZONE MEDIA INPUTS

Soil Core	SCRWA-B	SCRWA-C	SCRWA-D	SJSC-C	SJSC-D	Comments
Core Description	semifine	coarse	fine (with gypsum)	coarse	fine (with gypsum)	
Core Length	4 feet	4 feet	1 foot	4 feet	1 foot	
Core Soil Type	silt w/sand	well-graded sand and gravel	clay w/sand	poorly graded gravel w/silt and sand	silty clay	
Default DRASTIC S Layer Classification	silty loam	sand loam to sand	massive clay	sand loam to sand	massive clay	
Default DRASTIC I Layer Classification	sand and gravel with significant silt and clay (silt end of this range)	sand and gravel (sand end of this range)	silt/clay (clay end of this range)	sand and gravel (sand end of this range)	silt/clay (clay end of this range)	
Customized I Layer Classification	Between silt and loam	sand	clay	sand	clay	
Total Trihalomethane Concentration Removal	78%	56%	67%	57%	71%	Based on comparison of last effluent sample with first influent sample.
Total Trihalomethane Concentration Removal (adjusted)	31%	18%	67%	19%	71%	Normalized to 1 foot
Ratio of Removal to Sand Removal	1.70	1.00	3.63	1.00	3.78	
New Assigned DRASTIC S Layer Rating	4.1	7	1.9	7	1.9	
New Assigned DRASTIC I Layer Rating	3.5	6	1.7	6	1.6	

TABLE IV-2-3
VERTICAL HYDRAULIC CONDUCTIVITES FOR DIFFERENT SOIL TYPES

Soil Category	Soil Types	Vertical Hydraulic Conductivity (cm/s)	Vertical Hydraulic Conductivity Range (cm/s)
Clay	CL, CH, CH-CL, CH-GP, CL-CH, CL-GC, CL-GP, CL-GW, CL-ML, CL-SC, CL-SM, GC-CL MC, ML-CL, OH, OL, SC, SC-CL, SM-CL, Peat, Clay	10^{-7}	$<2\times10^{-7}$
Silt	ML, MH, ML-GM, ML-SC, ML-SM, ML-SP, ML-SW, SC-ML, SM, SM-GM, SM-ML, SM-SC, SM-SL, SP-SC, GC, GC-GM, GC-SC, GP-CL, Silt	10^{-6}	2×10^{-7} to 2×10^{-6}
Loam	SC-GC, SC-SM, SC-SP, SC-SW, SM-GP, SM-SP, SM-SW, SP-SM, SW-GC, SW-GM, SW-SC, SW-SM, SW-CL, GC-GP, GC-GW, GC-SW, GM, GM-GC, GM-GP, GM-GW, GM-ML, GM-SM, GM-SP, GP-GC, GP-GM, GW-CL, GW-GC, GW-GM, GW-SM, Fill, Soil, Cobbles with Matrix, Gravel with Matrix, Sand with Matrix	10^{-4}	2×10^{-6} to 2×10^{-4}
Sand	SW, SP, SP-SW, SW-SP, GP-SP, GP-SW, GS, GW-SP, GW-SW, SP-GP, SP-GW, SW-GW, Sand	10^{-1}	2×10^{-6} to 2×10^{-1}
Gravel/ Fractured Rock	GW, GP, Gravel, Bedrock, Cobbles, Rock	10^{0}	$> 2\times10^{-1}$

Notes:

Vertical hydraulic conductivity data and range derived from Fetter (1994).

TABLE IV-2-4
CALCULATIONS FOR CALIBRATION OF INPUT WEIGHTINGS

Input	**Input Rating**	**Atten-uation Achieved [%]**	**Δ Rating**	**Δ Atten-uation [%]**	**Δ Rating / Δ Atten-uation**	**Weight-ing [%]**
Depth to Groundwater			-3	63	-0.05	**49**
Baseline Condition: 40 feet	7	78				
Adjusted Condition: 5 feet	10	15				
Soil Media			2	-21	-0.10	**25**
Baseline Condition: Silt	4	78				
Adjusted Condition: Clay	2	99				
Impact of Vadose Zone Media			2	-22	-0.09	**26**
Baseline Condition: Silt	3	78				
Adjusted Condition: Clay	1	100				
Sum						100

Table IV-3-1:
WATER QUALITY OBECTIVE AND ASSIMILATIVE CAPACITY
EVALUATION OF POTENTIAL IMPACTS
RECYCLED WATER STUDY

	Representative Concentration*** (mg/L)			Regulatory Standards and Guidelines Used for Water Quality Objective (priortized in the given order)							Assimilative Capacity (mg/L)		Representative Concentration plus 20% of Assmiliative Capacity**** (mg/L)	
Chemical	**Santa Clara Subbasin**	**Llagas Subbasin**	**Water Quality Objective (mg/L)**	**1. CA MCL (mg/l)**	**2. Federal MCL (mg/l)**	**3. Secondary MCL (mg/l)**	**4. DPH Drinking Water Notification Level (mg/l)**	**5. PHG (CA OEHHA) (mg/L)**	**6. Federal MCLG (mg/L)**	**7. EPA Health Advisory for 10^{-4} Cancer Risk (mg/L)**	**Santa Clara Subbasin**	**Llagas Subbasin**	**Santa Clara Subbasin**	**Llagas Subbasin**
Boron	0.21	0.13	1	NA	NA	NA	1	NA	NA	NA	**0.79**	**0.87**	0.37	0.30
Calcium	62.29	54.94	NONE	NA	NA	NA	NA	NA	NA	NA	0	0	62.29	54.94
Magnesium	30.32	33.82	NONE	NA	NA	NA	NA	NA	NA	NA	0	0	30.32	33.82
Sodium	40.23	35.21	60 **	NA	NA	NA	NA	NA	NA	60 **	**19.77**	**24.79**	44.19	40.17
Sodium Adsorption Ratio (SAR)	1.05	0.92	NONE	NA	NA	NA	NA	NA	NA	NA	0	0	1.05	0.92
Potassium	1.70	1.70	NONE	NA	NA	NA	NA	NA	NA	NA	0	0	1.7	1.7
Sulfate	55.39	43.70	250	NA	NA	250	NA	NA	NA	NA	**194.61**	**206.30**	94.32	84.96
Nitrite	156.4 as NO2	124 as NO2	1 as N	1 as N	1 as N	NA	NA	1 as N	1 as N	NA	0	0	156.4 as NO2	124 as NO2
Nitrate	17.2 as NO3	26.7 as NO3	45 as Nitrate	45 as Nitrate	10 as N	NA	NA	10 as N	10 as N	NA	**27.8 as NO3**	**18.3 as NO3**	22.76 as NO3	30.36 as NO3
Chloride	63.53	44.61	250	NA	NA	250	NA	NA	NA	NA	**186.47**	**205.39**	100.83	85.69
Bromide	0.246	0.246	NONE	NA	NA	NA	NA	NA	NA	NA	0	0	0.246	0.246
Total Organic Carbon (TOC)	0.5	0.5	NONE	NA	NA	NA	NA	NA	NA	NA	0	0	0.5	0.5
Dissolved Organic Carbon	1	1	NONE	NA	NA	NA	NA	NA	NA	NA	0	0	1	1
Bromodichloromethane	0.0005	0.0005	0	NA	NA	NA	NA	NA	0	0.1	0	0	0.0005	0.0005
Bromoform	0.0005	0.0005	0	NA	NA	NA	NA	NA	0	0.8	0	0	0.0005	0.0005
Chloroform	0.0005	0.0005	0.07	NA	NA	NA	NA	NA	0.07	NA	**0.0695**	**0.0695**	0.0144	0.0144
Dibromochloromethane	0.0005	0.0005	0.06	NA	NA	NA	NA	NA	0.06	0.08	**0.0595**	**0.0595**	0.0124	0.0124
Bromochloroacetic Acid	0.001	0.001	NONE	NA	NA	NA	NA	NA	NA	NA	0	0	0.001	0.001
Dibromoacetic Acid	0.001	0.001	NONE	NA	NA	NA	NA	NA	NA	NA	0	0	0.001	0.001
Dichloroacetic Acid	0.001	0.001	0	NA	NA	NA	NA	NA	0	NA	0	0	0.001	0.001
Monobromoacetic Acid	0.001	0.001	NONE	NA	NA	NA	NA	NA	NA	NA	0	0	0.001	0.001
Monochloroacetic Acid	0.002	0.002	0.07	NA	NA	NA	NA	NA	0.07	NA	**0.068**	**0.068**	0.0156	0.0156
Trichloroacetic Acid	0.001	0.001	0.02	NA	NA	NA	NA	NA	0.02	NA	**0.019**	**0.019**	0.0048	0.0048
HAA5	NA	NA	0.06	0.06	0.06	NA	NA	NA	NA	NA	0	0	NA	NA
Coliforms, Total	13%	13%	5%	NA	5%	NA	NA	NA	0	NA	0	0	13%	13%
Fecal Coliforms	1%	1%	0	NA	NA	NA	NA	NA	0	NA	0	0	1%	1%
E. Coli	1%	1%	0	NA	NA	NA	NA	NA	0	NA	0	0	1%	1%
N-Nitroso Dimethylamine (NDMA)	0.000002	0.000002	0.00001	NA	NA	NA	0.00001	0.000003	NA	0.00007	**0.000008**	**0.000008**	0.0000036	0.0000036
Perchlorate	0.004	0.004	0.006	0.006	NA	NA	NA	0.006	NA	NA	**0.002**	**0.002**	0.0044	0.0044
Cyanide	0.01	0.01	0.15	0.15	0.2	NA	NA	0.15	0.2	NA	**0.14**	**0.14**	0.038	0.038
PFOS	0.000005	0.000005	0.0002 *	NA	NA	NA	NA	NA	NA	0.0002 *	**0.000195**	**0.000195**	0.000044	0.000044
PFOA	0.000005	0.000005	0.0004 *	NA	NA	NA	NA	NA	NA	0.0004 *	**0.000395**	**0.000395**	0.000084	0.000084
Phosphate	0.0395	0.0395	NONE	NA	NA	NA	NA	NA	NA	NA	0	0	0.0395	0.0395
Nitrilotriacetic acid (NTA)	0.1	0.1	NONE	NA	NA	NA	NA	NA	NA	NA	0	0	0.1	0.1
Ethylenediaminetetraacetic acid (EDTA)	0.1	0.1	NONE	NA	NA	NA	NA	NA	NA	NA	0	0	0.1	0.1
Surfactants (MBAS)	0.2	0.2	0.5	NA	NA	0.5	NA	NA	NA	NA	**0.3**	**0.3**	0.26	0.26
Terbuthylazine	0.1	0.1	NONE	NA	NA	NA	NA	NA	NA	NA	0	0	0.1	0.1

Notes:
Bold indicates some assimilative capacity.
* Provisional short term value.
** Maximum taste threshold.
*** Deriviation found in Table IV-3-2. Typical reporting limits used where data was not available.
**** Values are used in Table IV-3-2.

Table IV-3-2:
SUMMARY OF RECYCLED WATER AND BASELINE GROUNDWATER DATA
EVALUATION OF POTENTIAL IMPACTS
RECYCLED WATER STUDY

Parameter	Units	Typical Reporting Limit[1]	Current Baseline Groundwater Data								Pilot Study Threat	Recycled Water Data[6]									
			Overall Study Area[7]		Santa Clara Subbasin		Llagas Subbasin		Representative Concentration plus 20% Assimilative Capacity[3]			PARWQCP		SCRWA		SJ/SC WPCP		SWPCP		Overall Recycled Water Quality[8]	
			Mean[2]	Count	Mean[2]	Count	Mean[2]	Count	Santa Clara	Llagas		Mean	Count	Mean	Count	Mean	Count	Mean	Count	Min	Max
Biological[4]																					
Coliforms, Total	%		13%	23					13%	13%	3	67%	3	67%	9	60%	15	20%	5	20%	67%
E. Coli	%		0%	9					1%	1%	3	0%	3	0%	7	7%	15	20%	5	0%	20%
Fecal Coliforms	%		0%	9					1%	1%	3	0%	3	0%	7	27%	15	20%	5	0%	20%
Heterotrophic Plate Count[5]	CFU/mL		491	23					493	493	3	1957	3	8478	7	20052	15	2827	5	ND	64000
Inorganics																					
Boron	µg/L	100	196	1815	211.6	1441	134.8	374	368	304	3	331	3	403	5	449	15	409	5	321	505
Bromide	mg/L	0.02	0.25	653					0.25	0.25	2	0.23	0	0.00	2	0.23	10	0.23	0	ND	0.38
Calcium	mg/L	0.5	61.5	5813	62.3	5213	54.9	600	62.3	54.9	2	46.8	3	50.5	7	53.9	16	52.0	6	44	69
Chloride	mg/L	1	61.9	6837	63.5	6232	44.6	605	101.0	85.7	4	288	3	175	7	204	16	238	5	119	320
Magnesium	mg/L	0.5	30.7	5785	30.3	5193	33.8	592	30.3	33.8	2	34.7	3	30.6	7	29.6	15	38.4	5	25	42
Nitrate as NO3	mg/L	0.05 as N	23.5	14772	17.3	5002	26.7	9770	22.8	30.4	2	104	3	11	7	44	16	54	5	7.5	122
Nitrite as NO2	mg/L	0.05 as N	124	1571	156.4	1249	ND	322	156	124	2	ND	3	ND	7	1.94	15	0.08	5	ND	5.59
Phosphate	mg/L	0.03 as P	0.040	19					0.040	0.040	1	13	3	10.4	7	1.2	15	10.2	5	0.2	14
Potassium	mg/L	0.5	1.7	5246					1.7	1.7	1	15	0	30	2	15.0	10	15	0	12	32
Sodium	mg/L	0.5	39.7	5798	40.23	5193	35.21	605	44.2	40.2	4	215	3	139	7	147	16	177	5	118	230
Sodium Adsorption Ratio (SAR)	unitless		1.03	NA	1.05	NA	0.92	NA	1.05	0.92	4	5.80	NA	3.80	NA	3.99	NA	4.54	NA	3.53	5.38
Sulfate	mg/L	0.5	54.1	5915	55.39	5274	43.70	641	94.3	85.0	3	97	3	72	7	99	15	137	5	60	247
Total Filterable Residue at 180C (TDS)	mg/L	10	456.59	3872					465	465	3	864	3	676	7	735	16	841	5	630	1000
Emerging Contaminants and DBPs																					
N-Nitroso Dimethylamine (NDMA)	ng/L	2	ND	28					3.6	3.6	5	261	3	3	6	271	14	50	4	ND	490
Perfluorochemicals (PFBA)	ng/L	20	ND	4					20	20	5	1.2	0	0	2	1.2	10	1.2	0	ND	12
Perfluorochemicals (PFOS)	ng/L	5	ND	4					44.0	44.0	5	44.0	0	0	2	44.0	10	44.0	0	ND	87
Perfluorochemicals (PFOA)	ng/L	5	ND	4					84.0	84.0	5	61.9	0	20	2	61.9	10	61.9	0	ND	109
HAA6	µg/L	1	0.34	13					1.0	1.0	4	61		99		51		40			
Dibromoacetic Acid	µg/L	1	0.04	45					1.0	1.0	4	24.7	3	1.1	5	2.0	16	9.2	5	ND	30
Dichloroacetic Acid	µg/L	1	ND	46					1.0	1.0	4	14.6	3	36.1	5	16.9	16	12.1	5	ND	80
Trichloroacetic Acid	µg/L	1	ND	46					4.8	4.8	4	16.5	3	47.7	5	20.2	16	16.8	5	ND	124
Monobromoacetic Acid	µg/L	1	ND	13					1.0	1.0	4	4.1	3	0.7	6	1.3	16	1.2	5	ND	6.9
Monochloroacetic Acid	µg/L	2	ND	13					15.6	15.6	4	1.1	2	4.6	5	3.6	16	1.2	4	ND	21
Bromochloroacetic Acid	µg/L	1	0.42	13					1.0	1.0	4	20.8	2	8.6	2	7.0	15	8.6	4	ND	37
Total THMs	µg/L		0.096	5491	0.10	4729	0.076	762	16.10	16.10	2	170		115		53		196			
Bromodichloromethane	µg/L	0.5	0.010	10592	0.011	8965	0.002	1627	0.50	0.50	2	41.1	4	33.6	8	19.5	15	67.2	5	2.5	95
Bromoform	µg/L	0.5	0.019	7138	0.019	5979	0.021	1159	0.50	0.50	2	43.0	4	0.8	8	1.4	14	17.4	5	ND	61
Chloroform	µg/L	0.5	0.049	7191	0.046	6031	0.064	1160	14.40	14.4	2	13.6	4	68.8	8	22.5	14	42.5	5	2.7	95
Dibromochloromethane	µg/L	0.5	0.014	7068	0.016	5925	0.006	1143	12.40	12.4	2	72.0	4	11.9	8	9.7	14	69.0	5	0.8	115
General Water Quality Parameters																					
Alkalinity, Total as CaCO3	mg/L	1 as CaCO3	237	5549	238.9	5039	214.1	510	239	214	1	88	3	251	7	179	17	124	6	65.0	263
Bicarbonate Alkalinity	mg/L	1 as CaCO3	258	1802	274.4	1336	212.5	466	274	212	1	98	3	296	7	207	21	142	9	77.0	320
Chlorine, Total	mg/L	0.01	1.5	4					2.0	2.0	1	3.8	1	1.0	3	1.0	11	2.5	1	0.000	8.8
Dissolved Organic Carbon	mg/L	1	0.6	4					1.0	1.0	2	6.3	1	5.1	1	6.0	12	9.0	1	4.1	9.0
Dissolved Oxygen	mg/L		0.0038	4					0.0038	0.0038	1	5.0	0	8.6	2	5.0	10	5.0	0	0.04	8.7
ORP	mV		183	4					183	183	1	155	0	224	2	155	9	155	0	78.0	417
pH	pH Units		8.66	8729	8.96	6968	7.50	1761	8.7	7.5	1	7.10	4	7.59	6	7.33	18	7.03	6	6.5	8.1
Total Organic Carbon (TOC)	mg/L	0.5	0.36	23					0.50	0.50	2	6.22	3	4.94	7	6.46	15	8.25	5	4.0	10
Parameters with Low Occurrence in the Pilot Study																					
Cyanide	mg/L	0.01	0.000455	1059	0.00050	897	0.00022	162	0.04	0.04	3	ND	2	0.0008	6	0.01	14	ND	4	ND	0.06
Ethylenediaminetetraacetic acid (EDTA)	µg/L	100	3.48	15					100	100	3	26	0	196	4	26	12	18	2	ND	305
NTA	µg/L	100	ND	4					100	100	3	ND	0	ND	2	ND	3	ND	0	ND	ND
Perchlorate	µg/L	4	0.71	2223	0.036	509	0.91	1714	4.0	4.0	3	ND	0	ND	2	ND	3	ND	0	ND	ND
Surfactants (MBAS)	mg/L	0.2	0.0001	2356					0.3	0.26	3	0.13	2	0.11	6	0.08	5	0.16	4	ND	0.36
Terbuthylazine	µg/L	0.1	ND	4					0.1	0.10	3	0.10	1	ND	3	0.02	11	ND	1	ND	0.10

Notes:

1. Typical Reporting Limit from the bench test and pilot study data
2. For the purpose of calculating mean values, nondetects were evaluated as zero. "ND" is reported for the mean if all values are nondetect.
3. Basin-specific concentrations are used where there are a sufficient number of data to support quantification in each basin. Otherwise, the mean for the entire study area is applied to both basins. Where the groundwater data mean is below the typical reporting limit, the reporting limit was used. Additionally, 20 percent of the assimilative capacity as derived in Table 3-1 is included in these concentrations.
4. Total/Fecal Coliforms and E.Coli are presented in this table as frequency of detection rather than mean.
5. Heterotrophic plate count results were not used for this analysis, because there is limited accuracy with this analysis. Biologicals are adequately represented by the other biological parameters.
6. Mean values for recycled water sampled from each treatment plant. For PARWQCP and SWPCP where no data are available (count listed as 0), the concentration observed in SJSC WPCP is used as a surrogate.
7. Data includes groundwater data from the SCVWD database up to 2007, pilot study baseline, and the GAMA program.
8. Minimum and maximum is determined using data from all four treatment plant data.

NA - No data available.
Non-detects treated as zero concentration.
mg/L - milligrams per liter
µg/L - micrograms per liter
ng/L - nanograms per liter
MPN/100mL - most probable unit per 100 mL
CFU/mL - colony forming units per milliliter

Table IV-3-3:
RECYCLED WATER QUALITY RATING CALCULATION
EVALUATION OF POTENTIAL IMPACTS
RECYCLED WATER STUDY

		q/q_c						s						$s^{(-1/k)}$					
Parameter	**m**	**PARWQCP**	**SCRWA**	**SJ/SC WPCP**	**SWPCP**	**GROUND WATER**	**MAX**	**PARWQCP**	**SCRWA**	**SJ/SC WPCP**	**SWPCP**	**GROUND WATER**	**MAX**	**PARWQCP**	**SCRWA**	**SJ/SC WPCP**	**SWPCP**	**GROUND WATER**	**MAX**
Biological																			
Coliforms, Total	0.127	4.154	4.128	3.615	0.538	0.000	4.128	0.812	0.812	0.823	0.947	1.000	0.812	2.942	2.933	2.736	1.328	1.000	2.933
E. Coli	0.127	0.000	0.000	5.667	19.000	0.000	19.000	1.000	1.000	0.785	0.683	1.000	0.683	1.000	1.000	3.486	7.183	1.000	7.183
Fecal Coliforms	0.127	0.000	0.000	25.667	19.000	0.000	19.000	1.000	1.000	0.658	0.683	1.000	0.683	1.000	1.000	8.681	7.183	1.000	7.183
Inorganics																			
Boron	0.127	0.000	0.326	0.221	0.110	0.000	0.372	1.000	0.965	0.975	0.987	1.000	0.961	1.000	1.204	1.140	1.071	1.000	1.232
Bromide	0.042	0.000	0.000	0.000	0.000	0.000	0.545	1.000	1.000	1.000	1.000	1.000	0.982	1.000	1.000	1.000	1.000	1.000	1.100
Calcium	0.042	0.000	0.000	0.000	0.000	0.000	0.111	1.000	1.000	1.000	1.000	1.000	0.996	1.000	1.000	1.000	1.000	1.000	1.023
Chloride	0.255	1.851	1.042	1.017	1.360	0.000	2.168	0.766	0.834	0.836	0.804	1.000	0.746	3.972	2.559	2.519	3.097	1.000	4.563
Magnesium	0.042	0.143	0.000	0.000	0.266	0.000	0.392	0.994	1.000	1.000	0.990	1.000	0.986	1.030	1.000	1.000	1.053	1.000	1.075
Nitrate as NO3	0.042	3.580	0.000	0.946	1.384	0.000	4.360	0.937	1.000	0.972	0.964	1.000	0.931	1.396	1.000	1.157	1.210	1.000	1.445
Nitrite as NO2	0.042	0.000	0.000	0.000	0.000	0.000	0.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Phosphate	0.000	328.114	261.582	28.167	258.190	0.000	356.658	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Potassium	0.000	7.829	16.353	7.829	7.829	0.000	17.824	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Sodium	0.255	3.862	2.452	2.320	2.999	0.000	4.204	0.669	0.729	0.737	0.703	1.000	0.657	8.019	5.108	4.853	6.200	1.000	8.768
Sodium Adsorption Ratio (SAR)	0.255	4.552	3.128	2.813	3.338	0.000	4.143	0.646	0.697	0.711	0.688	1.000	0.659	9.549	6.465	5.823	6.901	1.000	8.634
Sulfate	0.127	0.024	0.000	0.051	0.449	0.000	1.619	0.997	1.000	0.994	0.954	1.000	0.885	1.016	1.000	1.034	1.277	1.000	1.885
Emerging Contaminants and DBPs																			
N-Nitroso Dimethylamine (NDMA)	0.424	71.500	0.000	74.357	12.958	0.000	135.111	0.162	1.000	0.160	0.327	1.000	0.124	12063.214	1.000	13130.729	324.857	1.000	48042.602
Perfluorochemicals (PFBA)	0.424	0.000	0.000	0.000	0.000	0.000	0.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Perfluorochemicals (PFOS)	0.424	0.000	0.000	0.000	0.000	0.000	0.977	1.000	1.000	1.000	1.000	1.000	0.749	1.000	1.000	1.000	1.000	1.000	4.462
Perfluorochemicals (PFOA)	0.424	0.000	0.000	0.000	0.000	0.000	0.298	1.000	1.000	1.000	1.000	1.000	0.895	1.000	1.000	1.000	1.000	1.000	1.771
HAA6																			
Dibromoacetic Acid	0.255	23.733	0.140	0.969	8.180	0.000	29.300	0.442	0.967	0.842	0.569	1.000	0.420	68.244	1.188	2.439	18.512	1.000	89.149
Dichloroacetic Acid	0.255	13.600	35.120	15.875	11.120	0.000	79.400	0.505	0.401	0.487	0.530	1.000	0.327	34.096	112.347	41.257	26.686	1.000	322.111
Trichloroacetic Acid	0.255	2.431	8.938	3.199	2.500	0.000	24.833	0.731	0.557	0.694	0.727	1.000	0.437	5.067	20.548	6.610	5.202	1.000	72.267
Monobromoacetic Acid	0.255	3.133	0.000	0.313	0.240	0.000	5.900	0.697	1.000	0.933	0.947	1.000	0.612	6.476	1.000	1.430	1.327	1.000	12.712
Monochloroacetic Acid	0.255	0.000	0.000	0.000	0.000	0.000	0.372	1.000	1.000	1.000	1.000	1.000	0.923	1.000	1.000	1.000	1.000	1.000	1.516
Bromochloroacetic Acid	0.255	19.800	7.575	6.000	7.600	0.000	35.900	0.462	0.579	0.609	0.578	1.000	0.399	54.331	16.923	12.956	16.988	1.000	115.551
Total THMs																			
Bromodichloromethane	0.042	81.200	66.275	38.040	133.480	0.000	189.000	0.829	0.836	0.856	0.812	1.000	0.800	2.631	2.518	2.234	2.931	1.000	3.162
Bromoform	0.042	84.900	0.500	1.784	33.760	0.000	121.000	0.828	0.983	0.957	0.860	1.000	0.816	2.656	1.093	1.252	2.178	1.000	2.869
Chloroform	0.042	0.000	3.780	0.559	1.951	0.000	5.597	1.000	0.936	0.981	0.955	1.000	0.923	1.000	1.410	1.102	1.268	1.000	1.513
Dibromochloromethane	0.042	4.804	0.000	0.000	4.568	0.000	8.274	0.928	1.000	1.000	0.930	1.000	0.910	1.471	1.000	1.000	1.457	1.000	1.630
General Water Quality Parameters																			
Dissolved Organic Carbon	0.042	5.300	4.100	4.992	8.000	0.000	8.000	0.925	0.933	0.927	0.911	1.000	0.911	1.498	1.430	1.481	1.619	1.000	1.619
Total Organic Carbon (TOC)	0.042	11.433	8.871	11.920	15.504	0.000	18.240	0.899	0.907	0.897	0.888	1.000	0.882	1.738	1.653	1.753	1.850	1.000	1.913
Parameters with Low Occurrence in the Pilot Study																			
Cyanide	0.127	0.000	0.000	0.000	0.000	0.000	0.526	1.000	1.000	1.000	1.000	1.000	0.948	1.000	1.000	1.000	1.000	1.000	1.321
Ethylenediaminetetraacetic acid (EDTA)	0.127	0.000	0.963	0.000	0.000	0.000	2.050	1.000	0.918	1.000	1.000	1.000	0.868	1.000	1.559	1.000	1.000	1.000	2.083
NTA	0.127	0.000	0.000	0.000	0.000	0.000	0.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Perchlorate	0.127	0.000	0.000	0.000	0.000	0.000	0.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Surfactants (MBAS)	0.127	0.000	0.000	0.000	0.000	0.000	0.373	1.000	1.000	1.000	1.000	1.000	0.960	1.000	1.000	1.000	1.000	1.000	1.232
Terbuthylazine	0.127	0.000	0.000	0.000	0.000	0.000	0.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
													SUM	12288.346	200.936	13251.674	456.380	37.000	48733.509
								Additional Parameters:					Aggregate Index, I (per Swamee)	0.162	0.372	0.160	0.311	1.000	0.124
							N=	37					Modified Aggregate Index, 1 – I (per Locus)	0.838	0.628	0.840	0.689	0.000	0.876
							k=	0.193426404					Recycled Water Quality	**9.61**	**7.45**	**9.63**	**8.08**		
							mscale=	0.02121826											

Volume V
Proposed Recycled Water Irrigation Screening Levels, Best Management Practices, and Ongoing Monitoring Recommendations

Recycled Water Irrigation and Groundwater Study
Santa Clara and Llagas Groundwater Subbasins
Santa Clara County, California

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V-4-1	List of Recycled Water Constituents to Monitor

LIST OF ACRONYMS AND ABBREVIATIONS

ACRONYM	**DESCRIPTION**
AAI	All appropriate inquiries
ASTM	American Society for Testing and Material
BMP	best management practice
GAMA	Groundwater Ambient Monitoring and Assessment
Locus	Locus Technologies
NDMA	n-nitrosodimethylamine
PARWQCP	Palo Alto Regional Water Quality Control Plant
PRWISL	Proposed recycled water irrigation screening level
RWQ	Recycled water quality
RWQCB	Regional Water Resources Control Board
SAR	Sodium Adsorption Ratio
SAT	Soil Aquifer Treatment
SCRWA	South County Regional Wastewater Authority
SCVWD	Santa Clara Valley Water District
SJ/SC WPCP	San Jose/Santa Clara Water Pollution Control Plant
SWPCP	Sunnyvale Water Pollution Control Plant
SWRCB	State Water Resources Control Board

EXECUTIVE SUMMARY

Volume V, prepared by Locus Technologies (Locus) on behalf of the Santa Clara Valley Water District (SCVWD), covers the final phase of the Recycled Water Irrigation and Groundwater Study. The overall goal of the study is to evaluate the potential impact to groundwater from expanded use of recycled water for irrigation in the Santa Clara and Llagas Subbasins (study area). The scope of this portion of the report is to establish guidance for the use of recycled water in irrigation in the study area in a manner that sustainably protects groundwater from this particular use. This includes the development of proposed recycled water irrigation screening levels (PRWISLs), best management practices (BMPs), and ongoing monitoring recommendations for recycled water and groundwater.

Proposed Recycled Water Irrigation Screening Levels

In conjunction with best management practices and ongoing monitoring recommendations, proposed recycled water irrigation screening levels (PRWISLs) are developed for recycled water irrigation aimed at protecting groundwater sources in the study area. The function of the PRWISLs is to provide guidance on threshold concentrations of constituents in recycled water for the given soil aquifer treatment (SAT) zone. For this study, the PRWISL is defined as the maximum concentration of a recycled water constituent for irrigation at which minimal groundwater degradation potential can be achieved.

Recycled water concentrations higher than the PRWISLs will always result in greater than minimal groundwater degradation potential. However, a recycled water quality that meets all the PRWISLs does not necessarily indicate minimal groundwater degradation potential because the PRWISL of each constituent assumes there is no contribution to the GWDP from the other constituents. To quantify the GWDP, the forward evaluation for determining the groundwater degradation potential as discussed in Volume IV must be performed.

PRWISLs vary within the study area based on the soil aquifer treatment capacity and representative groundwater quality. The PRWISLs also consider the constituent’s threat level determined from the pilot study and bench test in previous phases of this study. To determine proposed recycled water irrigation screening levels for recycled water irrigation, an inverse calculation approach was used from the methodology developed for determining the groundwater degradation potential. By constraining the groundwater degradation potential to an assumed target maximum acceptable level, which is numerically 20 for the lowest groundwater degradation potential, an analysis can be performed to compute the maximum recycled water concentration for each constituent that will result in the target groundwater degradation potential. Proposed recycled water irrigation screening levels are shown in Table V-2-1 and are established for each soil aquifer treatment zone and subbasin.

Best Management Practices

Best management practices (BMPs) are recommendations to maintain optimal use of recycled water for irrigation while protecting groundwater. BMPs evaluated in this report are specific to recycled water use as an irrigation source for landscape with the goal of minimizing the degradation of groundwater resources. BMPs that may affect groundwater degradation potential with respect to recycled water include practices such as dilution, fertilizer application, site selection, irrigation optimization, and gypsum application. Dilution may be an appropriate measure for areas where the quality of the recycled water is above proposed recycled water irrigation screening levels. In addition, source control or modifications of treatment processes may also be options for reducing the groundwater degradation potential. Reduced fertilizer application can minimize potential impacts of migration of nutrients found in recycled water to groundwater. Careful selection of sites for recycled water application is important to avoid the mobilization of other contamination sources that may be present onsite. Optimizing the irrigation system minimizes the total volume of irrigation needed for application and consequently minimizes the mass load of recycled water constituents applied. Gypsum application can promote soil drainage which is important for maintenance of landscaping, as well as preventing water logging and possible runoff of recycled water to surface waters. However, it also accelerates migration of recycled water constituents to groundwater. Therefore, its use needs to be carefully balanced.

Ongoing Monitoring Recommendations

Recommendations for ongoing monitoring were developed to monitor the potential long term impacts to groundwater from use of recycled water for irrigation in the Santa Clara and Llagas Subbasins. The goal of the ongoing monitoring is to provide timely recognition of any adverse changes in groundwater quality due to application of recycled water. This monitoring schedule serves as a general guideline for monitoring activities. Future deviations from this monitoring schedule may be appropriate to optimize this program.

Site-specific data can be used to directly calculate the groundwater degradation potential to help determine if additional monitoring is needed. The use of this data, along with available groundwater monitoring results from areas with similar physical and recycled water quality characteristics may reduce the need for additional monitoring.

If additional monitoring is needed within the area of current or planned recycled water irrigation, the location of monitoring wells should be prioritized to areas of highest groundwater degradation potential as shown on Figures IV-3-3 and IV-3-4 of Volume IV of this report.

The following is a summary of proposed criteria for achieving adequate monitoring:

1) Select or install wells at or adjacent to sites where recycled water irrigation is implemented. Monitoring wells should be downgradient of the application area.

2) While not every irrigation site needs to be monitored, at least one should be monitored to represent each region of expansion with similar calculated GWDP values. If a region of expansion contains different rating categories of GWDP, consider monitoring an irrigation site in each unique subregion.

3) Monitoring wells located between application areas and production wells will be useful in monitoring water quality that may affect production.

4) Monitor for the groundwater of interest (i.e. in the principal aquifer) and in shallower aquifers. Shallower aquifers can provide an early indication of changes in water quality.

5) Avoid monitoring wells that are screened in multiple aquifers, since samples would effectively be an average groundwater concentration across multiple aquifers.

6) Use denser monitoring well spacing in areas of higher GWDP where groundwater degradation is most likely to occur.

Groundwater monitoring is recommended at the following frequency guideline, which also varies depending on the groundwater degradation potential. The monitoring frequencies were developed based on observations from the pilot study phase of this study.

Highest Groundwater Degradation Potential in Represented Area	Monitoring Frequency		
	Year 1	Year 2-4	Year 5 and beyond
1-20	Quarterly	Semi-annually in spring and fall	Annually in fall
21-40	Quarterly	Quarterly	Semi-annually in spring and fall
41-60	Monthly	Quarterly	Semi-annually in spring and fall
61-100	Monthly	Quarterly	Quarterly

After a period of monitoring events, if evaluation of the data demonstrates that the quality of groundwater has not degraded past 20 percent of the assimilative capacity and does not show an increasing trend, the groundwater monitoring scope may be reduced in frequency or in the number of wells monitored. The schedule is designed to allow for more frequent observations in the beginning of implementation of expanded use of recycled water. This ensures that if groundwater degradation occurs as a result of recycled water use, it will be detected early. Conversely, the monitoring scope can be increased in frequency or number of wells if adverse impacts are encountered.

Recycled water monitoring is recommended for wastewater treatment plants in order to verify that recycled water quality does not change over time. If recycled water quality worsens over time, additional measures, such as additional treatment, source control, or dilution as specified in the BMPs should be implemented in order to maintain the same level of groundwater protection. During this study, recycled water concentrations were observed to be relatively consistent over time when sampled at the same location. Annual monitoring of recycled water is recommended from each treatment plant that provides recycled water for irrigation use. Additional sampling events should also be scheduled following any change in the treatment process. During this study, constituent concentrations in recycled water were observed to vary within the distribution system. Therefore, it is recommended that samples be collected at various points in the distribution system to evaluate the quality of recycled water being applied for irrigation. Samples should be collected at the irrigation site closest to the recycled water source, and at the irrigation site furthest from the recycled water source. Additional samples within the distribution system may be warranted based on size of the distribution system. Note that as the recycled water distribution systems are expanded, sampling locations may need to be revised or added over time.

A list of the constituents to be analyzed for future monitoring is presented in Table V-4-1. The list contains constituents of recycled water that were determined by this study to be of concern with regard to adverse impacts to groundwater. The list of constituents may be revised if it is suitably demonstrated that one or more of the constituents is consistently below detection in the recycled water source. The constituent should be below detection in all samples collected from the distribution system. All constituents should continue to be monitored in the recycled water source. In addition, this list of constituents may be adapted in the future to include new contaminants in recycled water that are identified and determined to have merit for monitoring.

The monitoring approach, including constituents monitored and monitoring frequency, may be revised as more site-specific data becomes available. To date, there is limited field-scale data on long-term impacts to groundwater from recycled water application, particularly for some of the constituents of concern. With additional data from further studies, revisions to this monitoring approach should be evaluated with consideration of the applicability of the new data to recycled water application within the study area.

VOLUME V
PROPOSED RECYCLED WATER IRRIGATION SCREENING LEVELS, BEST MANAGEMENT PRACTICES, AND ONGOING MONITORING RECOMMENDATIONS

1. INTRODUCTION

This report was prepared by Locus Technologies (Locus) on behalf of the Santa Clara Valley Water District (SCVWD) for the Recycled Water Irrigation and Groundwater Study. Volume V of this report covers proposed recycled water irrigation screening levels (PRWISLs), best management practices (BMPs), and ongoing monitoring recommendations. This volume focuses on the last phase of this study which is guidance for use of recycled water in irrigation in the study area in a manner that sustainably protects groundwater from this particular use. Protecting groundwater means ensuring that negative impacts of recycled water for irrigation in groundwater are minimized.

1.1. Purpose

This volume of the report includes proposed recycled water irrigation screening levels (PRWISLs), best management practices (BMPs), and ongoing monitoring recommendations. PRWISLs are maximum tolerable concentrations of recycled water constituents in irrigation water. BMPs are effective and practical methods for using recycled water in irrigation that aim to protect to groundwater quality. These BMPs were developed with two major considerations in mind: 1) to protect groundwater resources and 2) to maintain recycled water as a viable source for irrigation. Ongoing monitoring recommendations are established to maintain proposed recycled water irrigation screening levels in the irrigation water and preemptively identify potential effects to groundwater. Together, RSWLs, BMPs, and ongoing monitoring recommendations aim to minimize groundwater degradation from recycled water irrigation. The following goals were identified for Volume V:

- Define proposed recycled water irrigation screening levels for recycled water constituents.
- Establish best management practices for sustainable use of recycled water as an irrigation source with regard to protection of groundwater.
- Specify ongoing monitoring provisions to track irrigated recycled water and groundwater at implemented areas.

2. DEVELOPMENT OF PROPOSED RECYCLED WATER IRRIGATION SCREENING LEVELS

Proposed recycled water irrigation screening levels (PRWISLs) were developed for irrigation to protect groundwater sources in the study area, in conjunction with BMPs and ongoing monitoring recommendations. For this study, the PRWISL is defined as the maximum concentration of a recycled water constituent present in irrigation water at which minimal groundwater degradation potential can be achieved. Recycled water concentrations higher than the PRWISLs will always result in greater than minimal groundwater degradation potential. However, a recycled water quality that meets all the PRWISLs does not necessarily indicate minimal groundwater degradation potential because the PRWISL of each constituent assumes there is no contribution to the GWDP from the other constituents. To quantify the GWDP, the forward evaluation for determining the groundwater degradation potential as discussed in Volume IV must be performed. Recalculation of the GWDP is useful whenever there are changes in the recycled water quality..

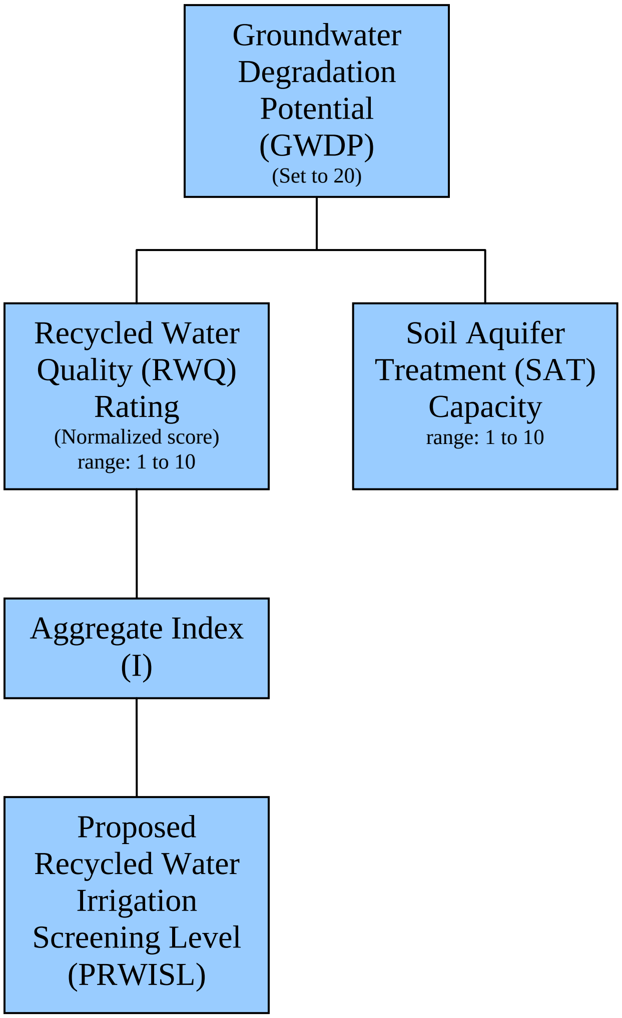
The PRWISLs vary within the study area based on the soil aquifer treatment capacity of a given area and the representative groundwater quality. The PRWISLs also consider the constituent's threat level as determined in Volume III of this study. The PRWISL of a given constituent is determined by assuming that the other recycled water constituent concentrations are equal to or less than the representative groundwater quality. The PRWISL of a single constituent represents the maximum tolerable concentration at which the target groundwater degradation potential can no longer be achieved regardless of the other constituent concentrations. PRWISLs are advisory levels based on the findings from this study. The PRWISLs may need to be refined as future studies contribute to the current understanding of recycled water fate and transport.

Proposed recycled water irrigation screening levels are shown in Table V-2-1 and are established for each soil aquifer treatment zone. For compatibility in determining a PRWISL with the method for determining groundwater degradation potential (Volume IV), only constituents evaluated in the groundwater degradation potential methodology were included in this evaluation. Constituents excluded from PRWISL evaluation include alkalinity, dissolved oxygen, oxidation reduction potential, chlorine, pH, total dissolved solids, and heterotrophic plate count. The rationale for exclusion of these constituents is documented in Volume IV of this study. In addition, a PRWISL was not developed for Sodium Adsorption Ratio (SAR) because the effect of SAR is not correlated to the SAT zones as the other constituents are.

2.1. Methodology

To determine proposed recycled water irrigation screening levels, an inverse calculation approach was used from the methodology developed for determining the groundwater degradation potential (Volume IV). An inverse calculation refers to setting the value of the result to determine the value of the input. The groundwater degradation potential describes the potential for groundwater quality to be impacted by recycled water used in irrigation. The groundwater degradation potential (GWDP) is based on (1) the hydrogeological characteristics (SAT capacity) and (2) the quality of the recycled water applied for a given area. A full description of the calculation methodology for SAT capacity and groundwater degradation potential is found in Volume IV of this report.

By constraining the groundwater degradation potential to a maximum target acceptable level that protects groundwater from negative impacts, an inverse analysis can be performed to compute proposed recycled water irrigation screening levels that meet the given criteria. Below is a flow chart of variables used in determining the proposed recycled water irrigation screening levels.



2.1.1. Groundwater Degradation Potential

Groundwater degradation potential is defined as the potential for groundwater to be impacted by recycled water used in irrigation. The full calculation method for GWDP was described in Volume IV of this study. The GWDP rating system ranges from 0 to 100 with a higher rating referring to a greater threat potential. For this inverse evaluation, the groundwater degradation potential was constrained to a target rating of 20. A rating of 20 is defined for areas with recycled water that has relatively low potential to degrade groundwater. For reference, the GWDP at the pilot study site was found to be 24 using site-specific data.

2.1.2. Soil Aquifer Treatment Capacity

Soil Aquifer Treatment (SAT) capacity is defined as the ability of the soil and aquifer to naturally treat recycled water contaminants. SAT capacity values for the entire study area were developed in Volume IV of this study, based on hydrogeological characteristics including the depth to groundwater, type of shallow soil media, and the type of vadose zone media. SAT capacity values ranged from 1 to 10 within the study area. Low SAT capacity values indicate areas of relatively protective conditions for groundwater. High SAT capacity values indicate areas where groundwater is more vulnerable to contamination from recycled water irrigation.

Because the SAT capacity varies within the study area, the PRWISLs were calculated separately for multiple values of SAT capacity. The SAT capacity range of 1 to 10 was divided into five categories as shown in Table V-2-1.

2.1.3. Recycled Water Quality Rating and Aggregate Index

In Volume IV of this study, recycled water quality (RWQ) ratings were calculated as an overall index of the quality of recycled water sources, considering the concentrations of various constituents that could threaten groundwater. The RWQ rating system ranges from 1 to 10, with higher values indicating higher constituent concentrations. The GWDP was calculated for each area by multiplying the SAT capacity rating with the RWQ rating. For the inverse calculation, the maximum acceptable RWQ rating is determined by the following equation

$$[\text{RWQ rating}] = \frac{[\text{GWDP rating}]}{[\text{SAT rating}]}$$

[RWQ rating] =	maximum acceptable recycled water quality rating.
[GWDP rating] =	groundwater degradation potential rating, which is set to the target threshold of 20 for this evaluation (Section 2.1.1).
[SAT rating] =	soil aquifer treatment capacity rating which ranges from 1 to 10 (Section 2.1.2).

Because the SAT rating varies within the study area, the RWQ rating is calculated separately for each SAT rating category. For each category, the more conservative (i.e. greater) value of SAT capacity was used to calculate the RWQ rating. Using this approach, maximum acceptable recycled water quality ratings are calculated for each zones of soil aquifer treatment capacity as shown in Table V-2-1.

As described in Volume IV, the RWQ ratings were calculated from the aggregate index (I) values using:

[unscaled RWQ rating] = 1 - I

The unscaled RWQ ratings were then rescaled to a range of 1 to 10, based on groundwater concentrations (RWQ rating = 1) and maximum recycled water concentrations (RWQ rating = 10). To back calculate the aggregate index from the maximum acceptable RWQ rating for this evaluation, the RWQ ratings were rescaled from zero to one using the same values. Then the aggregate index was calculated from the RWQ rating using the above equation.

2.1.4. Subindices, Groundwater Quality, and Subindex Exponent

As described in Volume IV, the aggregate index, I, was calculated using the following equations:

$$I = \left(1 - N + \sum_{i=1}^{N} s_i^{-1/k}\right)^{-k} \text{ such that } k = \frac{1}{\log_2(N-1)} \text{ and } s_i = \left(1 + \frac{q_i}{q_{ci}}\right)^{-m}$$

Where

I = Aggregate index of the recycled water quality.
N = Number of subindices considered. In this study, the number of subindices corresponds to the number of constituents evaluated (N=37).
s_i = Subindex for the individual constituent i.
q_i = Quality of constituent i, which is taken to be the difference between the constituent concentration in recycled water and $q_{ci.}$ q_i is set to zero if the recycled water concentration is lower than q_{ci}.
q_{ci} = Representative groundwater quality for constituent i, which is the current groundwater concentration of the given subbasin with 20 percent of the available assimilative capacity.
m = Subindex exponent. In Volume IV, the following equation was used:
m = [Threat] × ([Threat] – 1) × [mscale]
[mscale] = 0.020783 as determined in Volume IV.

[Threat] = Threat assigned to given constituent as determined in Volume III. Values range from 1 to 5.

The PRWISL for each constituent is the maximum concentration that results in the target groundwater degradation potential. To calculate that value, the specific constituent being evaluated would be the only constituent that contributes to groundwater degradation potential. All other constituent concentrations would be less than or equal to groundwater concentrations plus 20% assimilative capacity. For those constituents, the value of q is zero, and the subindex (s) value for those constituents would be 1. Using the constant value of N=37, and the assumption that 36 of the constituent subindex values are 1, the above equation reduces to I = s.

Using the subindex equation to solve for the constituent quality (q) yields:

$$q_i = \left(I^{-1/m} - 1\right) \times q_{ci}$$

This equation is used to calculate constituent quality values based on the aggregate index I (Section 2.1.3), the subindex exponent m (calculated using the constituent threat as shown above and in Volume IV), and the representative groundwater quality q_{ci}. Values of q_{ci} were determined for each constituent in each groundwater subbasin in Volume IV. Since the values of q_{ci} are different for each subbasin, the PRWISLs are calculated separately for each subbasin.

2.1.5. Proposed Recycled Water Irrigation Screening Level

The constituent quality (q_i) can be expressed as q_i = PRWISL - q_{ci}. Therefore the PRWISL for constituent i can be calculated as follows:

$$\mathrm{PRWISL}_i = \left(I^{-1/m} - 1\right) \times q_{ci} + q_{ci}$$

Using values of m and q_{ci} from Volume IV, and the aggregate index calculated for each SAT capacity, the calculated PRWISLs are shown in Table V-2-1. Direct use of the results of this equation can yield PRWISLs that are higher than maximum concentrations observed in recycled water. Where the calculated PRWISL is greater than the maximum observed concentration in recycled water, the maximum observed concentration is substituted as the PRWISL. This substitution was implemented because concentrations higher than current recycled water maximum values could not be evaluated in this study. Therefore, the PRWISLs must be set so that recycled water quality is either maintained or improved and is not allowed to decline.

2.2. Assumptions

Proposed recycled water irrigation screening levels are set such that the PRWISL of a given constituent will result in the target groundwater degradation potential (GWDP) of 20. This assumes that the quality of recycled water with respect to all other constituents will be at or below representative groundwater quality. As a result, a theoretical recycled water source with concentrations below the PRWISLs for the given SAT zone may still exceed the target GWDP, since the GWDP is calculated based on the aggregated quality of all constituents. PRWISLs were developed in this manner because there is no unique set of concentrations that would result in the target GWDP. To properly evaluate the GWDP for a given water chemistry, the forward calculation as described in Volume IV must be implemented. The PRWISLs are more appropriate for definitively determining when a recycled water source would have greater than minimal GWDP.

The PRWISLs assume that recycled water is the only source of pollution. Areas with other contamination sources in the surface or subsurface pose additional risk groundwater contamination due to mobilization of irrigation water. The irrigation water acts as a major vehicle for mobilizing constituents towards groundwater. It is recommended that application of recycled water is avoided in these areas, as discussed in Section 3.3.

2.3. Limitations

The development of the PRWISLs is subject to the same limitations as the determination of groundwater degradation potential, discussed in Volume IV. The threat values for this study were determined for each recycled water constituent based on available data from the bench test and pilot study. Additional long-term monitoring within the study area may reveal that some constituents are more or less of a threat compared to what was concluded from those investigations. Revisions to the threat levels would directly affect the PRWISLs.

The focus of the PRWISLs is to minimize groundwater degradation caused by recycled water irrigation. Separate consideration is needed for other factors that may limit the allowable concentration of recycled water. An example is salt tolerances of crops that may require more stringent recycled water levels.

Salt tolerances can limit the allowable quality of recycled water. Salts accumulate at the root zone as water is lost through transpiration of plants and evaporation. Plants that are exposed to more salt, expend greater energy to draw water from the soil. Tolerances vary by crop. *Salt Management Guide for Landscape Irrigation with Recycled Water in Coastal Southern California* (Tanji, et. al, date unspecified) provides data on salt thresholds for specific plant species. Winter precipitation and over-irrigating can contribute to the flushing of salts, which can be a concern for groundwater quality.

3. BEST MANAGEMENT PRACTICES

The best management practices (BMPs) presented in this section are recommendations to maintain optimal use of recycled water for irrigation while protecting groundwater. These BMPs are specific to recycled water use as an irrigation source for landscape, and are evaluated with respect to their potential impacts on groundwater resources. Because the main focus of this study is protection of groundwater, BMPs for recycled water use with regard to public health and safety, such as signage, are not discussed in this report unless they also have an impact on potential degradation of groundwater. A comprehensive overview of current BMPs for landscape irrigation can be found in publications such as *Turf & Landscape Best Management Practices* developed by the Irrigation Association (Irrigation Association, 2005). The document includes provisions for an irrigation system's overall quality, design, installation, maintenance, and management.

3.1. Improve Recycled Water Quality

Dilution of recycled water with higher quality water reduces the concentrations of residual contaminants found in recycled water. With dilution, recycled water can be made acceptable for use in areas that otherwise have too high of an acceptable groundwater degradation potential. Expanding the use of recycled water to these areas helps maximize the value of this resource. Areas where dilution should be implemented will vary by the quality of the recycled water source and the area's soil aquifer treatment capacity. Due to costs associated with implementing dilution (i.e. construction of an onsite holding tank), dilution is most practical for sites with large areas of landscaping. Title 22 prohibits any physical connection between recycled water systems and potable water systems without specific backflow protection devices.

Dilution may be an appropriate measure for areas where the constituent concentration of concern in the recycled water is above PRWISLs established for recycled water. PRWISLs, found in Chapter 2 of this document, specify threshold concentrations in recycled water that may achieve the target groundwater degradation potential. PRWISLs are specific to the soil aquifer treatment capacity for the area. Areas with differing soil aquifer treatment capacity have a different set of PRWISLs. Where the recycled water constituent concentration is above PRWISLs, dilution should be considered.

Dilution needs may change as the concentration of a constituent in recycled water may change over time. Periodically reevaluating dilution needs will ensure PRWISLs are met. If the concentration of a constituent in recycled water fluctuates in a given range, the upper value of that range should be used for dilution calculations. A higher concentration in recycled water will yield a greater dilution requirement. The monitoring recommendations in Section 4.2 would be sufficient for determining the appropriate amount of dilution.

In addition to dilution, source control (i.e. controlling the water quality at the treatment plant) may be an option for reducing the concentration of residual constituents of concern found in recycled water. Source control options could involve modifications to treatment processes that will improve the removal of the residual constituents. Source control could also include identification and elimination of sources of recycled water constituents from the waste stream used as the source for recycled water.

3.2. Fertilizer Use

Because nutrients such as nitrogen, phosphorus, and potassium found in fertilizer are also found in recycled water, the need for fertilizer in landscape management can be reduced. Nutrients found in recycled water are significant enough in quantity to supplement fertilizer application. Reducing fertilizer use is of particular importance with regard to nitrate, which is a major groundwater pollutant in a portion of the study area (SCVWD, 2010).

Balancing the overall load of nutrients onto irrigated landscape reduces excess nutrients that are not removed by the root uptake pathway. Over-fertilization in addition to recycled water use can exceed the root uptake as a sink for nutrients. Nutrients that are not taken up by plant needs can travel past the root zone and potentially reach groundwater.

Reducing fertilizer use is applicable for any site using recycled water for irrigation. Recycled water within the study area is currently obtained from one of four sources: Palo Alto Regional Water Quality Control Plant (PARWQCP), South County Regional Wastewater Authority (SCRWA), San Jose / Santa Clara Water Pollution Control Plant (SJ/SC WPCP), and Sunnyvale Water Pollution Control Plant (SWPCP). All of these recycled water sources contains concentrations of nutrients. Mean concentrations of nitrate from the four recycled water sources range from 10 to 104 mg/L as NO_3. Table IV-3-2 from Volume IV contains average concentrations of constituents, including nutrients, of each recycled water source.

To determine how much fertilizer is needed, the landscape manager needs to determine the annual quantity of nutrients needed for the landscape, the annual volume of the recycled water applied to the site, and the concentrations of nutrients found in the recycled water. The nutrient content of fertilizer is typically identified using three numbers representing the percentages by weight of nitrogen, phosphorus, and potassium. For example, a fertilizer labeled 21-7-14 contains 21% nitrogen, 7% phosphorus, and 14% potassium.

The following mass balance equation can be applied to determine the fertilizer needs for a given nutrient with application of recycled water.

$$[\text{Fertilizer need}] = [\text{Landscape requirement}] - 6.24\times10^{-2}\left(\frac{[\text{Vol. of RW}]\times[\text{Conc. in RW}]}{[\text{Area}]}\right)$$

Fertilizer need = Annual amount of nutrient in the form of fertilizer needed for landscape (lb/1000 sq ft-yr)

Landscape requirement = Annual amount of nutrient needed including uptake efficiency for the landscape based on type of plant (lb/1000 sq ft-yr)

6.24×10^{-2} = Conversion factor from [mg-ft/yr-L] to [lb/1000 sq ft-yr]

Vol. of RW = Annual volume of recycled water applied to landscape (acre-ft/yr)

Conc. in RW = Average concentration of the given nutrient in recycled water source (mg/L)

Area = Area of the irrigated landscape (acre)

Example:

Assume that the landscape manager at the pilot study site, by trial and error, determined that the nitrogen requirement for the given landscape is 1.8 lb of N / 1000 sq ft per year. Volume application of recycled water at the pilot study was 8,717 ccf/yr (20.0 acre-ft/yr) and the recycled water concentration of nitrate was 10.6 mg/L as N. The area of irrigation for the pilot study was 6.2 acres. The contribution of nitrogen from recycled water is 2.13 lb of N / 1000 sq ft per year. The difference is an excess of 0.33 lb of N / 1000 sq ft needed for fertilizer. This means that recycled water in this example can supply 118% of the nitrogen needs for the landscape. For this scenario, application of nitrate-containing fertilizer should be minimized or avoided.

Any changes with respect to landscaping requirements or recycled water applied will change the fertilizer needs. Landscaping requirements may change when the type of vegetation is replaced. Different landscape types may also have different fertilizer needs depending on the season. Change in the volume of recycled water applied per unit area or quality of recycled water can also change the fertilizer need. When such changes occur, reevaluate for the appropriate fertilizer need.

3.3. Site Selection

In considering areas for recycled water use, this study recommends screening sites for potential sources of pollution. Areas with other contamination sources in the surface or subsurface pose additional risk of groundwater contamination due to mobilization from the irrigation water. The irrigation water acts as a major vehicle for mobilizing constituents towards groundwater, which is true for any irrigation source. For example, known contamination sites that are undergoing soil and/or groundwater remediation would not be a candidate for irrigation with recycled water. Sites that are free of contamination issues avoid the potential for mobilizing contaminants that are already present at the site.

When considering potential expansion areas for recycled water irrigation, the soil aquifer treatment capacity can be used to indicate which locations are more protective of groundwater. Values of soil aquifer treatment capacity were determined in Volume IV for the entire study area, and are shown in Figures IV-2-11 and IV-2-12. Recycled water irrigation is less likely to impact groundwater in areas of high or good soil aquifer treatment capacity. Areas with marginal or least capacity should be evaluated carefully before recycled water irrigation is implemented.

In addition, sites need to be screened for proximity to nearby water supply wells. As established in Title 22, irrigation using recycled water should not take place within 50 feet of any domestic water supply well, unless the well owner specifically allows recycled water application within 50 feet, and a number of physical requirements for the well are met.

Sites should also be screened for vertical conduits (such as abandoned or improperly sealed wells) which may accelerate the mobilization of contaminants downward. Vertical conduits may be addressed by avoiding such sites or sealing the conduits prior to recycled water implementation. Evaluating the site stratigraphy may be useful for determining the potential for lateral movement of water. Where there is significant lateral movement of water consider also checking for vertical conduits around the site nearby.

3.3.1. Potential Contamination Sources

Potential contamination sources from the land surface include land disposal sites, stockpiles, disposal of sewage and water treatment plant sludge, heavy use of fertilizers and pesticides, accidental spills of hazardous materials, and particulate matter from airborne sources. Potential subsurface contamination sources above the water table include leaching septic systems, holding ponds, sanitary landfills, waste disposal in excavations, leakage from underground storage tanks or pipelines, sumps, drywells, and cemeteries.

3.3.2. Screening Method

If a potential area of expansion is not well characterized enough to make a decision on site selection, consider using tools from an environmental assessment of the area of interest. EPA's "All Appropriate Inquiries" (AAI) rule provides useful guidance on evaluating a property's environmental conditions and assessing potential liability for any contamination. Two American Society for Testing and Material (ASTM) standards are compliant to the AAI rule. These include ASTM International's E1527-05 "Standard Practice for Environmental Site Assessments: Phase I Environmental Site Assessment Process" and ASTM E2247-08 “Standard Practice for Environmental Site Assessments: Phase I Environmental Site Assessment Process for Forestland and Rural Property.” Important elements in screening for appropriate sites include:

- Interviews with past and present owners, operators and occupants;
- Review of historical sources of information;
- Review of federal, state, tribal, and local government records;
- Visual inspection of the facility and adjoining properties;
- Commonly known or reasonably ascertainable information;
- Degree of obviousness of the presence or likely presence of contamination at the property and the ability to detect the contamination.

3.4. Irrigation Effectiveness

The focus of this study is potential groundwater impacts resulting from use of recycled water for irrigation. BMPs that address the irrigation systems have a direct impact on the distribution of recycled water constituents at the surface, and thus the potential impact to groundwater. Optimizing the efficiency of an irrigation system minimizes the total volume of irrigation needed for application and consequently minimizes the mass loading of recycled water constituents to the site. An optimized irrigation system distributes water uniformly on the landscape, saving money from overwatering, and reducing ponding and surface runoff.

Irrigation using recycled water should be applied such that the infiltration of water past the active root zone is minimized. The volume of water past the root zone contributes to the advective transport of constituents to groundwater. Reducing the volume past the root active zone limits the advective migration of recycled water constituents towards groundwater while irrigation is being applied, although constituents are still flushed downward during precipitation events. Some water infiltration past the root zone is needed to remove salts from the root zone. Ideal irrigation systems should apply no more water than is needed to combat salt buildup. The amount of water needed to remove the excess salts from soils is known as the leaching requirement, which is generally 10 to 30 percent more than the landscaping water requirement.

3.4.1. Appropriate Irrigation Needs

Irrigation needs can be determined using the Landscape Coefficient Method which estimates irrigation needs of landscape plantings in California by using crop coefficients and reference evapotranspiration values. The landscape coefficient method is described in “A Guide to Estimating Irrigation Water Needs of Landscape Plantings in California” (University of California Cooperative Extension, California Department of Water Resources, 2000). It is critical that the determination of the water budget is done accurately so water needs of the crop are met without over-application.

Irrigation should be adjusted accordingly with weather patterns. Irrigation should not fully saturate the soil. Deficit irrigation techniques that leave room in the root zone for additional moisture from rainfall have been demonstrated to protect groundwater without yield reductions (Food and Agriculture Organization of the United Nations, 2002). To prevent deep percolation below roots and runoff, application should not exceed the infiltration rate of the soil or plant needs, except as needed for flushing salts. For salt management, Oster (SCVWD et al, date unspecified) recommends ceasing irrigation with recycled water once two inches of rainfall have occurred during the winter season, restarting irrigation in late spring. However, this recommendation is specific to redwood trees, and may not be appropriate for all landscape types. Seasonal reductions in recycled water application would reduce the annual mass loading of recycled water constituents and therefore reduce the potential impact to groundwater.

Landscape managers can also assess the characteristics of a site through a water audit every three years by a certified irrigation auditor, such as the SCVWD’s current Landscape Survey Program (LSP). The SCVWD’s LSP includes an in-depth evaluation of the entire water delivery system and points out inefficiencies that can add up to significant water losses. It also includes calculation of an optimum water budget and recommendations for improving system efficiency including upgrading irrigation hardware as well as providing a suggested yearly watering schedule.

3.4.2. Efficient Irrigation System

An efficient irrigation system can help protect groundwater by reducing the over-irrigation of recycled water and consequently the overall mass load of recycled water constituents at the site. The efficiency of an irrigation system can be improved through design, installation, and regular maintenance of the system. Several resources are available to improve an irrigation system. The California Department of Water Resources Model Water Efficient Landscape Ordinance (California Department of Water Resources, 2009) provides guidance on efficient irrigations systems. In addition, the Eastern Municipal Water District from Riverside County authored *"Recycled Water Use Guidelines and Best Management Practices"* (EMWD, date unspecified) which contains tips to improve the irrigation system. The Olivenhain Municipal Water District also maintains a "*Recycled Water Use Guidelines and Best Management Practices*" document (Olivenhain Municipal Water District, date unspecified) with similar content.

3.4.3. Time of Operation

The evening and early morning are typically recommended as optimal times to apply irrigation for two reasons: 1) there is less evaporation loss during this time and 2) there is less human exposure to recycled water due to lower foot traffic during this time. The disadvantage to early morning and late evening irrigation is a lack of potential photodegradation of light-sensitive constituents, such as n-nitrosodimethylamine (NDMA), which has been found to degrade in UV light. However, previous studies have shown that there is little difference in NDMA fate and transport between daytime and nighttime irrigation schedules (Gan et al, 2006). Therefore, due to the limited apparent benefit of photodegradation and potential health concerns associated with direct exposure to recycled water, irrigation during daylight hours is not recommended unless human contact with the irrigation water can be prevented.

3.5. Salt and Nutrient Management Plan

A salt and nutrient management plan should be prepared in accordance with the State Water Resources Control Board (SWRCB) Recycled Water Policy (SWRCB, 2009). The purpose of a salt and nutrient management plan is to protect groundwater from accumulating concentrations of salts and nutrients from recycled water and other sources that would degrade the quality of groundwater and limit its beneficial uses. The plans are tailored to address the water quality concerns in each groundwater basin or subbasin. The plans may also include constituents that impact water quality other than salts and nutrients. The SWRCB has also specified required elements for a salt and nutrient nanagement plan, including a basinwide monitoring plan, water recycling goals and objectives, salt and nutrient source identification, and implementation measures to manage the salt and nutrient loading. The plan should also include estimates for assimilative capacity, which was discussed in Volume IV of this report. The SWRCB recycled water policy states that salt and nutrient management plans should be completed and submitted to the appropriate Regional Water Resources Control Board (RWQCB) by 2014. The SCVWD is working to develop salt and nutrient management plans for the Santa Clara and Llagas Subbasins in coordination with basin stakeholders.

3.6. Gypsum Use

The use of gypsum greatly increases the percolation of water through clayey soils, improving infiltration and accessibility of water to plant roots. In Volume II of this study, gypsum was found to be very effective in increasing the hydraulic conductivity of soils within the study area. Good soil drainage is important to prevent water-logged soil and in turn promote healthy vegetation. However, with recycled water, increasing permeability also decreases the attenuation capacity of the soil due to less residence time for attenuation of recycled water constituents. Hence, mobility of constituents found in recycled water is increased when gypsum is applied.

In practice, gypsum is used in areas with clayey soils which have low permeability. An appropriate level of gypsum is best determined by trial and error such that sufficient infiltration is reached for the amount of water needed by the crop.

From a groundwater protection standpoint, gypsum should be used in moderation with recycled water. However, it should be noted under-application of gypsum can result in poor infiltration and possible ponding and/or runoff. Runoff of recycled water to surface water bodies is prohibited.

Oster (SCVWD et al, date unspecified) recommends gypsum application before the rain season begins because 1) it will prevent low soil salinities developing at the soil surface as a result of leaching by rain, 2) it will reduce sodium levels in the soil near the soil surface, and 3) salinity effects on plants are minimized during the winter due to low temperatures and high humidity. The effect of gypsum is most pronounced immediately after application. Hence, this recommended application schedule also has the benefit of increasing the infiltration rate most when recycled water application is expected to be lowest. With a properly operated irrigation system, the amount of applied recycled water should be reduced during the rain season.

4. ONGOING MONITORING RECOMMENDATIONS

Recommendations for ongoing monitoring were developed to evaluate the potential long term impacts to groundwater from use of recycled water for irrigation in the Santa Clara and Llagas Subbasins. The goal of the ongoing monitoring is to verify over the long term that the groundwater degradation is minimized as a result of recycled water use.

This chapter discusses constituents to analyze, sources to monitor, and frequency of sampling for an ongoing monitoring program. Monitoring recommendations also apply to further monitoring at the pilot study site. These monitoring recommendations serve as a general guideline for monitoring activities, based on the information compiled for this study. Future modifications of this monitoring schedule may be appropriate to optimize this program.

The approach used to develop these monitoring recommendations has similarities to the approach developed and used in *Monitoring Strategies for Chemicals of Emerging Concern (CECs) in Recycled Water* (SWRCB, 2010) including prioritization of constituents using concentrations in recycled water compared to a baseline value. However, the monitoring recommendations in this report are not limited to emerging contaminants, and the basis for selection of constituents is the groundwater degradation potential which is determined in the Volume IV of this report. The basis of selection from the SWRCB document was toxicological relevance. In the SWRCB document, the focus was on three reuse practices 1) indirect potable reuse via surface spreading of recycled water; 2) indirect potable reuse via subsurface injection of recycled water into a potable aquifer; and 3) urban landscape irrigation with recycled water. This report focuses only on the third reuse practice and uses constituent transport evaluations to guide these monitoring recommendations. The SWRCB used only toxicological information in guiding monitoring strategies.

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4.1. Groundwater Monitoring

Monitoring the quality of groundwater over time ensures that groundwater quality is maintained for the present and future. Ongoing monitoring allows for appropriate use of recycled water with respect to groundwater, and alerts if adjustments are needed in volume or in quality to the recycled water and the irrigation system. Collected groundwater monitoring data should be compared to baseline groundwater samples collected before recycled water irrigation begins, such as the current groundwater quality data presented in Volume IV.

4.1.1. Locations

Groundwater monitoring should target areas where recycled water for irrigation is currently being implemented, or is expected to be implemented. Wherever possible, existing wells should be used as opposed to installing new wells, as a cost-saving measure. Selected wells should target areas that have higher groundwater degradation potential, so that the most sensitive areas of the groundwater basins are monitored. The groundwater degradation potential for the study area is shown on Figure IV-3-3 and IV-3-4 in Volume IV of this report.

Site-specific data can be used to directly calculate the groundwater degradation potential to help determine if additional monitoring is needed. The use of this data, along with available groundwater monitoring results from areas with similar physical and recycled water quality characteristics may reduce the need for additional monitoring.

If additional monitoring is needed, monitoring wells should target both the principal aquifer and the shallow aquifer. The principal aquifer should be monitored since that is the primary groundwater source for most wells in the county. Monitoring of aquifers above the principal aquifer would be useful in providing advance indication of the transport of recycled water. Selected monitoring wells should have screen intervals that do not cross into multiple aquifers, to avoid the effects of diluting the representative groundwater. Wells that are screened in multiple aquifers, whether between a shallow and principal aquifer or among multiple aquifers within the principal zone would not be appropriate for this monitoring.

Ideal monitoring wells are located at sites where the irrigation with recycled water is currently implemented or planned for the future. Monitoring wells at or adjacent to such sites is recommended so that degradation of groundwater due to recycled water use can be observed as early as possible. Relative to the irrigation site, monitoring wells should be directly downgradient of the site to monitor for potential recycled water constituents that may reach groundwater. Monitoring well located between application sites and production wells are also useful to serve as early indication of changes in water quality that may affect production. Local water elevation data is useful in determining groundwater flow direction. Existing knowledge of the site soil profile, from historical boring logs, can also be useful in determining if there are any preferential flow patterns at the site. Depth to water and generalized groundwater gradient direction can be provided by the SCVWD if available, upon request. While not every irrigation site needs to be monitored, at least one should be monitored to represent each region of expansion with similar GWDP values. If a region of expansion contains different rating categories of GWDP, consider monitoring an irrigation site in each unique subregion.

The number of monitoring wells will depend on the extent of expanded use of recycled water. The more wells implemented in the monitoring program, the better characterized the transport of recycled water will be and ideally each area of planned expansion would be represented. However, cost considerations will limit the number of wells. Preferably, existing wells should be used where available.

Within the area of current or planned recycled water irrigation, the location of monitoring wells should prioritized to areas of highest groundwater degradation potential as shown on Figures IV-3-3 and IV-3-4 of Volume IV of this report. As mentioned above, direct calculation of the groundwater degradation potential using site-specific data and consideration of available groundwater monitoring results from areas with similar physical and recycled water quality characteristics would help identify areas where additional monitoring is needed.

The following is a summary of proposed criteria for achieving adequate monitoring:

1) Select or install wells at or adjacent to sites where recycled water irrigation is implemented. Monitoring wells should be downgradient of the application area.

2) While not every irrigation site needs to be monitored, at least one should be monitored to represent each region of expansion with similar GWDP values. If a region of expansion contains different rating categories of GWDP, consider monitoring an irrigation site in each unique subregion.

3) Monitoring wells located between application areas and production wells will be useful in monitoring water quality that may affect production.

4) Monitor for the groundwater of interest (i.e. in the principal aquifer) and in shallower aquifers. Shallower aquifers can provide an early indication of changes in water quality.

5) Avoid monitoring wells that are screened in multiple aquifers, since samples would effectively be an average groundwater concentration across multiple aquifers.

6) Use denser monitoring well spacing in areas of higher GWDP where groundwater degradation is most likely to occur.

4.1.2. Frequency

The frequency of groundwater monitoring should be associated with the groundwater degradation potential for each area. Areas with higher groundwater degradation potential merit more frequent monitoring to ensure that groundwater impacts are detected early, and steps can be taken to address those impacts, if warranted. Areas of lower groundwater degradation potential are only likely to show groundwater impacts, if any, over longer time frames.

As a starting point for determination of groundwater monitoring frequency, the results of the pilot study (Volume III) were reviewed. The pilot study site, using site-specific data, has a groundwater degradation potential of 24 on a scale of 1 to 100, which is classified as low potential. The first occurrence of recycled water constituents in groundwater during the pilot study was approximately three months after recycled water implementation, when PFCs were observed in the groundwater. In the pilot study, PFCs were not detected during baseline sampling, and they could be uniquely attributed to the recycled water source. Therefore, three months was established as the reasonable minimum time frame for evaluation of recycled water impacts in areas of low groundwater degradation potential. For a monitoring program, this corresponds to quarterly sampling. Monitoring frequencies for areas with different groundwater degradation potentials should be increased or decreased accordingly.

Since some groundwater degradation was observed in the pilot study under relatively protective conditions, quarterly monitoring is recommended initially as a minimum for all areas to ensure groundwater is protected. Initial monthly monitoring is appropriate for areas of relatively high groundwater degradation potential. Previous phases of the study have shown that over time, groundwater concentrations are expected to become asymptotic as conditions approach long-term steady state. Therefore, it is appropriate to gradually reduce the monitoring frequency over time. Reduced monitoring frequency over time allows for initial confirmation of lack of groundwater degradation, followed by ongoing monitoring at a more appropriate frequency for evaluating long-term conditions.

Below is a recommended schedule of groundwater sampling, with the year indicating the amount of time after recycled water application begins:

Highest Groundwater Degradation Potential in Represented Area	Monitoring Frequency		
	Year 1	Year 2-4	Year 5 and beyond
1-20	Quarterly	Semi-annually in spring and fall	Annually in fall
21-40	Quarterly	Quarterly	Semi-annually in spring and fall
41-60	Monthly	Quarterly	Semi-annually in spring and fall
61-100	Monthly	Quarterly	Quarterly

After a period of monitoring events, if evaluation of the data obtained demonstrates that the quality of groundwater has not degraded past 20 percent of the assimilative capacity and does not show an increasing trend, consideration may be given to reducing the groundwater monitoring scope by decreasing the monitoring frequency or the number of wells monitored. Reduced groundwater monitoring scope should still be within reason to adequately ensure groundwater quality is maintained. Before a reduction in monitoring scope, trend analysis with forward projection of the groundwater concentrations should be used to demonstrate that the concentrations will not exceed 20 percent of the assimilative capacity over a longer time frame. Conversely, if adverse impacts are encountered in a specific area the monitoring scope can be adjusted to increase in frequency or in the number of wells monitored in the specific area.

The long-term monitoring frequencies in the above schedule may be revised with the consideration of additional long-term monitoring data from sites with recycled water irrigation. To date, there is limited field-scale data on long-term impacts to groundwater from recycled water application. With additional data from further studies, revisions to this monitoring frequency should be evaluated with consideration of the applicability of the new data to recycled water application within the study area.

4.2. Recycled Water Sampling

Recycled water monitoring is recommended for treatment plants so that quality of the recycled water is known. If recycled water quality worsens over time, this can have an effect on the groundwater degradation potential, which should be reassessed. Maintaining quality of recycled water ensures safety of groundwater resources.

In addition to recycled water sampling, irrigation water sampling (i.e. sampling of the final product of the water, including any dilution if applicable) is useful in assessing if irrigation water has concentrations exceeding the proposed recycled water irrigation screening levels specified in this report.

4.2.1. Frequency

At minimum, annual monitoring of recycled water is recommended from each wastewater treatment plant that provides recycled water for irrigation use. More frequent monitoring of recycled water may be useful for determining seasonal changes in the water quality, or evaluating water quality changes when improvements in the treatment process are implemented.

4.2.2. Number of Monitoring Points

Constituent concentrations in recycled water may vary within the distribution system. For instance, during the pilot study, PFCs were not detected at the recycled water source, but were detected in water from the irrigation system. Although only one point in the distribution system was monitored for the pilot study, this information is consistent with known fate and transport processes and observations from the bench test, including formation of PFCs from precursors. Concentrations of disinfection byproducts (NDMA, haloacetic acids) were also observed to vary between samples collected directly from the plant and samples collected from the pilot study site. Samples collected at various points in the distribution system may provide further insight on the quality of recycled water over the distribution system. It is not always appropriate to collect recycled water samples only from the treatment plant. Instead, samples should be collected at irrigation sites closest to the recycled water source as well as irrigation sites furthest from the recycled water source. Sampling at those points would have the greatest potential to capture the variability of recycled water chemistry within the study area. Note that as the recycled water distribution systems are expanded, sampling locations may need to be revised or added over time

Any treatment changes or improvement at the water treatment facility can impact the quality of recycled water. Additional monitoring may be needed, in such events, to determine how quality of water may change. If the treatment change results in a reduction in recycled water quality, this may warrant counter measures to meet PRWISLs for recycled water.

4.3. Constituent List

A list of the constituents to be analyzed for future monitoring is found in Table V-4-1. The list contains constituents of recycled water that were determined by this study to be of concern with regard to adverse impacts to groundwater. The constituent list is in accordance with recommendations for further monitoring as discussed in Volume III. This constituent list is recommended for all groundwater and recycled water samples. The reporting limits for all analyses should be at or below the typical reporting limits listed on Table V-4-1.

The list of constituents may be revised if it is demonstrated that one or more of the constituents is consistently below detection, or alternatively below the associated groundwater concentration, in the recycled water source. Three consecutive results below the detection limit or groundwater concentration would be appropriate support for eliminating a constituent from further analysis in groundwater monitoring. However, the constituent must be below detection or groundwater concentration in all samples collected from the distribution system. Some constituents, such as PFCs, may not be detected at the recycled water source, but could be detected further in the distribution system. If monitoring at all points in the distribution system (as recommended in Section 4.2.2) yields concentrations below detection or below the groundwater concentration of a constituent for three consecutive monitoring events, there is sufficient evidence to demonstrate minimal potential for impact of that constituent in the irrigated recycled water. Therefore, the constituent analysis may be eliminated from the sampling program for that recycled water source. If a constituent is eliminated from the sampling program for a specific recycled water source, it may also be eliminated from the groundwater sampling program from the associated area of application. Similarly, the *Monitoring Strategies for Chemicals of Emerging Concern (CECs) in Recycled Water* (SWRCB, 2010), allows for removal of constituents where updated data indicate that the current measured environmental concentrations are less than a “monitoring trigger level”. For this monitoring program, the current groundwater quality is analogous to the “monitoring trigger level”.

The original full constituent list should be applied for recycled water and groundwater samples after any changes in the treatment process that would affect recycled water quality. In addition, this list of constituents may be adapted in the future to include new contaminants in recycled water that are identified and determined to have merit for monitoring.

4.4. Quality Control Samples

Quality control samples such as travel blanks and field duplicates are a valuable part of an overall sampling program to ensure that the sampling program yields analytical results that are representative of the water analyzed and are not biased on the sampling/analysis process or errors from the process. This study recommends collecting and analyzing one set of quality control samples: one travel blank and one field duplicate for every twenty samples, starting in the first year of implementation. Additional types of quality control samples may be warranted if analytical or sampling bias is suspected.

A field duplicate is a duplicate, independent sample collected at the same place, at the same time. The field duplicate and project sample are taken from the same source, stored in separate containers and analyzed independently. It is used to estimate sampling and laboratory analysis precision. Duplicate samples should generally be collected for samples where more constituents are expected to be above the detection limit. For this sampling program, this is expected to be the recycled water source samples.

A travel blank is a sample of analyte-free media, usually deionized water. It is useful to identify errors or cross contamination attributed to shipping and handling procedures.

REFERENCES

California Regional Water Quality Control Board, San Francisco Bay Region, 2007, *Screening for Environmental Concerns at Sites with Contaminated Soil and Groundwater*, Interim Final, November, Revised May 2008.

California Regional Water Quality Control Board, San Francisco Bay Region, 2010, *San Francisco Bay Basin (Region 2) Water Quality Control Plan (Basin Plan)*, Incorporating all amendments approved by the Office of Administrative law as of December 31 2010.

California Department of Water Resources, 2009, *Model Water Efficient Landscape Ordinance*, September 10.

Eastern Municipal Water District, date unspecified, *Recycled Water Use Guidelines and Best Management Practices*, http://www.emwd.org/news/ordinances/ord_68.2-RW-Best-Practices.pdf

Food and Agriculture Organization of the United Nations, 2002, *Deficit Irrigation Practices*, ISSN 1020-1203, ISBN 92-5-104768-5, Rome.

Gan, J., Bondarenko, S., Ernst, F., Yang, W., Ries, S.B., and Sedlak, D.L., 2006, Leaching of N-nitrosodimethylamine (NDMA) in Turfgrass Soils During Wastewater Irrigation, Journal of Environmental Quality, 2006, Vol. 35, No. 1, pp. 277-284, doi: 10.2134/jeq2005.0264.

Irrigation Association, 2005, *Turf and Landscape Irrigation Best Management Practices*, prepared by the Water Management Committee, April.

Olivenhain Municipal Water District, date unspecified, *Recycled Water Use Guidelines and Best Management Practices*, http://www.olivenhain.com/files/docs/recycled_water/RWbmp.pdf

Ray, M.C., Kulongoski, J.T., Belitz, Kenneth, 2009, Groundwater Quality Data in the San Francisco Bay Study Unit, 2007: Results from the California GAMA program: US Geological Survey Data Series 396, Available at http://pubs.usgs.gov/ds/396.

Santa Clara Valley Water District, 2010, *2009 Groundwater Quality Report*, Groundwater Monitoring and Analysis Unit, March.

Santa Clara Valley Water District, City of Mountain View, and South Bay Water Recycling, date unspecified, Solution Project Report a Cooperative Investigation.

State Water Resources Control Board (SWRCB), 2009, *Recycled Water Policy*, Approved May 14 2009.

State Water Resources Control Board (SWRCB), 1968, *Resolution No. 68-16 Statement of Policy with Respect to Maintaining High Quality of Water in California*, Adopted October 28 1968.

State Water Resources Control Board (SWRCB), 2010, *Monitoring Strategies for Chemicals of Emerging Concern (CECs) in Recycled Water, Recommendations of a Science Advisory Panel*, convened by State Water Resource Control Board, June 25.

Stegman, E.C., 1988, *Best Management Practices Manual for Oakes Irrigation Area*, Chapter V, Water Management, North Dakota State University.

University of California Cooperative Extension, California Department of Water Resources, 2000, A Guide to Estimating Irrigation Water Needs of Landscape Plantings in California, the Landscape Coefficient Method and WUCOLS III, August.

US Environmental Protection Agency, 1987, DRASTIC: A Standardized System for Evaluating Ground Water Pollution Potential Using Hydrogeologic Settings, EPA/600/2-87/035, June.

US Environmental Protection Agency, 2005, Brownfields Fact Sheet: All Appropriate Inquiries Final Rule, EPA 560-F-05-240, October.

Tanji, K., Grattan, S., Grieve, C., Harivandi, A., Rollins, L., Shaw, D., Sheikh, B., Wu, L., date unspecified, *Salt Management Guide for Landscape Irrigation with Recycled Water in Coastal Southern California: A Comprehensive Literature Review*, circa 2006/2007.

TABLES

Table V-2-1:
PROPOSED RECYCLED WATER IRRIGATION SCREENING LEVELS (PRWISLs)
RECYCLED WATER STUDY

		Santa Clara Subbasin					Llagas Subbasin				
		SAT zone: 1-2	SAT zone: 3-4	SAT zone: 5-6	SAT zone: 7-8	SAT zone: 9-10	SAT zone: 1-2	SAT zone: 3-4	SAT zone: 5-6	SAT zone: 7-8	SAT zone: 9-10
Parameter	Units										
Biological											
Coliforms, Total	%	66.67%	66.67%	66.67%	44.91%	29.06%	66.67%	66.67%	66.67%	44.91%	29.06%
E. Coli	%	20.00%	20.00%	7.57%	3.45%	2.24%	20.00%	20.00%	7.57%	3.45%	2.24%
Fecal Coliforms	%	20.00%	20.00%	7.57%	3.45%	2.24%	20.00%	20.00%	7.57%	3.45%	2.24%
Inorganics											
Boron	µg/L	505.00	505.00	505.00	505.00	505.00	505.00	505.00	505.00	505.00	505.00
Bromide	mg/L	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38
Calcium	mg/L	69.20	69.20	69.20	69.20	69.20	69.20	69.20	69.20	69.20	69.20
Chloride	mg/L	320.00	320.00	277.81	187.73	151.00	320.00	320.00	235.73	159.29	128.13
Magnesium	mg/L	42.20	42.20	42.20	42.20	42.20	42.20	42.20	42.20	42.20	42.20
Nitrate as NO3	mg/L	122.00	122.00	122.00	122.00	122.00	122.00	122.00	122.00	122.00	122.00
Nitrite as NO2	mg/L	5.59	5.59	5.59	5.59	5.59	5.59	5.59	5.59	5.59	5.59
Phosphate	mg/L	14.13	14.13	14.13	14.13	14.13	14.13	14.13	14.13	14.13	14.13
Potassium	mg/L	32.00	32.00	32.00	32.00	32.00	32.00	32.00	32.00	32.00	32.00
Sodium	mg/L	230.00	230.00	121.58	82.15	66.08	230.00	230.00	110.57	74.72	60.10
Sulfate	mg/L	247.00	247.00	247.00	247.00	210.79	247.00	247.00	247.00	247.00	190.00
Emerging Contaminants and DBPs											
N-Nitroso Dimethylamine (NDMA)	ng/L	490.00	11.51	6.61	5.22	4.58	490.00	11.51	6.61	5.22	4.58
Perfluorochemicals (PFBA)	ng/L	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00
Perfluorochemicals (PFOS)	ng/L	87.00	87.00	80.74	63.82	56.01	87.00	87.00	80.74	63.82	56.01
Perfluorochemicals (PFOA)	ng/L	109.00	109.00	109.00	109.00	106.93	109.00	109.00	109.00	109.00	106.93
HAA5	µg/L	263.00	75.48	42.85	35.90	33.06	263.00	75.48	42.85	35.90	33.06
Bromochloroacetic Acid	µg/L	36.90	6.94	2.75	1.86	1.50	36.90	6.94	2.75	1.86	1.50
Total THMs	µg/L	366.00	366.00	366.00	251.23	221.17	366.00	366.00	366.00	251.23	221.17
General Water Quality Parameters											
Dissolved Organic Carbon	mg/L	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00
Total Organic Carbon (TOC)	mg/L	9.62	9.62	9.62	9.62	5.58	9.62	9.62	9.62	9.62	5.58
Parameters with Low Occurrence in the Pilot Study											
Cyanide	mg/L	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Ethylenediaminetetraacetic acid (EDTA)	µg/L	305.00	305.00	305.00	305.00	223.53	305.00	305.00	305.00	305.00	223.53
NTA	µg/L	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Perchlorate	µg/L	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Surfactants (MBAS)	mg/L	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36
Terbuthylazine	µg/L	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10

Notes:

1. For each SAT zone, the most conservative value (ie greater SAT rating) is used for calculating the Recycled Water Quality Rating
2. The maximum possible Recycled Water Quality Rating is 10.
3. The target acceptable Groundwater Degradation Potential is taken to be 20.
4. The derived equation for determing PRWISLs is as follows: PRWISL = (I^(-1/m)-1)*qc+qc
5. Where the PRWISL determined by the equation is greater than the maximum observed in recycled water, the maximum observed value becomes the PRWISL.
6. The PRWISL of a given constituent is developed by assuming that the other recycled water constituents are equal to or less than the representative groundwater quality. The PRWISL represents the maximum tolerable concentration at which the target groundwater degradation potential could still be achieved. However, water quality that is below the PRWISL for each constituent will not neccesarily achieve a groundwater degradation potential below the target level.

TABLE V-4-1
LIST OF RECYCLED WATER CONSTITUENTS TO MONITOR
RECYCLED WATER STUDY

Constituent	Suggested Analytical Method	Units	Typical Reporting Limit[1]
Boron	EPA 6010	µg/L	100
Calcium	EPA 6010	mg/L	0.5
Magnesium	EPA 6010	mg/L	0.5
Sodium	EPA 6010	mg/L	0.5
Sulfate	EPA 300.0	mg/L	0.5
Chloride	EPA 300.0	mg/L	1
Total Filterable Residue at 180C (TDS)	SM2540C	mg/L	10
Bromochloroacetic Acid	EPA 552.2	µg/L	1
Dibromoacetic Acid	EPA 552.2	µg/L	1
Dichloroacetic Acid	EPA 552.2	µg/L	1
Monobromoacetic Acid	EPA 552.2	µg/L	1
Monochloroacetic Acid	EPA 552.2	µg/L	2
Trichloroacetic Acid	EPA 552.2	µg/L	1
Heterotrophic Plate Count	SM 9215 B	CFU/mL	1
Coliforms, Total	SM 9221 B	MPN/100mL	2
Fecal Coliforms	SM 9221 E	MPN/100mL	2
N-Nitroso Dimethylamine (NDMA)	EPA 521	ng/L	2
Perfluorochemicals (PFBA)	MWH LC/MS/MS	ng/L	20
Perfluorochemicals (PFOS)	MWH LC/MS/MS	ng/L	5
Perfluorochemicals (PFOA)	MWH LC/MS/MS	ng/L	5
Ethylenediaminetetraacetic acid (EDTA	EPA 300 (mod)	µg/L	100
Surfactants (MBAS)	SM 5540C	mg/L	0.2
Bromide	EPA 300.0	mg/L	0.02
Nitrilotriacetic acid (NTA)	EPA 300 (mod)	µg/L	100
E. Coli	SM 9221 F	MPN/100mL	2
Perchlorate	EPA 314.0	µg/L	4
Cyanide	SM 4500CN E	mg/L	0.01
Terbuthylazine	EPA 525 plus	µg/L	0.1

Notes:
1) Typical reporting limits as seen in pilot study and bench test.