

# Riverbed Filtration System

Demonstration Project Results and Recommendations



# Orange County Water District

## RIVERBED FILTRATION SYSTEM

Demonstration Project Results and Recommendations

Prepared By:

Adam Hutchinson, PG, CHG, Recharge Planning Manager

Christine Pham, Senior Scientist



October 2024

## Acknowledgments:

This project would not have been possible without the contributions of many dedicated staff at OCWD as well as outside experts. We would like to acknowledge the support of the following:

Grisel Rodriguez, Sr Scientist, OCWD (Retired)

Greg Woodside, OCWD, Now with San Bernardino Valley MWD

Sandy Scott Roberts, Engineer, OCWD, Now with Brown and Caldwell

Brendan Neel, Hydrogeologist, OCWD

Gary Yoshiba, Hydrogeologist, OCWD

Megan Plumlee, Research Director, OCWD

OCWD Recharge Operations Staff

Mike Milczarek, President, Geosystems Analysis (GSA)

## Table of Contents

---

### Sections

1.0	Background .....	2
2.0	Clogging and Forebay Solids Monitoring Project .....	6
3.0	Recharge Water Sediment Removal Study .....	15
4.0	Riverbed Filtration .....	17
4.1	Riverbed Filtration System Pilot Testing .....	17
4.2	Riverbed Filtration System Demonstration Project.....	19
4.2.1	Olive Basin .....	21
4.3	Demonstration Project Objectives and Metrics .....	23
4.4	RFS Test Results.....	24
4.4.1	Impact of RFS on Clogging and Basin Performance .....	24
4.4.2	Impact of RFS on Water Quality.....	29
4.4.3	RFS Capacity and Design Considerations .....	37
4.5	Summary .....	40
5.0	RFS Expansion Potential.....	41
5.1	Potential Yield Estimates Using Recharge Facilities Model .....	47
5.2	Next Steps .....	49
6.0	References .....	51

### Tables

Table 1: Storage, Maximum Percolation Rate, and Target Percolation Rate for Cleaning: Terminal Recharge Basins* .....	8
Table 2: Objectives and Metrics of RFS Demonstration Project .....	23
Table 3: Olive Basin Recharge Rates .....	25
Table 4: Olive Basin RFS Operational Cycles .....	27
Table 5: Water Quality Testing for RFS .....	30
Table 6: Water Quality Testing for Biological Clogging Parameters (2014- 2019) .....	34
Table 7: Water Quality Testing for Bacterial Parameters (2014- 2019).....	35
Table 8: Water Quality Testing for CEC's (2016- 2019).....	36
Table 9: RFS Design Parameters .....	37
Table 10: RFS Collector Testing Summary.....	38
Table 11: Storage, Maximum Percolation Rate, and Current Conveyance Capacities: Terminal Recharge Basins* .....	43
Table 12: Estimated Gravity RFS Conveyance Dimensions .....	44



## Table of Contents

---

### Figures

Figure 1: Santa Ana River Watershed .....	2
Figure 2: Location of Prado Dam and OCWD Recharge Facilities .....	3
Figure 3: OCWD Surface Water Recharge Facilities .....	7
Figure 4: Weekly Moving Average Percolation Rates in Miller Basin with SAR, Imported, and GWRS Water .....	9
Figure 5: Raw TSS Concentrations for Imperial Dam (blue), Weir Pond 4 (green), and Little Warner Outflow (red) .....	10
Figure 6: Average TSS for Base Flow Season (from April 1 to September 30) and Storm Flow Season (from October 1 to March 31) at Imperial Highway, Weir Pond 4 and Warner Outflow .....	11
Figure 7: False-Color Overlay Image of Sediment Load and Removal in Warner System*.	12
Figure 8: Sediment Column Schematic.....	12
Figure 9: Modeling Kraemer Basin Percolation Decay with SAR water .....	13
Figure 10: Percolation Test Cells Being Supplied with SAR Water Treated Using Different Technologies. Raw water is untreated SAR water (control). .....	16
Figure 11: Pilot Riverbed Filtration System.....	18
Figure 12: Construction of the Pilot Riverbed Filtration System .....	18
Figure 13: Location and Layout of the Riverbed Filtration System (RFS) Demonstration Project .....	20
Figure 14: Location RFS Demonstration Project Manifolds.....	21
Figure 15: Atlantis Flo-Tank Module .....	21
Figure 16: As-Built Diagram of Monitoring Wells AM-51 and -51A (Not to Scale) .....	22
Figure 17: Groundwater Levels in Monitoring Wells AM-51 and -51A.....	23
Figure 18: Olive Basin Percolation Rate with Unfiltered Santa Ana River Water October 2009 to January 2012 .....	24
Figure 19: Monthly Recharge in Olive Basin, 2001-2023 .....	25
Figure 20: Daily Olive Basin Water Level and Percolation Rate, 2015-2023 .....	26
Figure 21: Daily Olive Basin Percolation Rate for 9 Operational Cycles .....	27
Figure 22: Percolation Rate in Olive Basin with Unfiltered SAR Water and RFS Cycles 3/7/9 Projection.....	28
Figure 23: Pumping Equipment for Obtaining Samples from Collector Pipe .....	29
Figure 24: Total Suspended Solids in Influent Source Water and Product Water from RFS31	
Figure 25: Average Particle Size Distribution of TSS in Influent Source Water and Product Water from RFS.....	32
Figure 26: Construction of SAR RFS System in the SAR Channel .....	33
Figure 27: Total Suspended Solids in Source Water (SAR) and Product Water from SAR RFS System .....	33
Figure 28: Removal Efficiencies for CECs (2016- 2019).....	37
Figure 29: RFS Collector Flow Testing Results .....	39
Figure 30: Potential Area of Full-Scale RFS .....	42



## Table of Contents

---

Figure 31: Turlock Irrigation District Infiltration Gallery Design .....	45
Figure 32: Construction of Infiltration Gallery in Tuolumne River .....	45
Figure 33: Groundwater Levels at SAR-14 and Flow in the SAR.....	46
Figure 34: Potential Conveyance of RFS Water to Terminal Basin System.....	48
Figure 35: Average Annual Additional Recharge, Alternatives 3a and 3b.....	49

### Appendices

Appendix A	Summary of Cloth Filtration Pilot Testing
Appendix B	Water Quality Data
Appendix C	RBF System Collector Testing
Appendix D	Recharge Facilities Model Update and RFS Simulations (Jacobs, 2023)

## Acronyms and Abbreviations

---

### Acronyms and Abbreviations

Ac: acres

Afy: Acre-feet per year

AOC: Assimilable Organic Carbon

CEC: Constituents of Emerging Concern

Cfs: Cubic feet per second

DOC: Dissolved Organic Carbon

F: Fahrenheit

Ft: Feet

Ft msl: Feet mean sea level

GWRS: Groundwater Replenishment System

HDPE: High-Density Polyethylene

IAH: International Association of Hydrogeologist

In: Inches

Mi<sup>2</sup>: Square miles

Mg/L: Milligrams per liter

MWD: Metropolitan Water District of Southern California

OCWD: Orange County Water District

PVC: Polyvinyl Chloride

RBF: Riverbank Filtration

RFS: Riverbed Filtration System

SAR: Santa Ana River

SAT: Soil Aquifer Treatment

Study: Recharge Water Sediment Removal Feasibility Study

TOC: Total Organic Carbon

TSS: Total Suspended Solids

TID: Turlock Irrigation District

USACE: United States Army Corps of Engineers

WCM: Water Control Manual



## Executive Summary

Clogging due to the accumulation of suspended solids is a constraint that limits the capacity of the Orange County Water District's (OCWD) surface water recharge system. To decrease clogging and increase system capacity, OCWD conducted extensive pilot testing of multiple methods designed to remove suspended solids from Santa Ana River (SAR) water and the resultant impact on recharge. Based on these tests, Riverbed Filtration, which is a variation of Riverbank Filtration, was shown to be highly effective in removing total suspended solids (TSS) and increasing recharge rates. As a result, in 2013, OCWD constructed a large-scale demonstration Riverbed Filtration System (RFS) that covers approximately 10 acres and produces up to 20 cubic feet per second (cfs) of treated water using gravity flow. The treated water is conveyed to Olive Basin which had historically received untreated SAR water.

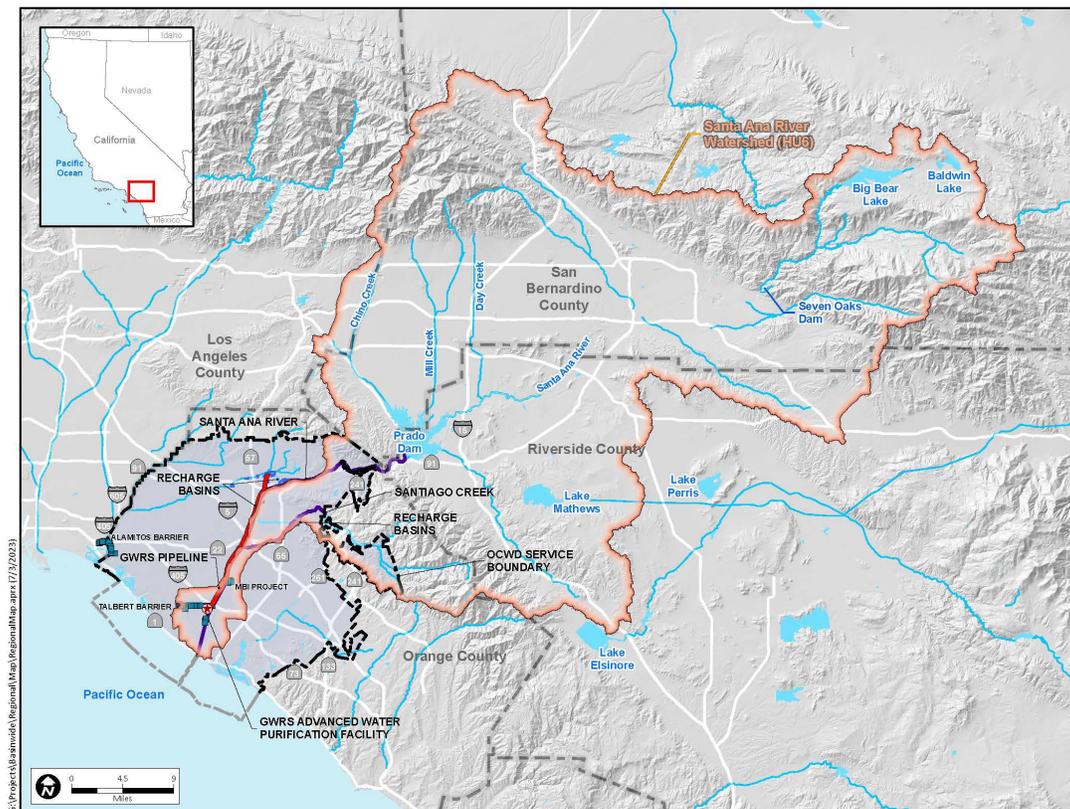
Extensive data collection and testing of the RFS was conducted from 2015 to 2023. The scope of testing included measuring the capacity of the RFS using different types of subsurface collection system materials, measuring the impact on recharge rates in Olive Basin, and measuring reductions in TSS concentrations and other water quality parameters. In summary, the RFS removed an average of 96 percent of the TSS in SAR water and more than doubled the recharge capacity of Olive Basin. The increased recharge capacity of Olive Basin is consistent with increases seen in other recharge basins receiving low TSS imported water and highly treated recycled water produced by the Groundwater Replenishment System.

The demonstration test results show that the RFS has the potential to increase recharge system capacity, particularly within the Terminal Recharge Basins, which is a series of eight shallow and deep recharge basins starting at Warner Basin and extending to Raymond Basin. These basins are particularly prone to clogging because suspended solids rapidly accumulate on the recharge surface in the placid waters of the basins. Simulations conducted with OCWD's Recharge Facilities Model suggest that an average of 8,000 to 10,000 acre-feet per year of additional SAR water could be captured and recharged that would otherwise be lost to the ocean.

Given the significant potential for increased recharge and capturing water that would otherwise be lost to the ocean, it is recommended that additional work be done to evaluate the appropriate size, location, and costs of a full-scale RFS in the SAR channel. This would include an analysis of using gravity, pumping, or some combination to draw water out of the RFS and convey it to the Terminal Recharge Basins.

## 1.0 Background

The Orange County Water District (OCWD) is a special governmental water agency that was created by the state of California in 1933 to manage the surface water and groundwater resources in northern and central Orange County. OCWD covers an area of approximately 350 square miles and serves a population of 2.5 million. Orange County is at the downstream end of the Santa Ana River watershed (Figure 1). The Mediterranean-type climate in Orange County is generally mild, with annual rainfall of approximately 14 inches, and average monthly temperatures ranging from 58 to 75°F. Most of the rainfall occurs from December through March. OCWD programs include aquifer replenishment or managed aquifer recharge (MAR), seawater intrusion control, water quality protection and improvement, water recycling, and stormwater conservation (OCWD, 2015; OCWD, 2017a).

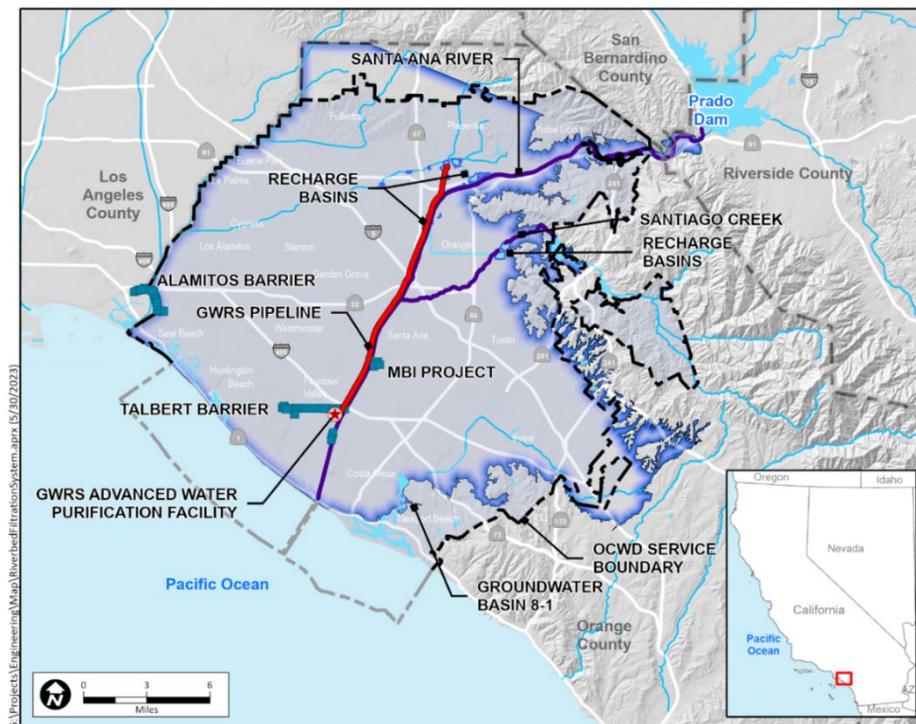


**Figure 1: Santa Ana River Watershed**

The key source of recharge water to the Orange County groundwater basin is the Santa Ana River (SAR), the longest coastal river in southern California. SAR flows are generally composed of treated wastewater discharged from upstream sewage treatment plants and seasonal storm flows. OCWD also recharges advanced treated (Reverse Osmosis and Advanced Oxidation) recycled wastewater from the Groundwater

Replenishment System (GWRS) and purchases imported water as an additional recharge source. Lastly, the groundwater basin receives unmeasured recharge from precipitation, subsurface inflow from surrounding foothills, and infiltration of irrigation water (OCWD, 2015).

The base flow of the SAR has declined in recent years from a high of 150,000 acre-feet in 2005 to approximately 65,000 to 70,000 acre-feet in recent years. Further declines in SAR base flow are expected due to increased wastewater recycling and conservation by agencies in the upper SAR watershed. As a result, stormwater represents an important source of local supply that should be captured and recharged to the maximum extent possible. Central to being able to capture large volumes of stormwater is Prado Dam, which is located upstream of OCWD's recharge facilities (See Figure 2).



**Figure 2: Location of Prado Dam and OCWD Recharge Facilities**

Since the dam was originally constructed in 1941, OCWD and the US Army Corps of Engineers (USACE) have collaborated to utilize Prado Dam to increase the capture and recharge of stormwater to the OCWD groundwater basin. Over the years, the volume of stormwater that can be temporarily impounded behind Prado Dam in what is called the Water Conservation Pool has increased to the current elevation of 505 feet msl, which equates to approximately 20,000 acre-feet of storage. Captured stormwater is released slowly by the USACE at a rate that can be captured by OCWD recharge facilities downstream of Prado Dam.

Starting in 2017, OCWD has been working with the USACE and other stakeholders to evaluate using Forecast Informed Reservoir Operations (FIRO) to further increase the amount of stormwater that can be temporarily impounded behind Prado Dam without compromising the primary flood risk management purpose of the dam. FIRO is an innovative research and operations partnership that uses modern weather forecasting, runoff modeling, and watershed monitoring to help water managers selectively retain or release water from reservoirs that reflect current and forecasted conditions. FIRO's application of modern science and technology can optimize the use of limited water resources and represents a cost-effective option to adapt to extreme weather events unique to the U.S. West Coast. The ultimate goal of FIRO is to inform the update of USACE's Water Control Manual (WCM) for Prado Dam to allow flexible FIRO operations. The WCM is the official document that governs the operation of the reservoir, and modifying it requires various degrees of analysis and review, depending on the proposed changes.

The Final Viability Assessment of FIRO at Prado Dam was published in November 2023 ([Prado FIRO Final Viability Assessment](#)). This report found that FIRO is viable at Prado Dam and that 4,000 to 6,000 ac-ft of additional stormwater could be captured on average depending on the final target elevation (510 ft or 512 ft, NGVD29).

While FIRO will increase the volume of water that can be captured in the Water Conservation Pool, there is still the problem of clogging of the recharge basins that receive this water. Clogging of OCWD's recharge facilities is caused primarily by suspended sediments in SAR water and to a lesser extent, by biological growth fueled by organic carbon and nutrients in the recharge water. Since suspended sediment concentrations are much higher in stormflow, clogging rates are much higher when recharging stormwater. So, to maximize the benefits of increased stormwater capture at Prado Dam, OCWD must find a way to minimize clogging of its recharge facilities. We know this is possible because recharge rates achieved when using water with little to no suspended sediment, such as imported water from the Metropolitan Water District of Southern California (MWD) and highly treated recycled water from OCWD's GWRS facility, are 2 to five times greater than what is achieved with SAR water.

Another driver for maximizing the recharge capacity of existing recharge facilities is the price of land. Land in Orange County is expensive. OCWD's most recent purchase of land in 2014 for a surface recharge facility cost \$1.6M per acre. Moreover, the availability of land where recharge is most feasible is limited and in high demand.

This report documents the work OCWD has done to:

- 1) Study clogging mechanisms impacting OCWD's recharge basins and suspended solids loading from diverting and recharging Santa Ana River water;
- 2) Studying multiple methods to remove suspended solids from Santa Ana River water;
- 3) Testing Riverbed Filtration as a means to remove suspended solids from Santa Ana River water prior to recharge; and,
- 4) Evaluating the potential increased recharge if Riverbed Filtration were scaled up.

## 2.0 Clogging and Forebay Solids Monitoring Project

Dr. Herman Bouwer once wrote:

---

*Clogging of the infiltration surface and resulting reductions in infiltration rates are the bane of all artificial recharge systems (Bouwer, 2002).*

---

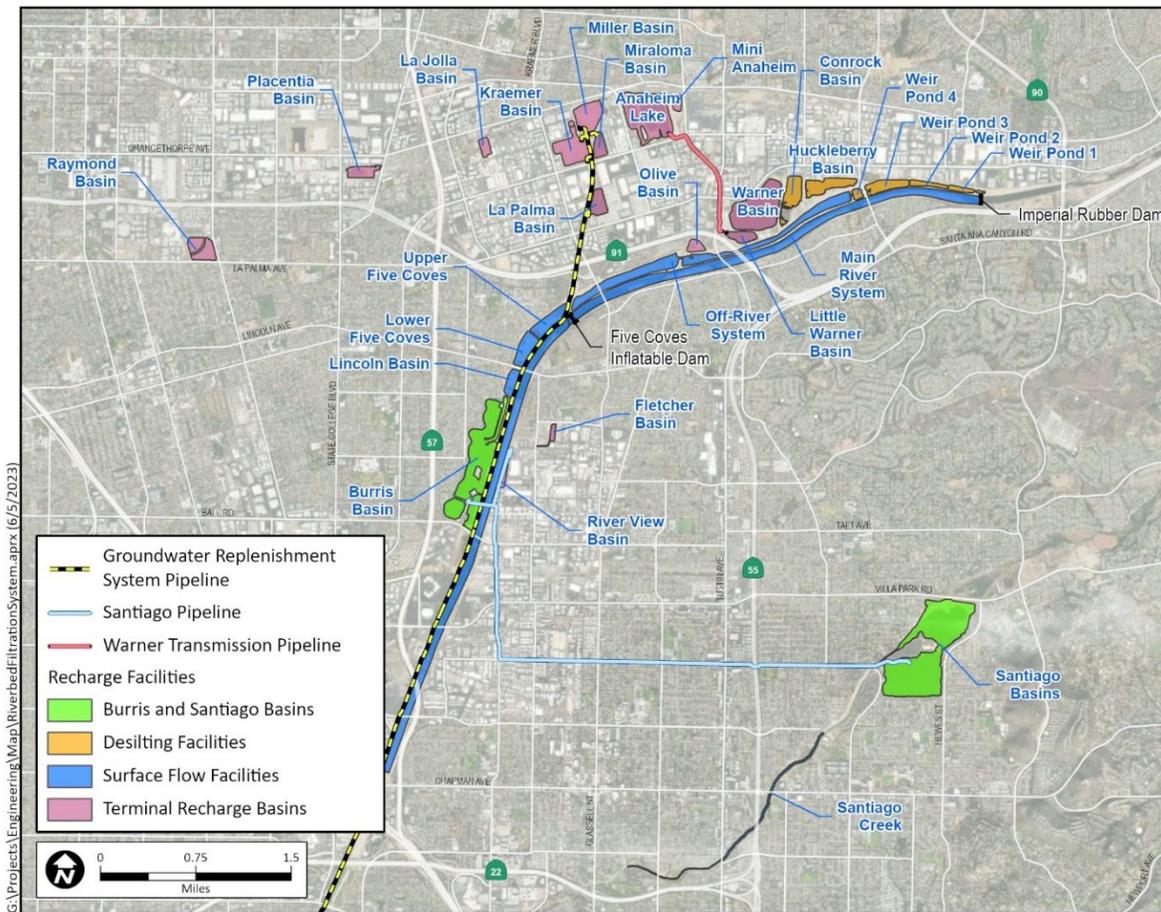
In many cases, clogging is what limits the capacity of managed aquifer recharge (MAR) facilities. To maximize the capacity of MAR facilities, understanding clogging and developing successful mitigation strategies are critical.

Over time, all surface water spreading facilities will clog (Baveye et al., 1998; Bouwer et al., 2001; Bouwer and Rice, 2001; Bouwer, 2002; Schubert, 2004). Surface waters used for recharge often contain significant quantities of suspended sediments and microorganisms, which lead to clogging (Behnke, 1969; Bouwer and Rice, 1989). It must be noted that the clogging seen in spreading basins is different than in rivers and stream channels due to the self-cleaning potential of rivers and stream channels, which can reduce clogging depending on the timing and magnitude of runoff events (Lacher, 1996; Schubert, 2004; Rehg et al., 2005). For more information on clogging, see the clogging monographs published by the International Association of Hydrogeologists (IAH) at <https://recharge.iah.org>. The IAH clogging monograph includes a case study of OCWD's recharge system.

Clogging can be caused by physical, biological, and chemical processes. Each of these processes can work individually or collectively to reduce infiltration rates. Factors that influence the development and extent of a clogging layer include effluent water quality, basin soil texture, ponding depth, hydraulic loading rate and cycle, and vegetation.

As shown in Figure 3, the OCWD surface water recharge facilities have been grouped into different systems. With respect to clogging, these systems behave differently and can be placed into four categories:

1. Burris and Santiago Basins
2. Desilting Facilities
3. Surface Flow Facilities
4. Terminal Recharge Basins



**Figure 3: OCWD Surface Water Recharge Facilities**

For Burris and Santiago Basins, recharge rates are mainly a function of water level elevation. The Santiago Basins are former gravel pits with nearly vertical side walls of very coarse sediments. As a result, the recharge capacity of Santiago Basins is mainly a function of the water level in the basin, with increasing percolation rates as the water level increases. While clogging may be occurring, it appears that the annual draining process largely restores the basin’s recharge capacity.

The Desilting Facilities (Weir Ponds 1, 2, 3, and 4) are located immediately downstream of Imperial Rubber Dam. These facilities are primarily used to remove the heavier sediment load from water diverted off the SAR and contribute little to no recharge to the basin.

Clogging is not a significant issue in the Surface Flow Facilities, which include the SAR Channel, Off-River Channel, and Santiago Creek, because these facilities receive a supply of constantly moving water. Clogging still occurs at a low rate and is remedied by using heavy equipment to disturb the clogging layer while water is flowing through the facility.

Where clogging has the greatest impact on recharge capacity is in the Terminal Recharge Basins, that is, basins where water is pooled for recharge purposes, where the relatively calm conditions within the basins allow suspended sediments in the source water to settle out and clog the basin surface. The largest capacity terminal basins that receive SAR water are within the Warner System and Upper Recharge System and include the following basins: Warner Basin, Anaheim Lake, Miller Basin, and Kraemer Basin. Smaller terminal basins in these systems include Mini-Anaheim Lake, La Jolla Basin, Placentia Basin, and Raymond Basin. Figure 3 shows the location of the Terminal Recharge Basins.

Maximum percolation rates in the terminal basins are achieved immediately after they are drained, dried, and cleaned. OCWD operations staff will target cleaning the basins once the percolation capacity has declined by 60 percent or more; however, many factors affect when the basins can be cleaned and thus percolation rates may decline lower than the target rate before they can be cleaned. Table 1 lists the maximum storage capacity, maximum percolation rate, and target percolation rate for cleaning the Terminal Recharge Basins.

**Table 1: Storage, Maximum Percolation Rate, and Target Percolation Rate for Cleaning: Terminal Recharge Basins\***

Basin	Max Storage (af)	Maximum Percolation Rate (cfs)	Target Percolation Rate for Cleaning (cfs)
Warner Basin	2,620	70	20
Anaheim Lake	2,260	100	40
Mini-Anaheim Lake	13	20	8
Miller Basin**	300	45	18
Kraemer Basin	1,170	120	45
La Jolla Basin	26	30	10
Placentia Basin**	350	10	4
Raymond Basin**	370	10	4
<b>Total</b>	<b>7,109</b>	<b>405</b>	<b>149</b>

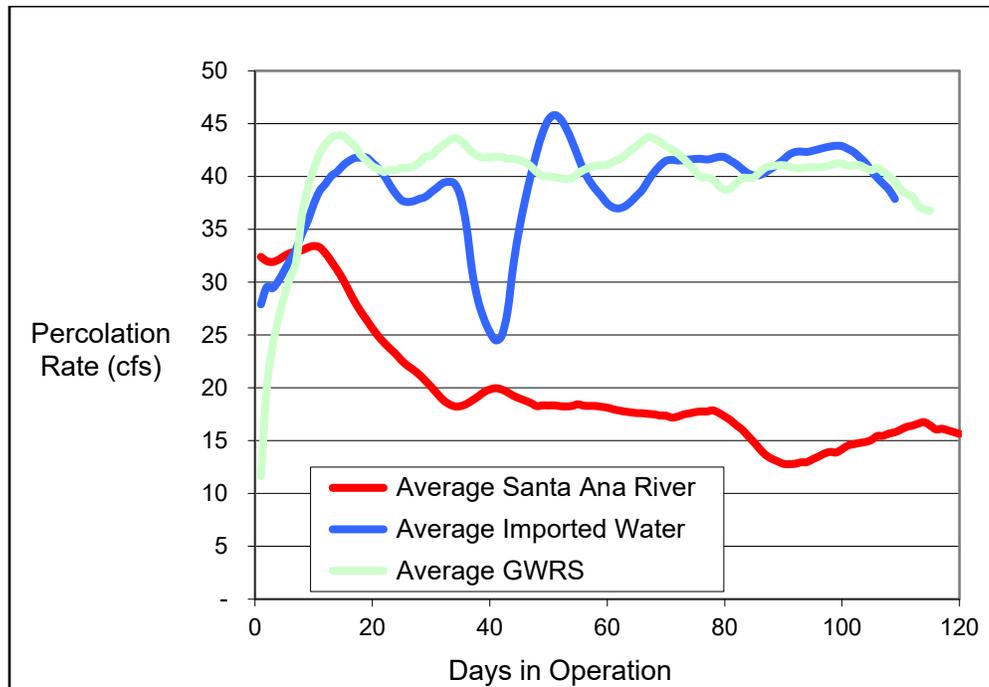
\*Olive Basin is not included because it utilizes the Demonstration Scale Riverbed Filtration System as a permanent feature.

\*\*These basins are owned by the Orange County Flood Control District and can be affected by flood control operations.

An example of how clogging affects the terminal recharge basins is the performance of Miller Basin using three different sources of water. Figure 4 shows the weekly moving average percolation rate with SAR water, imported water from MWD, and GWRS water. The average SAR rate is from eight recharge cycles spanning 2004-08. Imported water percolation rates are from two cycles in 2006-07. GWRS percolation rates are from four cycles from 2008-10. The variability in recharge rate with imported water is not due to changes in basin percolation capacity but supply constraints. Figure 4 shows that SAR percolation rates decline exponentially while the percolation rate with imported and GWRS water remains very stable over the period shown. Over 90 days, the total recharge achieved with imported and GWRS water is **double** that achieved with SAR water.



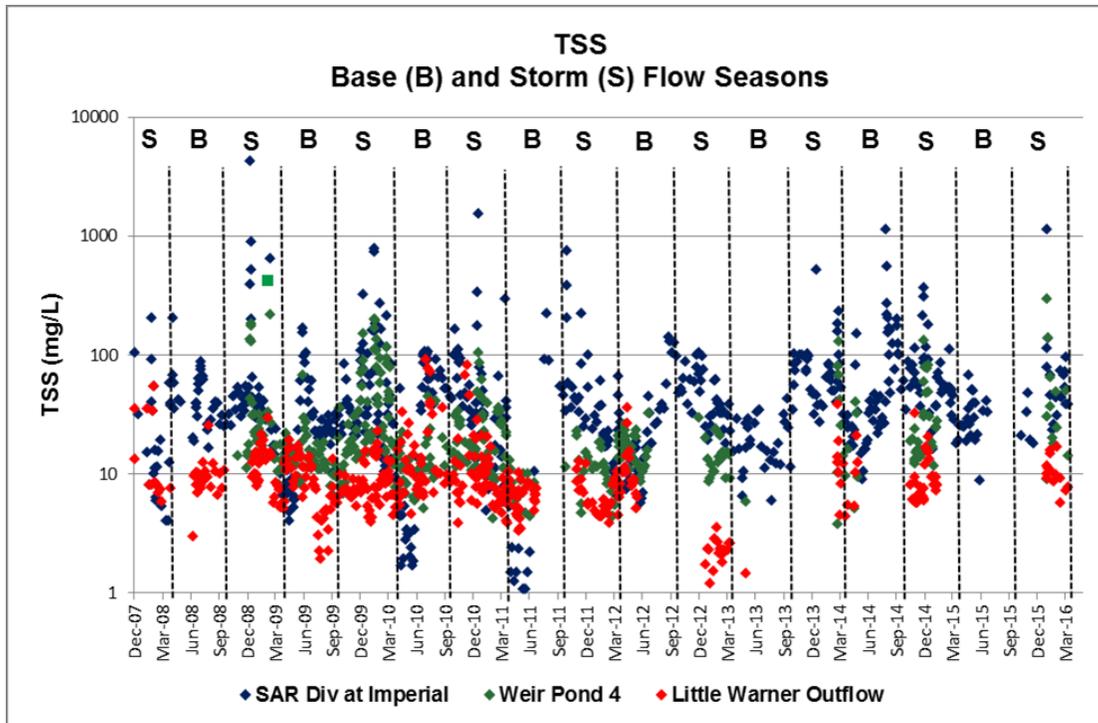
This behavior is confirmed with more recent data from Miraloma and La Palma Basins, which are dedicated to the recharge of GWRs water. Percolation rates in these basins remain very stable for as much as a year or longer before cleaning is needed.



**Figure 4: Weekly Moving Average Percolation Rates in Miller Basin with SAR, Imported, and GWRs Water**

*The performance of Miller Basin with different sources of water has been replicated in other terminal basins. These observations reveal that clogging significantly limits the capacity of these terminal basins. However, there exists substantial potential to enhance recharge capacity if cost-effective measures can be implemented to mitigate clogging caused by suspended solids in SAR water.*

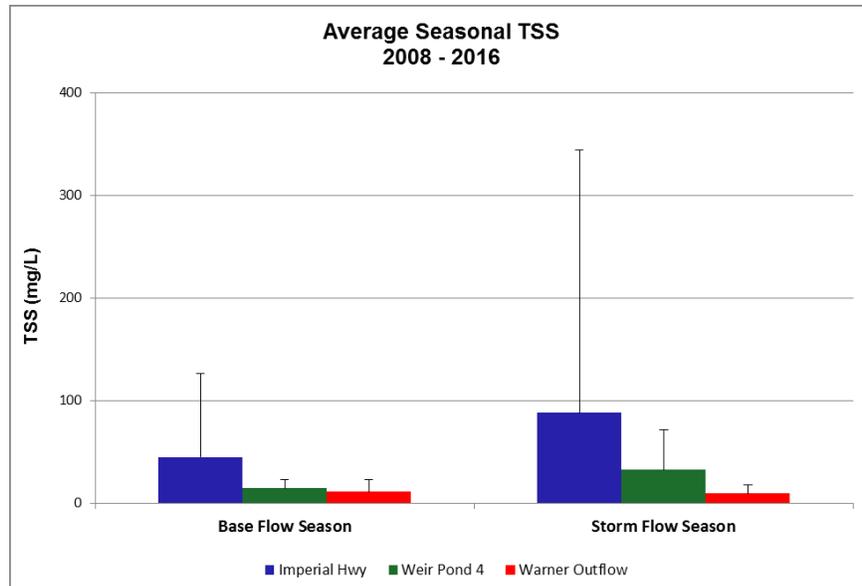
To better understand the clogging potential of SAR water and how it changes within the recharge system, a multi-year Forebay Solids Monitoring Project (2007-2016) was implemented to quantify the transport of total suspended solids (TSS) and to attempt to determine their overall impact on clogging over an extended period encompassing seasonal variations in TSS quantity and quality (OCWD, 2017b). This study improved OCWD’s understanding of the spatial and temporal distribution of the TSS in the SAR and OCWD’s recharge system. TSS data collected at the Imperial Rubber Dam (also called Imperial Highway), Wier Pond 4, and Little Warner Basin outlet represents the source of SAR supply to the Terminal Recharge Basins (see Figure 3).



**Figure 5: Raw TSS Concentrations for Imperial Dam (blue), Weir Pond 4 (green), and Little Warner Outflow (red)**

As shown in Figure 5, TSS concentrations are highest during the storm flow season (Oct-March) and lower during the Base flow season (April-Sept) with TSS concentrations declining, primarily due to gravity settling, as diverted water moves through the recharge system. During the study period, the maximum SAR TSS concentration of 4,250 mg/L was measured on December 8, 2008.

The TSS data was averaged with respect to the base flow and storm flow seasons (Figure 6). Storm flow season TSS entering the desilting system from the SAR was, as anticipated, significantly greater (by 43 mg/L, on average); however, following passage through the Desilting System and Warner Basin, the average TSS output to the downstream terminal recharge basins via Little Warner Outflow was reduced.



**Figure 6: Average TSS for Base Flow Season (from April 1 to September 30) and Storm Flow Season (from October 1 to March 31) at Imperial Highway, Weir Pond 4 and Warner Outflow**

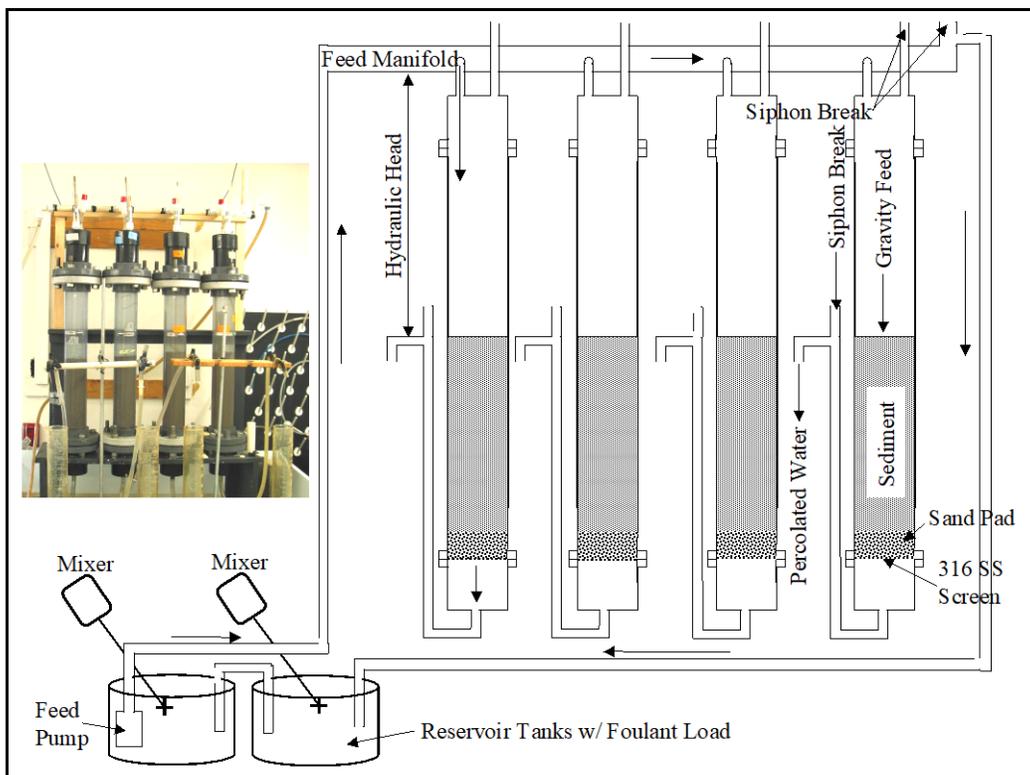
The Forebay Solids Monitoring Study showed that there is a substantially higher TSS load during the storm season and that, despite the effectiveness of the Desilting System and Warner Basin in reducing TSS concentrations (Figure 7), clogging of terminal recharge basins using SAR water still represents a significant constraint to maximizing basin recharge capacity as demonstrated by clogging trends presented in Figure 4.

The potential benefits of reducing TSS concentrations in recharged water were verified through an OCWD Clogging Study at the Field Research Lab (FRL). In this study, both laboratory and field data were used to develop a relatively simple mathematical model capable of describing basin percolation kinetics. Laboratory data was obtained using column studies. The columns, shown in Figure 8, were filled with clean, native sediment from one of OCWD's recharge basins and then supplied with water with mixtures of locally derived suspended solids (also called foulants) to create water with a range of known TSS concentrations. The TSS deposited at the sediment/water interface was estimated as a function of time by the product of the TSS concentration and the total volume of water percolated through the column. A log-decay expression was fitted to this data using the method of Marquardt nonlinear regression (Statgraphics, Centurion XV, Statpoint Incorporated, Herndon, VA).



**Figure 7: False-Color Overlay Image of Sediment Load and Removal in Warner System\***

\*False-color overlay depicting sediment load and removal in the Upper Desilting System based on the March 7, 2011, image. To produce the false color map, ImagePro was used to extract the red channel as a monochrome image, and a relative false color scale was produced in which the portion of the Weir Pond system visually corresponding to the heaviest sediment loading in the original image was set to red, and the portion of Warner Basin corresponding visually to the least sediment loading was set to blue. Following a rendering of this false-color image, the features corresponding to the Upper Desilting System were extracted and pasted back into the original image again.



**Figure 8: Sediment Column Schematic**

This log-decay expression was then applied to percolation data obtained in Kraemer Basin for SAR water for three cycles, from 1997-98, 2004-05, and 2005. The results of this analysis are shown in Figure 9. The model was able to describe the overall kinetics of percolation decay quite well, suggesting a general similarity between the behavior of the laboratory sediment columns and the basin. The average foulant concentration predicted by this model was 8.20 mg/L, which is in line with the TSS data measured at the Little Warner Outflow in the Forebay Solids Monitoring Study (Figure 6). The model was also able to predict the clogging behavior of Kraemer Basin using low TSS imported water. This model suggests that initial percolation rate, TSS concentration (aka foulant loading), and the interaction between TSS and sediment at or near the sediment/water interface can describe the decay (aka clogging) of percolation over time. Simulating the performance of a recharge basin indicates that the reduction of overall TSS concentration loading is perhaps the most effective method of improving recharge basin efficiency (Phipps, Lyon, and Hutchinson, 2007).

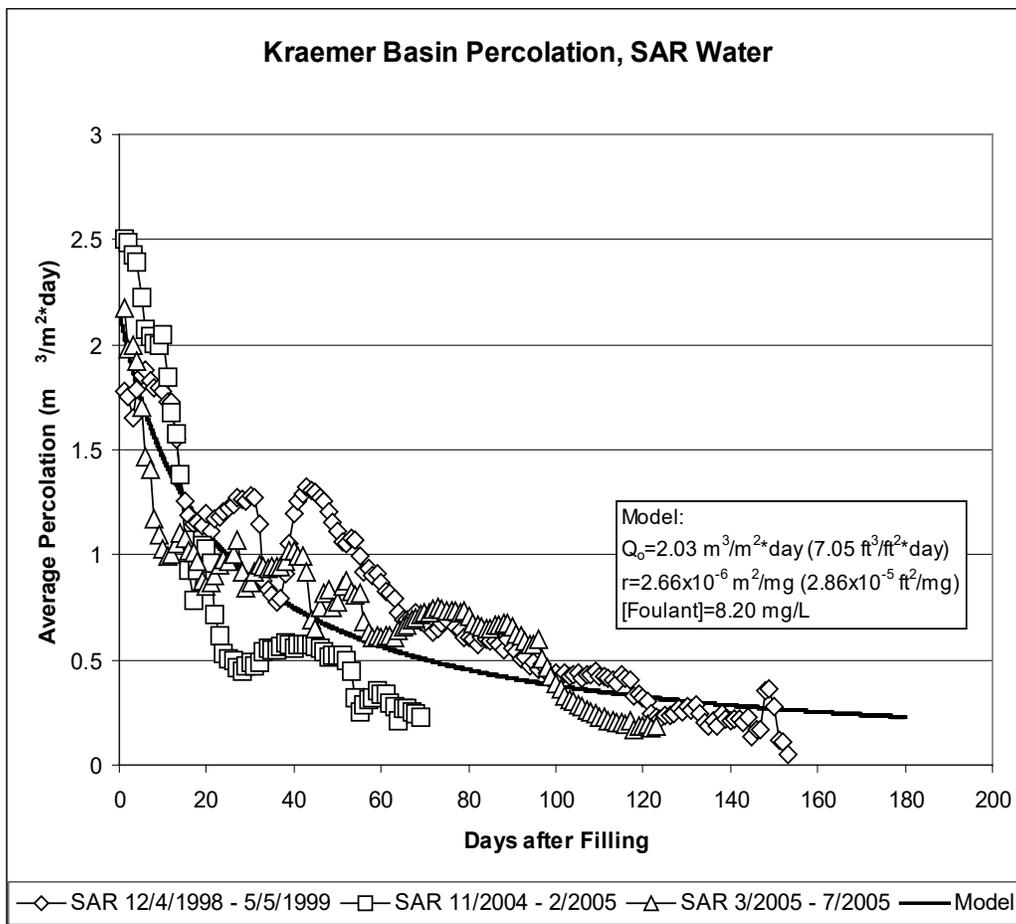


Figure 9: Modeling Kraemer Basin Percolation Decay with SAR water

Finally, it must be noted that percolation decay equations were developed for many of the basins, including the terminal basins, and incorporated into OCWD's Recharge Facilities Model (RFM) (OCWD, 2009). Incorporating these decay equations in the RFM was crucial in being able to calibrate the model to historical data. As a result, the RFM has become a valuable planning tool in evaluating the recharge impacts of various projects, such as constructing additional recharge facilities or changes in the availability of SAR flows.

For this report, the RFM will be a key tool to evaluate the potential additional recharge that could be achieved by reducing TSS concentrations in SAR water.

### 3.0 Recharge Water Sediment Removal Study

Recognizing that TSS was a constraint in maximizing OCWD's capacity to recharge SAR water, particularly stormwater, OCWD embarked on a multi-phased Recharge Water Sediment Removal Feasibility Study (Study) in 2008 to evaluate the feasibility of removing sediment from SAR water.

The Study included three phases:

#### Phase 1

- Evaluate existing recharge operations and water quality data
- Establish preliminary goals and objectives
- Review treatment technologies

#### Phase 2

- Conduct testing of selected treatment technologies using small-scale units at OCWD's Field Research Lab

#### Phase 3

- Conceptual design
- Prepare a Feasibility Study report

Based on Phase 1 findings, Phase 2 included small-scale testing of five different treatment technologies, including:

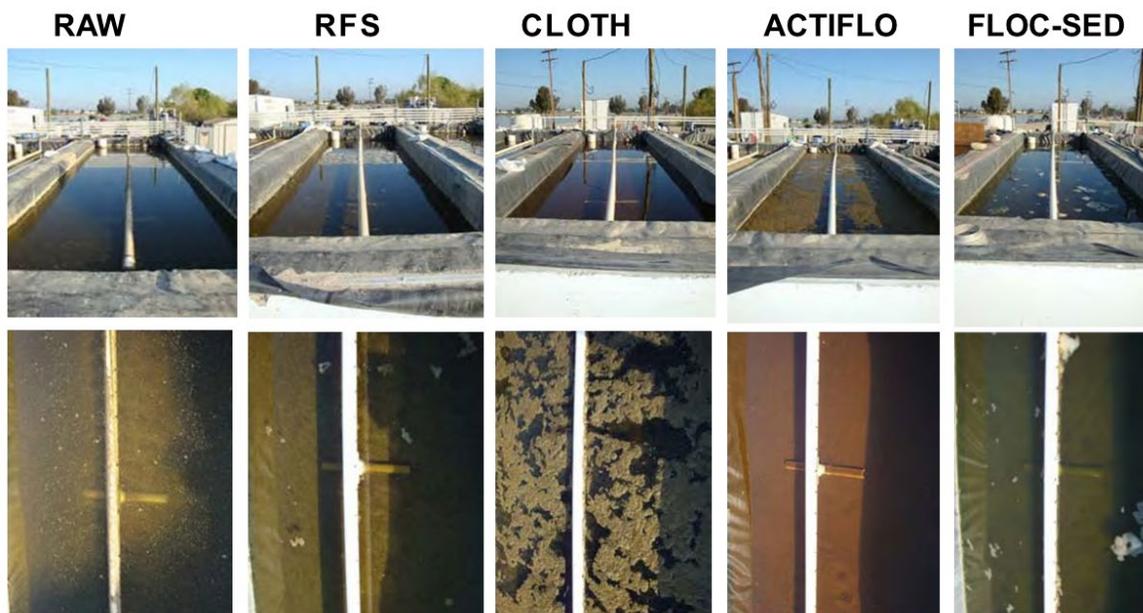
- Flocculation-Sedimentation (Floc-Sed)
- Dissolved Air Flootation (DAF)
- Ballasted Sedimentation (Actiflo)
- Cloth Filtration (with and without chemical pre-treatment)
- Riverbed Filtration (Passive, RFS)

Raw, untreated SAR water served as the control.

Multiple evaluation methods were used to assess the performance of these methods, including:

- Turbidity and TSS
- Laboratory percolation columns
- Percolation test cells
- Modified fouling index (MFI) (Schippers and Verdouw, 1980)
- Particle size distribution

Figure 10 is a picture of the percolation test cells being supplied with water treated using different technologies.



**Figure 10: Percolation Test Cells Being Supplied with SAR Water Treated Using Different Technologies.** Raw water is untreated SAR water (control).

Phase 2 testing showed that Riverbed Filtration System (RFS) was the superior treatment method with flocculation-sedimentation being the worst (OCWD, 2010). One of the unexpected outcomes of the Study was that any treatment method that used chemical additions, such as flocculants and polymers, while able to produce low turbidity water, resulted in elevated rates of clogging. It is suspected that residual flocculants or polymers remaining in the recharge water interacted with fine-grained sediments (silts and clays) within the native sand to cause clogging.

Following completion of the Study, Demonstration Scale testing of Cloth Filtration, using no pre-treatment chemicals, and RFS was conducted. Testing of Cloth Filtration was conducted from 2012 -16 and showed that this method of treatment can only handle water with a relatively limited range of TSS concentrations (10-30 mg/L) and, even with treatment, it was not possible to measure improvements in recharge rates. Due to these limitations, it was determined that the opportunities to deploy Cloth Filtration in other parts of the recharge system were limited. A summary of Cloth Filtration testing is summarized in Appendix A.

## 4.0 Riverbed Filtration

The Riverbed Filtration System (RFS) is a variant of Riverbank Filtration (RBF). Riverbank Filtration is used to withdraw water through a riverbank or under a river channel or lake by placing a production well adjacent to the surface water body. RBF has been used for many years to acquire surface water. European water suppliers have been using this technology in conjunction with conventional treatment methods for over a century due to its relatively inexpensive and sustainable means of improving the quality of surface waters (Hiscock and Grisceck, 2002). In contrast, the use of RBF in the United States began less than 50 years ago (Ray et al., 2002). RBF provides passive exposure to processes such as adsorption, oxidation/reduction reactions, and physical-chemical filtration and also provides biodegradation and dilution that can significantly improve water quality (Weiss et al., 2003). Through these mechanisms, RBF changes surface water into water with characteristics close to that of groundwater (Kuehn and Mueller, 2000; Speth et al., 2002; USBR, 2006).

While RBF seeks to obtain significantly improved water quality for water to be used for potable purposes, the RFS studied by OCWD seeks primarily to remove suspended solids to minimize clogging and thus enhance the performance of groundwater recharge facilities. The RFS provides other water quality improvements, but these are secondary to removing TSS from the recharge water.

### 4.1 Riverbed Filtration System Pilot Testing

As part of Phase 2 of the Study, a pilot-scale RFS was constructed in the upper portion of OCWD's Off-River channel as shown in Figure 11. The Off-River channel was formerly part of the main SAR channel until the Center Levee was constructed in 1972. This is an ideal location to study the RFS because the geology is similar to the SAR channel and OCWD controls the flow in the Off-River channel.

The pilot system was constructed of eight 8-inch diameter slotted PVC laterals that are 180 feet long, buried approximately 3 to 4 feet below the channel surface (red lines on Figure 11) (Milczarek et al., 2010; Keller et al., 2010). A ten-foot blank section connected the slotted sections to the 14-inch diameter collector pipe (yellow line in Figure 11). A collection vault was positioned in the center with four laterals on each side. Pumps were installed in the vault to provide a hydraulic low point to induce water to flow through the laterals and to extract water from the system. An extensive monitoring well network was installed to monitor levels and temperatures of surface water and groundwater (wells with prefix P and MW in Figure 11). Figure 12 is a photograph showing the construction of the Pilot RFS.



Figure 11: Pilot Riverbed Filtration System



Figure 12: Construction of the Pilot Riverbed Filtration System

The pilot system produced 3 to 4.5 cubic feet per second (cfs), which was lower than expected due to unsaturated conditions in the area of the four upstream laterals. Water level and temperature data were used to evaluate the amount of surface water immediately above the laterals that flowed vertically to the laterals versus lateral flow from previously recharged water. This work showed that approximately 80 percent of the water produced by the system was induced surface water flow to the laterals with the other 20 percent previously recharged water (GeoSystems Analysis, 2009).

The quality of the water produced by the pilot system was excellent with no detectable suspended solids in the water (OCWD, 2010). This resulted in high, sustained percolation rates compared to the control, which was untreated SAR water (see Section 3.0).

#### **4.2 Riverbed Filtration System Demonstration Project**

The RFS Demonstration Project was constructed in 2013 using the uppermost section of the pilot system and expanding the system downstream as shown in Figures 13 and 14.

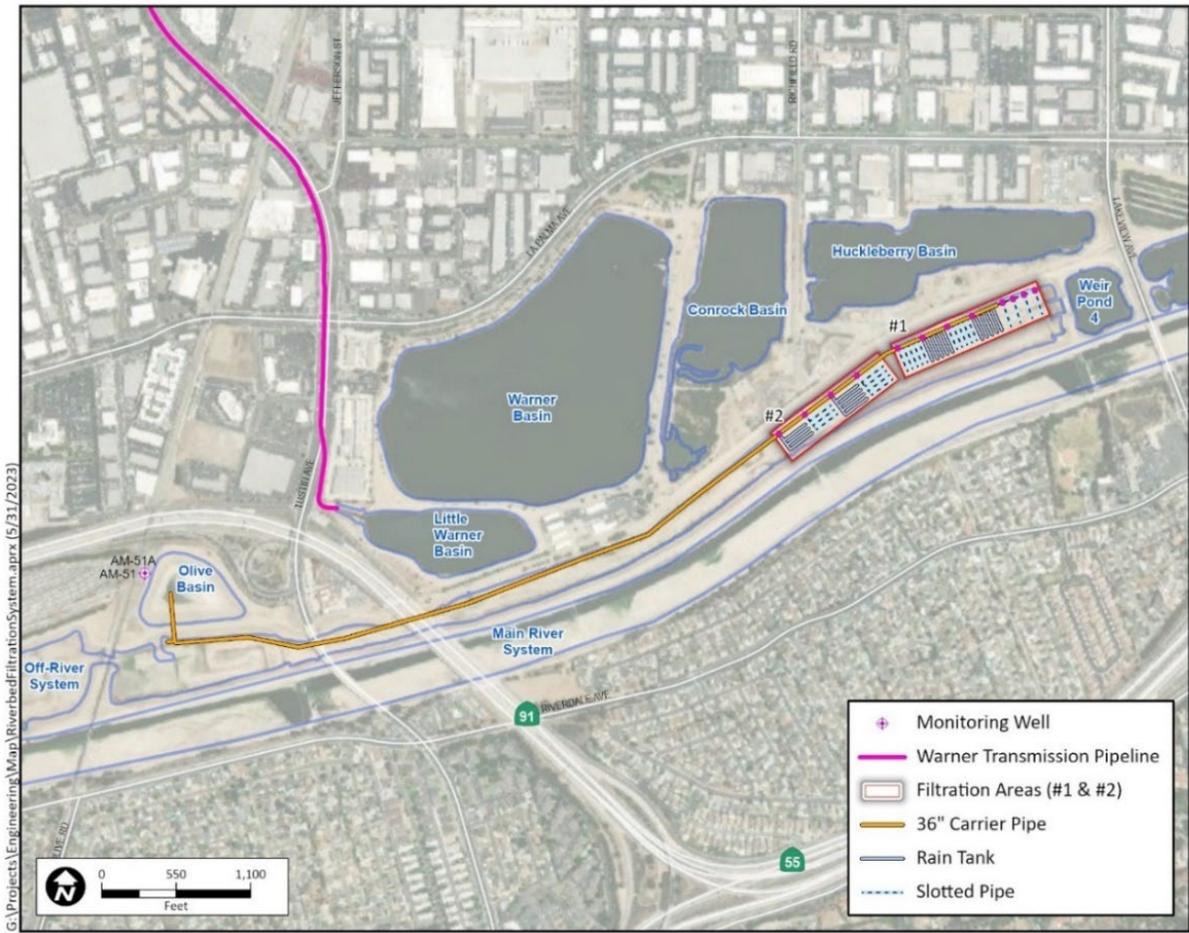
The RFS Demonstration Project was constructed with two types of collectors:

- Slotted PVC pipe
- Flo-Tanks (aka Rain Tanks)

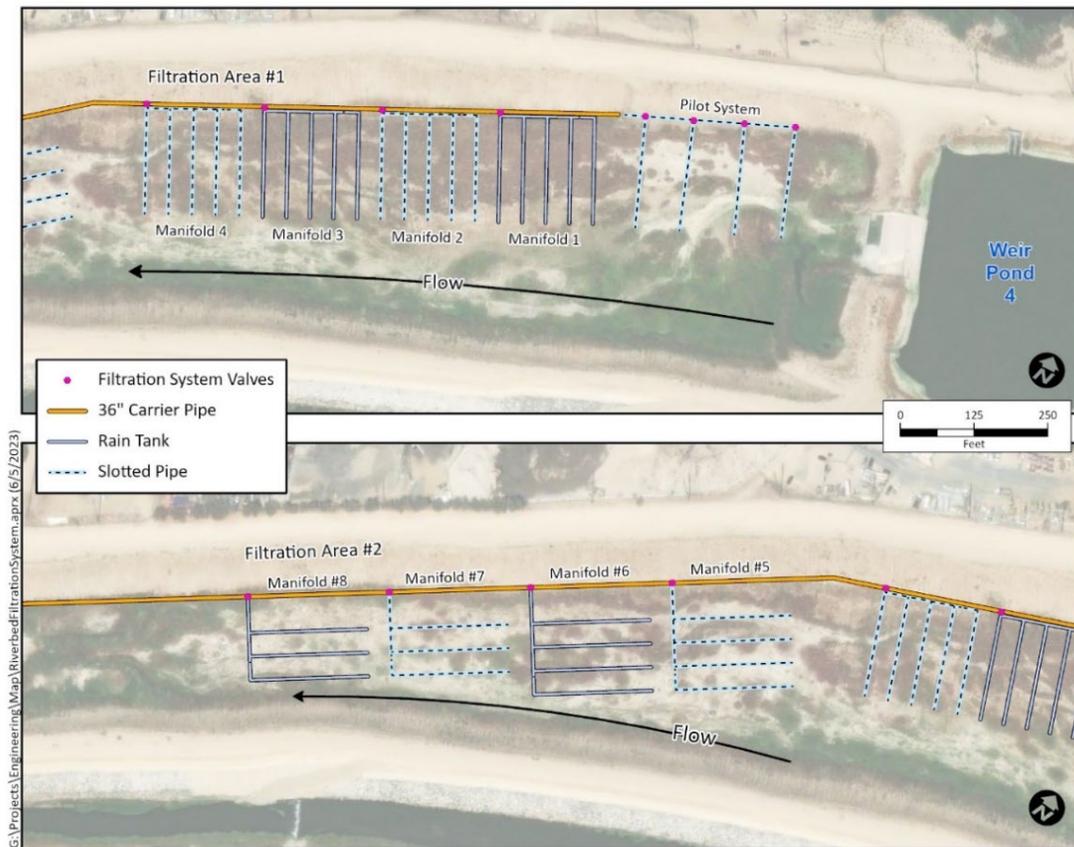
The Flo-Tanks were added as a collector type to assess any potential differences in performance, costs, and future maintenance, particularly if there was a need to repair collectors that could be damaged in a full-scale system by scour in the main SAR channel.

All the collectors were placed a minimum of 3 feet below the ground surface and ranged in length from 180 – 200 feet. The slotted PVC pipes are 8 inches in diameter and buried in a gravel mixture. Native material was then placed on top of the gravel to the ground surface. The Atlantis Flo-Tank® (Atlantis Corporation, Australia) modules were placed end to end and wrapped in geotextile fabric. Once buried, native material was placed around and above the tanks on the ground surface. Each Flo-Tank module is 17.7 inches high, 16 inches wide, and 27 inches long. Figure 15 is a photo of one module. The RFS footprint covers approximately 10 acres.

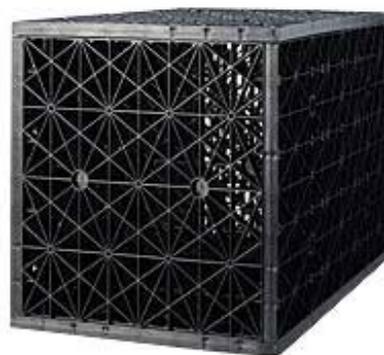
Each set of slotted PVC or Flo-Tank collectors, other than the four pilot study collectors, drained to a manifold that could be controlled by a single valve. This allowed for testing various combinations of collector types and orientations as one set of collectors was constructed parallel to the flow in the Off-River channel and the others perpendicular to the flow (see Figure 14). All of the collectors drained to a main 36-inch HPDE carrier pipeline that conveyed the filtered water to Olive Basin. A SonTek IQ flowmeter (<https://www.ysi.com/sontek-iq-series>) was installed near the end of the carrier pipeline to measure flows into Olive Basin.



**Figure 13: Location and Layout of the Riverbed Filtration System (RFS) Demonstration Project**



**Figure 14: Location RFS Demonstration Project Manifolds**



**Figure 15: Atlantis Flo-Tank Module**

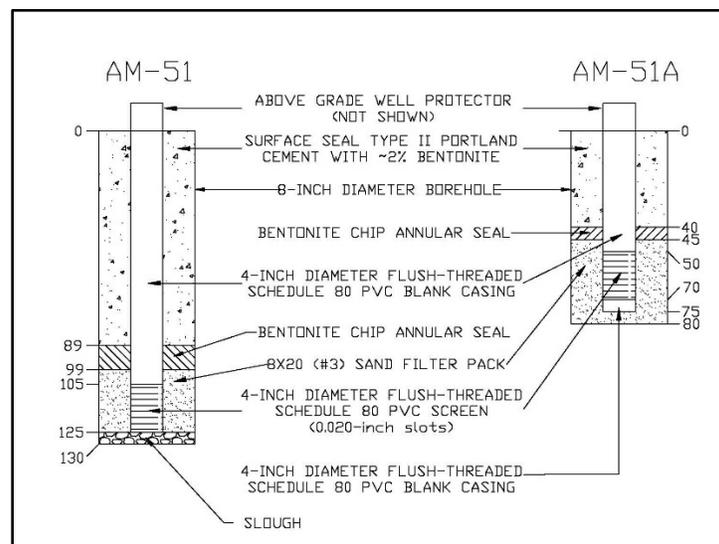
The target capacity was 15 cfs, which is based on a percolation rate of 3 feet/day over the approximate 10-acre RFS area.

The RFS was put into operation in March 2014. There were several issues with the flowmeter that prevented obtaining recharge rate measurements until the flowmeter was replaced in 2015. So, although the basin was used for recharge, inflow data is only available starting in March 2015.

### 4.2.1 Olive Basin

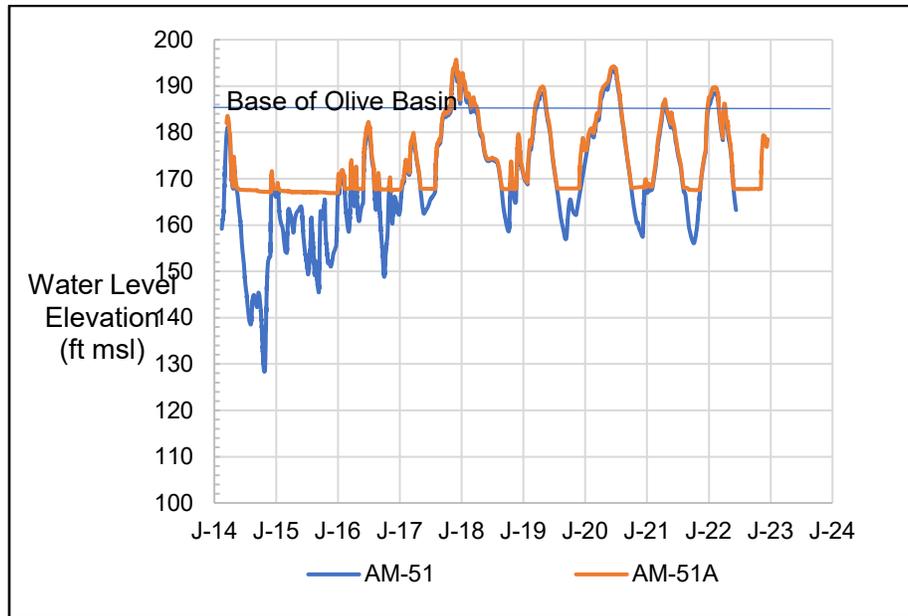
The receiving recharge basin, Olive Basin, is a former sand and gravel borrow pit that was purchased by OCWD in 1972 (see Figure 13). When full, the basin has a wetted area of 5.8 acres and a maximum depth of 40 feet. Historically, surface water from the SAR was diverted to the basin for recharge. In 2008, a project to relocate the inflow pipeline from mid-way up the basin bank to the basin bottom was completed. This was done to reduce the amount of erosion that took place when the basin was filled. This project alone greatly increased the recharge capacity of the basin. Starting in March 2015, only filtered SAR water from the RFS water was supplied to the basin. A comparison of historical recharge performance using unfiltered SAR water and RFS water provides a measure of the increased recharge due to the RFS.

To characterize the recharge and water quality impacts of the RFS, two groundwater monitoring wells were installed adjacent to Olive Basin, AM-51 and AM-51A. Well AM-51 is screened in the deeper principal aquifer while AM-51A is shallow and was designed to intercept water recharged at Olive Basin. When groundwater basin levels are low, AM-51A only receives water recently recharged at Olive Basin, however, when groundwater basin levels are high, deeper groundwater levels rise to levels higher than the bottom of Olive Basin. Figure 16 shows how the wells were constructed.



**Figure 16: As-Built Diagram of Monitoring Wells AM-51 and -51A (Not to Scale)**

Water level data from monitoring wells AM-51 and AM-51A from 2014 to 2023 are shown in Figure 17. What is noteworthy is that there are periods when water levels are higher than the base of Olive Basin. These periods of mounding must be considered when evaluating the recharge performance of Olive Basin, as mounding can reduce percolation rates in the basin. Figure 17 also shows periods when there is no water in AM-51A (horizontal orange line at 167.8 ft msl).



**Figure 17: Groundwater Levels in Monitoring Wells AM-51 and -51A**

#### 4.3 Demonstration Project Objectives and Metrics

The objectives and metrics of the RFS Demonstration Project are summarized in Table 2.

**Table 2: Objectives and Metrics of RFS Demonstration Project**

Objectives	Metric(s)
Assess the Impact of RFS on Clogging and Basin Performance.	<ul style="list-style-type: none"> <li>• Difference in Olive Basin percolation rate with unfiltered SAR water and RFS water</li> <li>• Projected percolation rate with RFS water</li> </ul>
Assess the Impact of RFS on Water Quality	<ul style="list-style-type: none"> <li>• Changes in water quality in the source water (Weir Pond 4) and the RFS water (Olive Basin)</li> <li>• Changes in water quality in RFS water (Olive Basin) and recharged water (Monitoring Well AM-51A)</li> <li>• Changes in RFS water quality as a function of TSS loading</li> </ul>
Assess RFS Capacity and Optimal Design Parameters	Flow generated by RFS with: <ul style="list-style-type: none"> <li>• Different collector types</li> <li>• Different collector orientation</li> <li>• Different collector spacing</li> <li>• Different surface water flow rates</li> <li>• Different depths to groundwater</li> </ul>

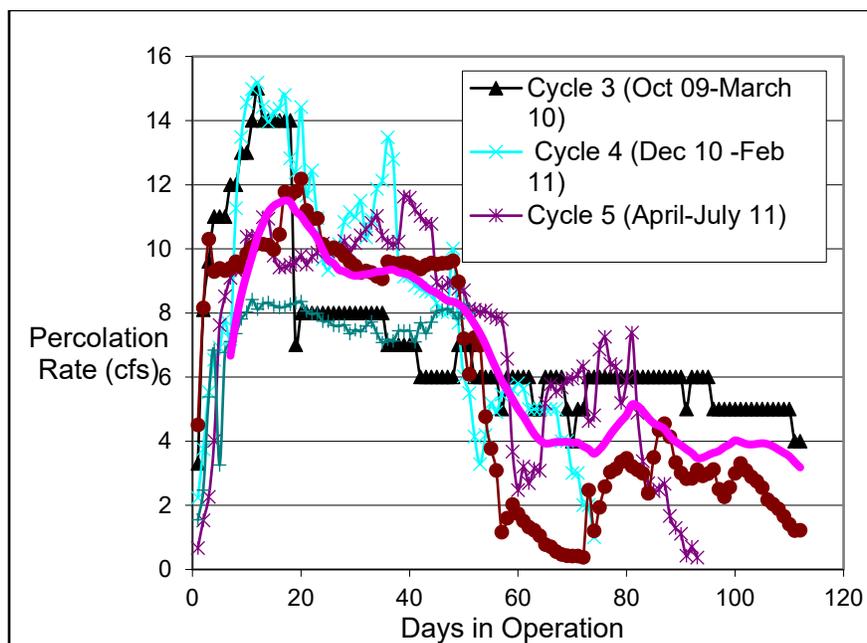
## 4.4 RFS Demonstration Project Test Results

RFS was put into operation in March 2014; however, there were issues with the inflow meter that ultimately required replacing the meter. As a result, recharge data using the RFS are available starting in March 2015. The RFS results are presented in sections corresponding to the objectives presented in Table 2.

### 4.4.1 Impact of RFS on Clogging and Basin Performance

Olive Basin percolation rate data from 2007 to 2012 was compiled and plotted to establish baseline basin performance with unfiltered SAR water, shown in Figure 18 except for data for the first two operational cycles covering January 2008 to April 2009 because the estimates of inflow to the basin during this period are uncertain. Inflow to the basin was measured using a sharp-crested weir. A total of seven operational cycles were defined ranging in length from 50 to 170 days. An operational cycle starts when the basin is placed into service following a cleaning event and stops when the basin is taken out of service for cleaning.

Within each operational cycle, the percolation rate follows the typical slow rise as the basin is filled, reaching a maximum when the basin becomes full. Soon after reaching its maximum, clogging sets in and the percolation rate begins to decline. Based on Cycles 3 through 7, the average percolation rate declines from approximately 11 cfs to 4 cfs over 60 days. Figure 18 shows the daily percolation rates for Cycles 3 through 7 and the moving average of these five cycles. The next section compares this performance to RFS-treated water.

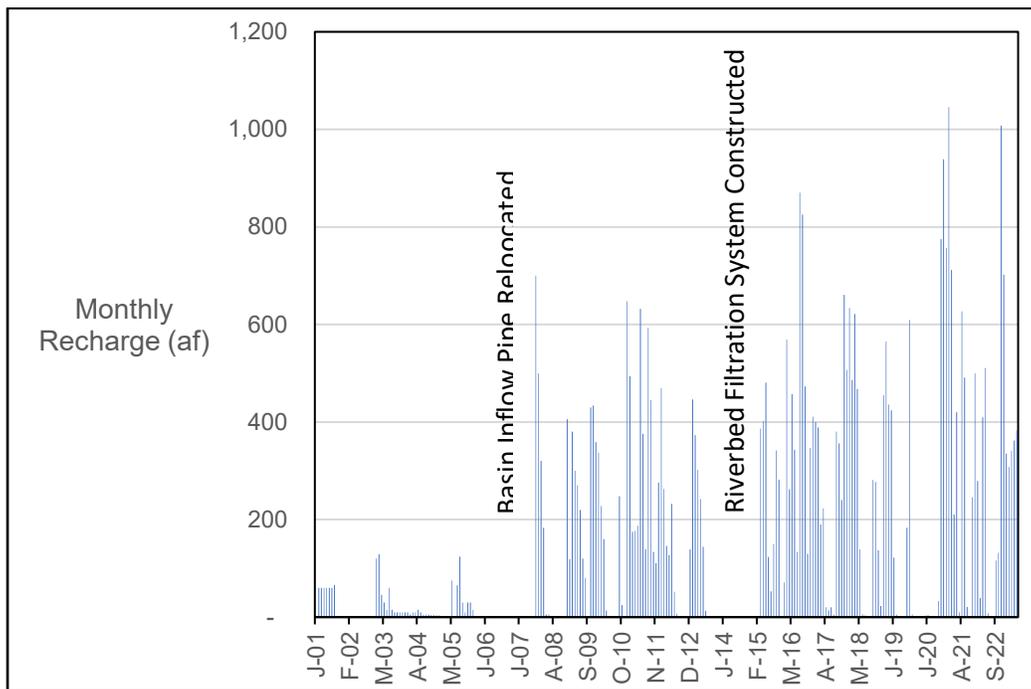


**Figure 18: Olive Basin Percolation Rate with Unfiltered Santa Ana River Water  
October 2009 to January 2012**

Figure 19 shows the monthly recharge in Olive Basin from 2001 to 2023. It is clear that relocating the inflow pipeline in 2008 greatly improved the recharge capacity of the basin. Installation of the RFS in 2013 also improved the recharge capacity of the basin. One challenge in analyzing basin performance is that the supply of water to the basin tends to be inconsistent. This is partially because sending water to the upper Off-River channel is a lower priority compared to other facilities and also due to the low supply of SAR base flow in the summer months. Also embedded in this are changes in operational approaches to managing the entire recharge system. Table 3 summarizes the recharge rates during these periods.

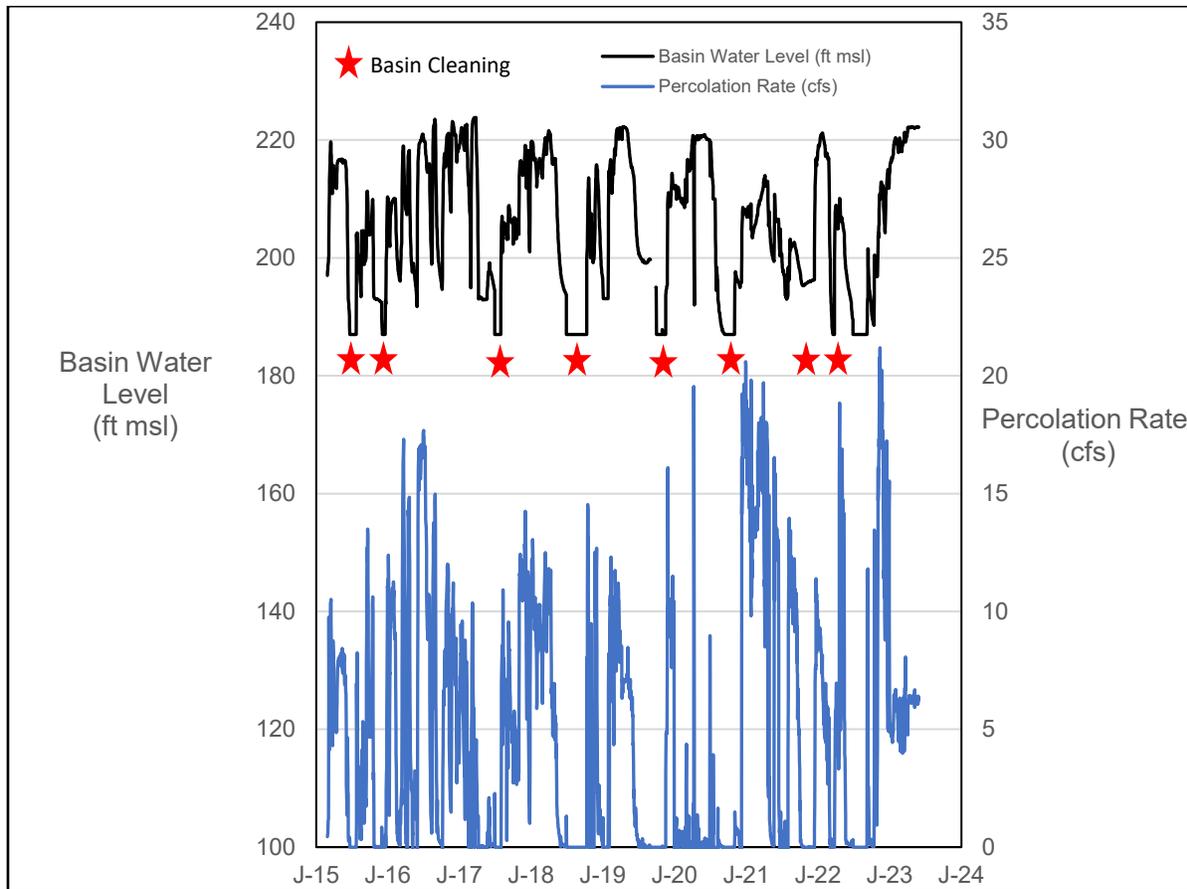
**Table 3: Olive Basin Recharge Rates**

Period	Total Recharge (af)	Total Months	Months in Operation	Avg Recharge when in Operation (af/month)	Change in Avg Recharge (%)	Maximum Monthly Recharge (af)
2001-2008	1,361	84	40	34	N/A	129
2008-2013, Post Inflow Pipe Relocation	13,186	74	50	264	+780%	700
2013-2023, RFS	28,127	111	83	339	+130%	1,046



**Figure 19: Monthly Recharge in Olive Basin, 2001-2023**

Figure 20 shows the daily basin water level and percolation rate from 2015 to 2023 and when the basin was cleaned. Using these cleaning events as endpoints results in 9 recharge cycles over 8 years.

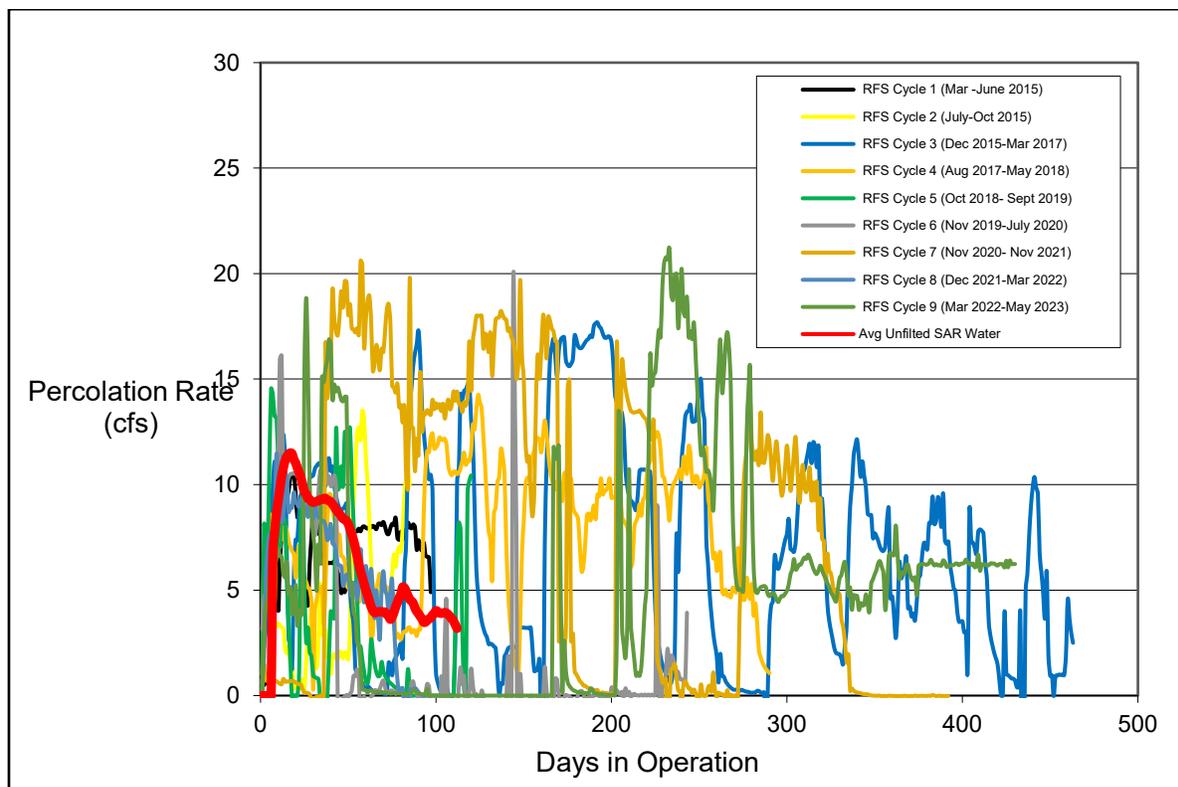


**Figure 20: Daily Olive Basin Water Level and Percolation Rate, 2015-2023**

Figure 21 shows the daily percolation rate for each operational cycle. For comparison, the average percolation rate for unfiltered SAR water is also shown. Table 4 summarizes the total recharge, length of each cycle, maximum percolation rate achieved, and average percolation rate for each operational cycle. The same information for unfiltered SAR water is also shown. Note that due to the variability in supply to the basin, the average percolation rate does not represent a true average.

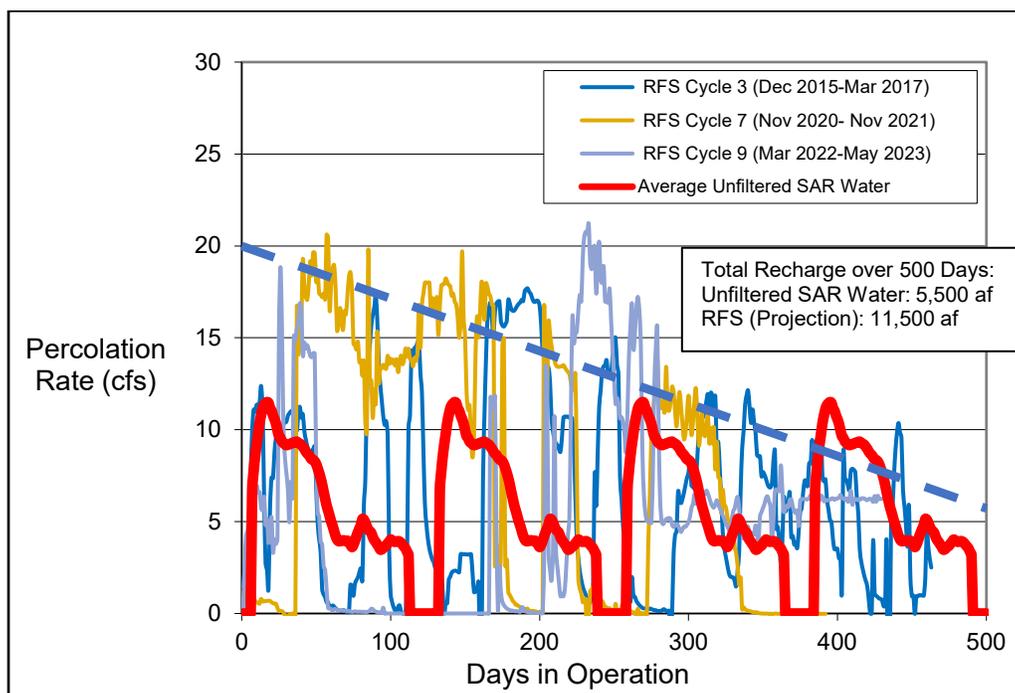
**Table 4: Olive Basin RFS Operational Cycles**

Cycle	Total Recharge (af)	Length (days)	Maximum Daily Percolation Rate (cfs)	Avg Percolation Rate (cfs)
1 (Mar-June 2015)	1,340	97	11	7
2 (July-Oct. 2015)	800	85	14	5
3 (Dec. 2015-March 2017)	6,120	463	18	7
4 (Aug. 2017-May 2018)	4,500	290	14	8
5 (Oct. 2018-Sept. 2019)	2,730	262	15	5
6 (Nov. 2019-July 2020)	800	243	20	2
7 (Nov. 2020-Nov. 2021)	6,060	392	21	8
8 (Dec. 2021-March 2022)	1,050	95	11	6
9 (March 2022-May 2023)	4,655	430	21	5
Unfiltered SAR	1,420	110	12	6



**Figure 21: Daily Olive Basin Percolation Rate for 9 Operational Cycles**

It is clear from Figure 21 that percolation rates are significantly higher with the RFS compared to using unfiltered SAR water. To assess the relative performance of RFS water, a percolation decay trend based on the three longest operational cycles (Cycles 3, 7 and 9) is compared to multiple cycles of unfiltered SAR water, assuming that 20 calendar days are needed to drain, dry, and clean the basin. Cycles 3, 7 and 9 ran for 463, 392 and 430 days, respectively. Using the percolation decay trend for these cycles and adding 20 days on the end for cleaning, totals approximately 500 days. Figure 22 shows that over 500 days, the estimated percolation rate of RFS water would start at 20 cfs and decay to approximately 6 cfs, for a total recharge volume of 11,500 af. Over this same period, unfiltered SAR water would require three cleanings and recharge a total of 5,500 af. This analysis suggests that RFS water would achieve double the recharge volume of unfiltered SAR water. This is consistent with the performance of recharge basins using imported or GWRS water (see Section 2, Figure 4).



**Figure 22: Percolation Rate in Olive Basin with Unfiltered SAR Water and RFS Cycles 3/7/9 Projection**

Under natural conditions, the typical percolation rate in the SAR channel adjacent to the Off-River channel ranges from 0.1 – 0.7 feet/day. Based on the maximum inflow to Olive Basin of 21 cfs (or 42 acre-feet per day) generated within the 10-acre footprint of the RFS means that the average unit percolation rate over the RFS is approximately 4 feet/day. This means that the RFS is inducing greater percolation rates than what occurs naturally.

#### 4.4.2 Impact of RFS on Water Quality

Water quality data of interest can be placed into two categories: 1) Parameters that impact clogging; and 2) Parameters that impact public health. Table 5 lists the constituents and parameters tested for.

Water quality samples were obtained from the following locations:

1. Weir Pond 4 (Represents source water)
2. Collector Pipe at Olive Basin (Represents filtered water, also called Product Water)
3. Surface water in Olive Basin
4. Monitoring Wells AM-51/51A.

Samples from Weir Pond 4 were obtained using standard surface water collection methods. To obtain water from the RFS collector pipe, a submersible Dayton Plug-In Utility Pump (110V AC, ½ HP, 74 GPM flowrate) was used. The pump and collection equipment were contained within a metal shed as shown in Figure 23.



**Figure 23: Pumping Equipment for Obtaining Samples from Collector Pipe**

Surface water from Olive Basin was obtained using standard surface water collection methods. Groundwater samples obtained from monitoring wells AM-51 and AM-51A were obtained with temporary submersible pumps.

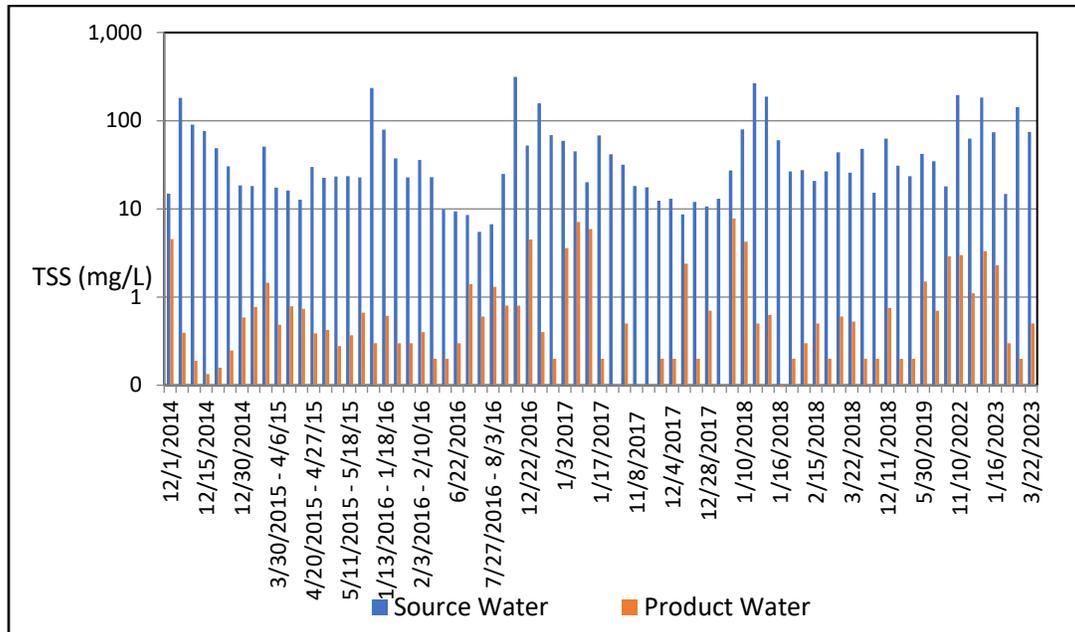
**Table 5: Water Quality Testing for RFS**

Category	Parameters
Physical Clogging	<ul style="list-style-type: none"> <li>• TSS, particle size distribution</li> </ul>
Biological Clogging	<ul style="list-style-type: none"> <li>• Nitrogen</li> <li>• Phosphorus</li> <li>• TOC and DOC</li> </ul>
Chemical Clogging	<ul style="list-style-type: none"> <li>• Precipitable cations/anions (e.g., Ca, Mg, Na, HCO<sub>3</sub>, SO<sub>4</sub>, Cl)</li> <li>• pH</li> </ul>
Public Health	<ul style="list-style-type: none"> <li>• Indicator bacteria</li> <li>• Arsenic and other metals</li> <li>• Organic halides (TOX)</li> <li>• Constituents of Emerging Concern (CECs)</li> </ul>

#### 4.4.2.1 Parameters Related to Clogging

As listed in Table 5, clogging mechanisms fall into three broad categories: Physical Clogging, Biological Clogging, and Chemical Clogging. Over many years of research, OCWD has found that the primary driver of clogging within OCWD's recharge system is physical clogging caused by the accumulation of suspended solids on the recharge surface. A measure of the physical clogging potential of water is the concentration of Total Suspended Solids (TSS). TSS concentrations were measured by OCWD staff using USEPA standard method #2540D. For completeness, water quality data for other clogging mechanisms were collected and are presented in Appendix B. For the major cations/ anions (e.g. Ca, Mg, Na, HCO<sub>3</sub>, SO<sub>4</sub>, Cl) that are commonly associated with chemical clogging, no statistically significant differences were observed between the average concentrations in the source and product waters.

Figure 24 shows TSS concentrations in the source water, which is water flowing over Weir Pond 4, and the product water, which is the filtered water obtained from the RFS collector pipe from 2014-2023.

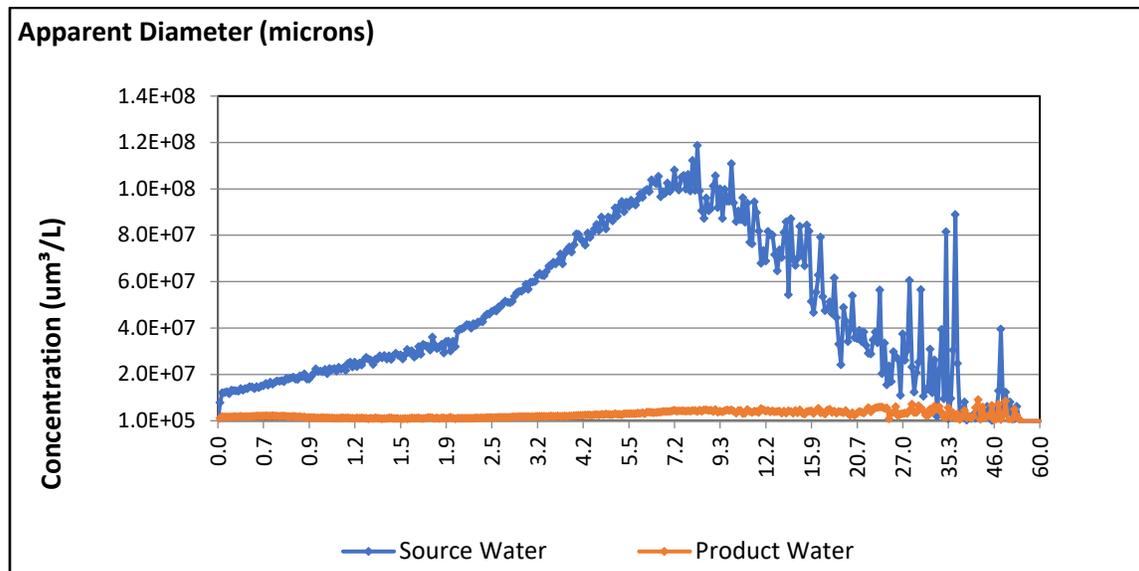


**Figure 24: Total Suspended Solids in Influent Source Water and Product Water from RFS**

(Note Log Scale; samples with a date range are weekly averages)

TSS concentrations of the source water ranged from 6 mg/L to a high of 315 mg/L. TSS concentrations in the product water ranged from non-detect to 8 mg/L. TSS removal by the RFS ranged from 70 to 99 percent and averaged 96 percent.

Particle size distribution data (n=34) was collected between 2014 - 2017 to characterize the removal efficiency of the various size particles ranging from an apparent diameter of 0.6 to 60  $\mu\text{m}$  that comprise the suspended solids. Figure 25 shows the average particle size distribution for SAR water and product water. SAR water has a significantly higher concentration of particles and larger sizes (up to  $1.2 \times 10^8 \mu\text{m}^3/\text{L}$  within the 7-9 $\mu\text{m}$  range) compared to the product water (up to  $4.8 \times 10^6 \mu\text{m}^3/\text{L}$  within the same particle range). This demonstrates the high capacity of the RFS in removing suspended solids within the colloidal, clay, and silt size ranges.

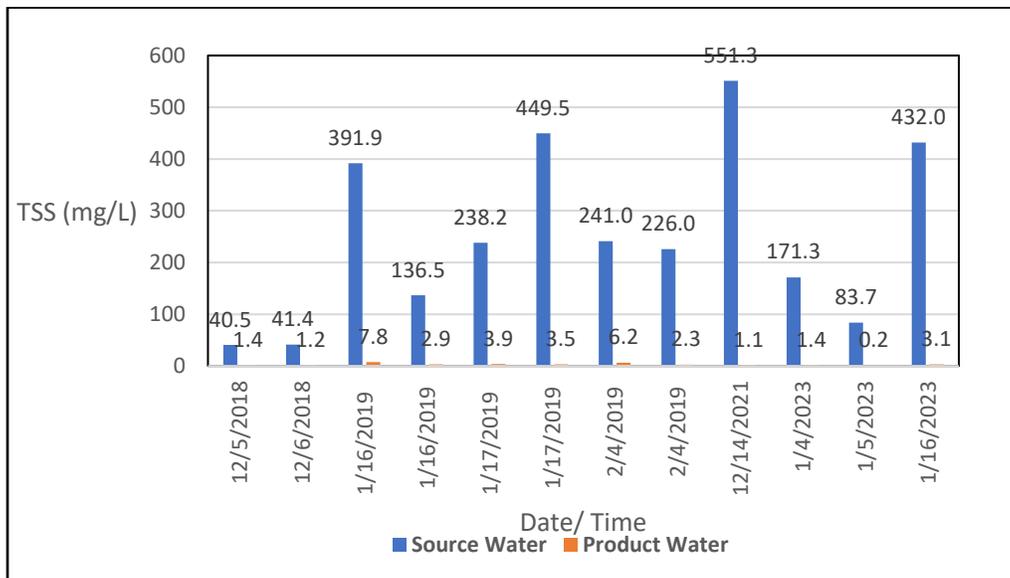


**Figure 25: Average Particle Size Distribution of TSS in Influent Source Water and Product Water from RFS**

TSS concentrations in the source water at Wier Pond 4 are lower than in the SAR channel because the water has had the chance to move through several desilting ponds. As shown in Figure 24, the maximum TSS concentration measured at Weir Pond 4 during this study was 315 mg/L. To assess RFS performance under a higher TSS load, a small-scale SAR RFS was installed in 2018 in the SAR channel, given that any future, full-scale implementation of RFS would likely encounter these greater TSS loads. The SAR RFS was constructed of one 20-foot long, 4" diameter slotted PVC pipe with (0.010" slot size) and buried in a gravel envelope with native sand placed above it (see Figure 26). This is the same design as the larger RFS in the Off-River channel. A small submersible pump with a power connector and discharge pipe with a locking cap was used to pump filtered water from the system to measure TSS concentrations during high TSS (>300 mg/L) loading events. Due to drought and lack of large storm events, only four events were sampled from 2018 - 2023 that exceeded the 300 mg/L threshold with TSS concentrations ranging from 392 to 551 mg/L. For all samples obtained, the TSS removal averaged 99 percent (Figure 27). The SAR RFS results indicate that even at higher TSS loads, the RFS remains an effective means to reduce TSS concentrations in the source water.



**Figure 26: Construction of SAR RFS System in the SAR Channel**



**Figure 27: Total Suspended Solids in Source Water (SAR) and Product Water from SAR RFS System**

In summary, the RFS in the Off-River channel and the SAR channel were very effective in removing suspended solids removing an average of 96 to 99 percent of the TSS in the source water.

Total and Dissolved Organic Carbon (TOC and DOC) were monitored to assess the potential for biological clogging. TOC is the bulk measurement of organic content, whereas DOC represents the amount of organic carbon excluding colloidal and

particulate organic matter. As shown in Table 6, TOC and DOC removal were 53 and 50 percent, respectively, which is consistent with historical soil aquifer treatment (SAT) data (Laws et al., 2011, Mia et al., 2012; Murray, 2020). TOC and DOC removal in SAT is typically dominated by biodegradation and adsorption mechanisms.

Nutrients, specifically total nitrogen and phosphate phosphorous (orthophosphate) were also monitored as they can contribute to biological growth and are associated with biological clogging. Slight reductions were observed between the source water and product water, with approximately 5 percent of total nitrogen removed compared to approximately 9 percent removal of phosphate phosphorous (orthophosphate) (Table 6).

**Table 6: Water Quality Testing for Biological Clogging Parameters (2014- 2019)**

	Source Water (WP4)	Product Water*	Change
Parameter	<b>Total Organic Carbon (mg/L) (n=11, 8*)</b>		
Maximum	10.90	3.93	
Minimum	5.49	2.77	
Median	6.47	3.52	
Average	7.40	3.45	53.4% reduction
Standard Deviation (±)	1.87	0.36	
Parameter	<b>Dissolved Organic Carbon (mg/L) (n=11, 8*)</b>		
Maximum	9.85	3.79	
Minimum	4.31	2.69	
Median	6.47	3.45	
Average	6.75	3.35	50.4% reduction
Standard Deviation (±)	1.56	0.41	
Parameter	<b>Total Nitrogen (mg/L) (n=11, 8*)</b>		
Maximum	5.50	4.20	
Minimum	1.12	1.80	
Median	2.80	2.30	
Average	2.80	2.55	8.8% reduction
Standard Deviation (±)	1.39	0.85	
Parameter	<b>Phosphate Phosphorous (orthophosphate) (mg/L) (n=11, 8*)</b>		
Maximum	1.32	0.78	
Minimum	0.41	0.55	
Median	0.59	0.69	
Average	0.70	0.67	4.8% reduction
Standard Deviation (±)	0.27	0.09	

\* = Number of Product Water Samples

#### 4.4.2.2 Parameters Related to Public Health

Parameters measured relating to public health included bacterial parameters and constituents of emerging concern (CECs). Bacterial indicators such as total coliform, E. coli, and enterococcus showed greater than 98 percent removal across the system as shown in Table 7. This is consistent with other studies showing soil straining and inactivation of pathogens near the soil surface (Ausland et al., 2002; Guessab et al., 1993; Gerba & Goyal, 1985; NRC, 1994; Quanrud, 1998; Sallway, et al., 2020).

**Table 7: Water Quality Testing for Bacterial Parameters (2014- 2019)**

	Source Water (WP4)	Product Water*	Change
Parameter	<b>Total Coliform (CFU/100) (n=13, 8*)</b>		
Maximum	24000.00	300.00	
Minimum	220.00	1.00	
Median	1900.00	36.00	
Average	4490.77	80.63	98.2% reduction
Standard Deviation (±)	6756.39	107.59	
Parameter	<b>E. Coli (CFU/100) (n=16, 8*)</b>		
Maximum	1340.00	17.00	
Minimum	19.00	0.10	
Median	121.00	1.00	
Average	176.31	3.29	98.1% reduction
Standard Deviation (±)	363.3	5.78	
Parameter	<b>Enterococcus (CFU/100) (n=9, 3*)</b>		
Maximum	390.00	3.00	
Minimum	4.00	0.10	
Median	140.00	2.00	
Average	134.1	1.70	99.2% reduction
Standard Deviation (±)	139.17	1.47	

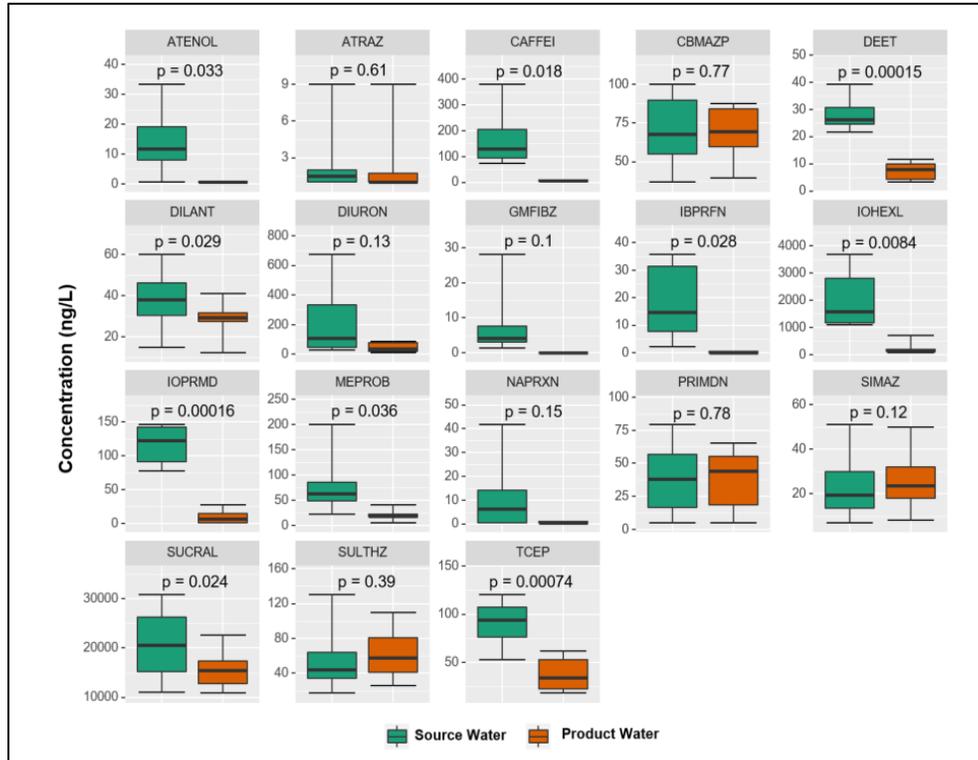
\* = Number of Product Water Samples

Water quality data collected between 2014-2019 show differences in CEC removal rates with the RFS. Of the 18 CECs detected, which are listed in Table 8, 10 show statistically significant differences ( $p < 0.05$ ) between median concentrations in the source water and filtered product water (Figure 28). The CECs were placed into three removal categories: Efficient ( $> 80\%$ ), Moderate (30- 80%), or Poor ( $< 30\%$ ). These compounds likely originated from treated wastewater effluent discharge at upstream sites into the river. The increased concentrations observed in Simazine (SIMAZ) and Sulfamethoxazole (SULTHZ) are not statistically significant and may be due to the

accuracy of the measurement. The variability in removal depends on compound properties (i.e., biodegradable and sorption characteristics of compounds result in greater removal over shorter travel times). The removals seen in this study are consistent with other studies on SAT removal of CECs (Yu et al., 2006; Laws et al., 2011).

**Table 8: Water Quality Testing for CEC's (2016- 2019)**

Parameter	Average Source Water Concentration (ng/L)	Average Product Water Concentration (ng/L)	% Removal	Removal Efficiency
	n = 6	n = 6		
Gemfibrozil (GMFIBZ)	8.23 ± 10.0	0.1 ± 0.0	98.8	Efficient (> 80%)
Ibuprofen (IBPRFN)	18.3 ± 14.6	0.2 ± 0.2	98.7	
Caffeine (CAFFEI)	171.0 ± 116.0	5.6 ± 3.2	96.7	
Atenolol (ATENOL)	14.3 ± 11.6	0.5 ± 0.0	96.5	
Naproxen (NAPRXN)	11.7 ± 16.0	0.7 ± 0.3	94.3	
Iopromide (IOPRMD)	117.0 ± 30.8	9.6 ± 10.7	91.8	
Iohexol (IOHEXL)	2030.0 ± 1110.0	231.0 ± 229.0	88.6	Moderate (30-80%)
Diuron (DIURON)	225.0 ± 258.0	46.5 ± 32.8	79.3	
Meprobamate (MEPROB)	81.1 ± 62.6	20.5 ± 11.8	74.7	
N,N-diethyl-m-toluamide (DEET)	28.3 ± 6.4	7.4 ± 3.5	73.7	
Tris-2-chlorethyl phosphate (TCEP)	90.6 ± 24.9	37.8 ± 18.6	58.3	
Dilantin (DILANT)	38.0 ± 15.7	28.5 ± 9.4	25.0	Poor (< 30%)
Sucralose (SUCRAL)	20800.0 ± 7710.0	15700.0 ± 4220.0	24.5	
Atrazine (ATRAZ)	2.7 ± 3.1	2.5 ± 3.2	6.4	
Primidone (PRIMDN)	38.8 ± 28.8	37.9 ± 25.0	2.3	
Carbamazepine (CBMAZP)	70.1 ± 24.5	68.7 ± 18.7	2.0	
Simazine (SIMAZ)	23.7 ± 16.0	26.0 ± 14.6	-9.7	
Sulfamethoxazole (SULTHZ)	56.2 ± 39.9	62.6 ± 31.2	-11.4	



**Figure 28: Removal Efficiencies for CECs (2016-2019)**

( $p < 0.05$  indicates compounds that have statistically significant difference)

#### 4.4.3 RFS Capacity and Design Considerations

The RFS was designed to identify critical factors affecting RFS capacity and efficiency. To identify these factors, the RFS was designed with two different types of collectors and with sets of collectors oriented parallel and perpendicular to surface water flow. Table 9 summarizes the RFS design parameters. Figure 14 shows the layout of the RFS.

**Table 9: RFS Design Parameters**

Collector	Material	Open Area/Slotted Pipe (ft)	Orientation to Surface Flow
Pilot System	4-inch Slotted PVC	720	Perpendicular
Manifold 1	Flo-Tanks (aka Rain Tanks).	720	Perpendicular
Manifold 2	4-inch Slotted PVC	720	Perpendicular
Manifold 3	Flo-Tanks (aka Rain Tanks).	720	Perpendicular
Manifold 4	4-inch Slotted PVC	720	Perpendicular
Manifold 5	4-inch Slotted PVC	720	Parallel
Manifold 6	Flo-Tanks (aka Rain Tanks).	720	Parallel
Manifold 7	4-inch Slotted PVC	540	Parallel
Manifold 8	Flo-Tanks (aka Rain Tanks).	540	Parallel

During testing of the various combinations of collector types and orientation, it became clear that there were other factors affecting flows generated by the RFS. These include:

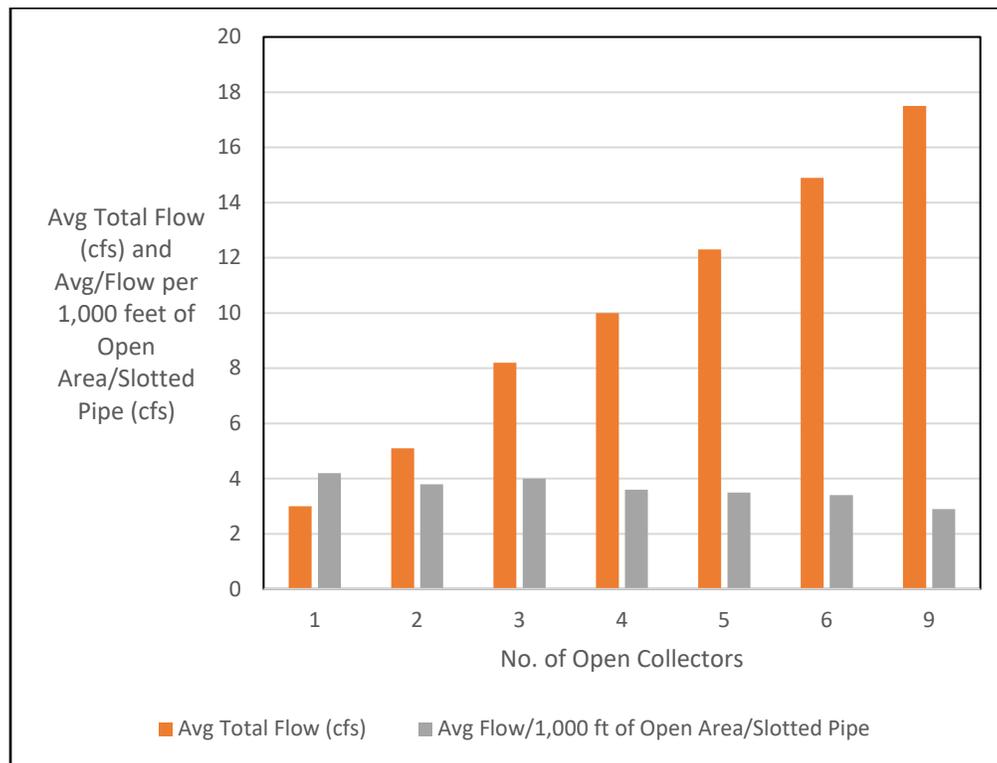
1. Flow rate of surface water over the RFS
2. Flow rate of surface water in the adjacent Santa Ana River channel
3. Water level in Olive Basin

It proved challenging to establish conditions when all these variables were similar to provide reproducible results. As a result, it was not possible to test all potential manifold combinations; however, in over three years of testing, 15 separate combinations were tested, and attempts were made to reproduce the test results for each combination. These test results are presented in Appendix C.

In general, total flow increases with the number of open collectors, ranging from 3 cfs with one collector open to 18 cfs with all of them open as shown in Table 10 and Figure 29. The average flow per open collector is presented; however, since some of the collectors have different open area/slotted pipe lengths, the average flow per 1,000 ft of open area/slotted pipe is also calculated.

**Table 10: RFS Collector Testing Summary**

	1	2	3	4	5	6	9
# Open Collectors	1	4	2	3	3	1	1
Number of Test Combinations	1	4	2	3	3	1	1
Avg Total Flow (cfs)	3.0	5.1	8.2	10.0	12.3	14.9	17.5
Avg Flow/Collector (cfs)	3.0	2.6	2.7	2.5	2.5	2.5	1.9
Total Length of Open Area/Slotted Pipe (ft)	720	1,350	2,070	2,820	3,480	4,320	6,120
Avg Flow (cfs)/1,000 ft of Open Area/Slotted Pipe	4.2	3.8	4.0	3.6	3.5	3.4	2.9



**Figure 29: RFS Collector Flow Testing Results**

The notable test results are as follows:

1. The average flow per 1,000 feet of open area/slotted pipe decreases as more sections are open.
2. There is no indication that the type of lateral (PVC or Flo-tank) or orientation relative to surface flow has any significant impact on performance.

These results suggest that system performance is not sensitive to collector system construction or orientation to surface water flow direction. It does appear to be sensitive to spacing in that flow per unit of open area/slotted pipe is higher when alternate manifolds are open. This suggests that the number of collectors exceeded the sustainable recharge rate of the overlying sediments. As a result, optimizing the spacing of the collectors is something that should be carefully considered in the design of a full-scale system. Another aspect that should be evaluated is the capacity of the carrier pipeline as this could have a role in impacting system capacity at the higher flow rates.

#### **4.5 RFS Test Summary**

Based on data collected over 10 years from 2013 to 2023, the RFS is effective in reducing TSS concentrations by an average of 96 percent. RFS removal efficiency does not appear to be affected by higher TSS loads as demonstrated by the removal seen in the SAR Pilot RFS. The reduced TSS concentration approximately doubles the recharge capacity of Olive Basin. This increased recharge is consistent with the performance of other recharge basins receiving low-TSS imported or GWRS water.

The RFS improves overall water quality in a manner consistent with what occurs in SAT, despite the relatively short 2–3 feet distance between the channel surface and the RFS. There are no indications that biological or chemical clogging of the RFS is taking place. Bacteria removal was very effective and the CEC removal variable.

RFS efficiency is not sensitive to collector system construction or orientation to surface water flow direction; however, it does appear to be sensitive to spacing. Pipe diameter could also be a factor limiting the potential yield of the RFS (Geosystems Analysis, 2009). These are factors that should be considered during the design of a full-scale system.

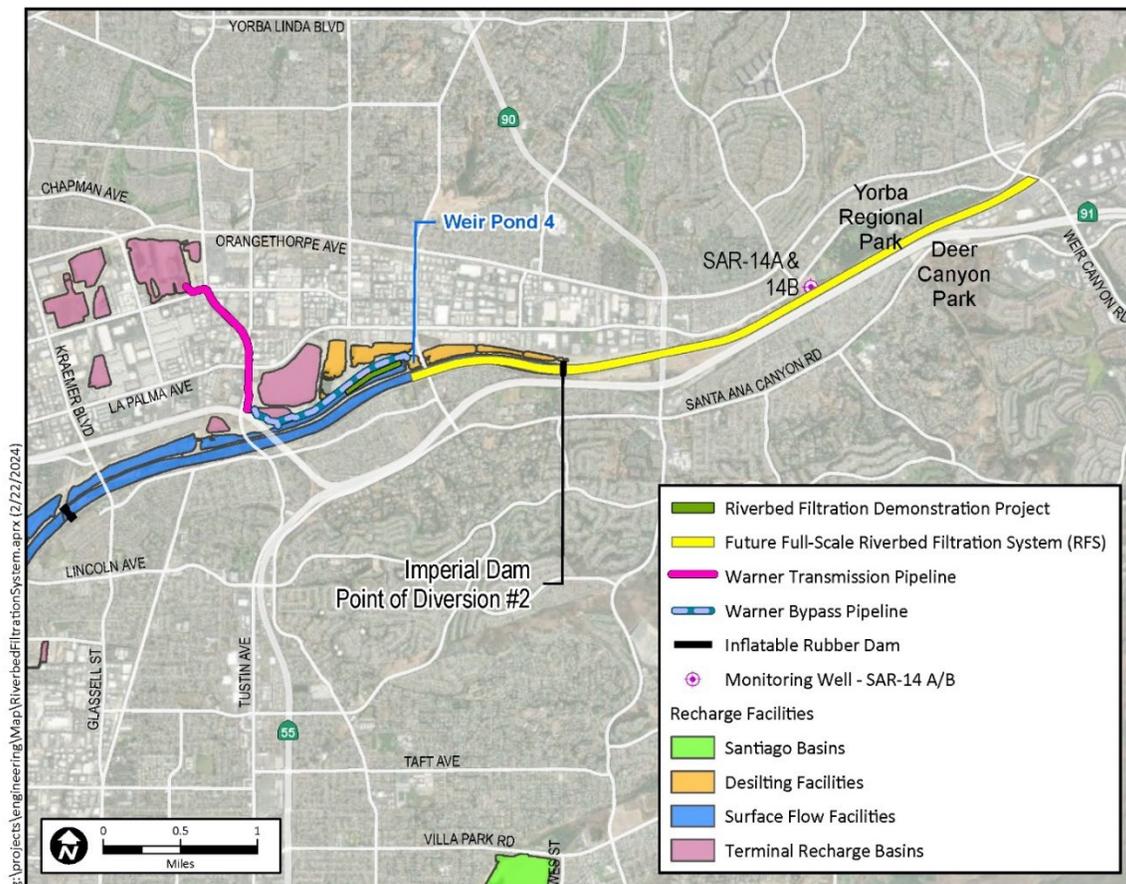
## 5.0 RFS Expansion Potential

Historically, diverting and capturing storm water from the Santa Ana River has been done on the surface using sand berms and inflatable rubber dams. The RFS presents a fundamental shift in capturing and diverting storm water below the surface. If you were to compare both systems side by side with the same flow in the Santa Ana River, more water would be diverted and recharged by the RFS over time due to reduced clogging and thus result in more water being captured over the long-term.

Another benefit of the RFS is that it can be installed in reaches of the Santa Ana River channel where there is little to no recharge due to shallow groundwater conditions. The RFS would take advantage of the permeable channel sediments by creating a system that would induce downward flow through these sediments into buried subsurface laterals. The shallow depth of the RFS reduces the potential of extracting water that has been previously recharged. In fact, testing of the Pilot RFS showed that 80 percent of the water captured was induced by the RFS.

An expanded RFS has the greatest potential to increase the recharge rates of the Terminal Recharge Basins because they are most prone to clogging. This means the RFS would need to be constructed so the outflow can be conveyed to the Warner System or to other infrastructure conveying flow to downstream Terminal Recharge Basins. Conceptually, the potential area where a full-scale RFS could be constructed is shown in Figure 30.

There is also the potential to deploy the RFS in the Off-River channel and SAR channel downstream of Wier Pond 4 to supply Five Coves Basins, Santiago Basins, and Santiago Creek. Although these facilities would benefit from receiving filtered water, they are less sensitive to clogging compared to the Terminal Recharge Basins. For this report, these facilities are not considered; however, they could be examined as part of a future phase.



**Figure 30: Potential Area of Full-Scale RFS**

The maximum flow rate that can be conveyed through the Weir Ponds to the Warner System is 400 cfs. The outflow from the Warner System to downstream basins is limited to 170 cfs through the Warner Transmission Pipeline. Historically, these conveyance capacities have been adequate because clogging of the recharge basins quickly reduces the need for flow once basin storage is exhausted. With the RFS, reduced clogging will mean that increased flows will be needed to satisfy the recharge capacities of the basins. As a result, the current conveyance capacities could become the limiting factor. Table 11 shows how the maximum storage and percolation rates of the receiving basins compare with current conveyance capacities. The total maximum capacity of basins supplied by the Warner Transmission Pipeline is 405 cfs, which is much greater than the 170 cfs capacity of the pipeline. Optimizing the capacity of the Warner Transmission Pipeline will be explored in a later section of this report.

**Table 11: Storage, Maximum Percolation Rate, and Current Conveyance Capacities: Terminal Recharge Basins\***

Basin	Max Storage (af)	Maximum Percolation Rate (cfs)	Current Conveyance Capacity (cfs)
<b>Weir Pond/Warner Basin System</b>			<b>400</b>
Warner Basin System*	4,320	70	
<b>Warner Transmission Pipeline</b>			<b>170</b>
Anaheim Lake	2,260	100	
Mini-Anaheim Lake	13	20	
Miller Basin	300	45	
Kraemer Basin	1,170	120	
La Jolla Basin	26	30	
Placentia Basin	350	10	
Raymond Basin	370	10	
<b>Total</b>	<b>7,109</b>	<b>405</b>	

\*Includes Huckleberry Basin, Conrock Basin, and Little Warner Basin

The SAR channel upstream of Weir Pond 4 to Weir Canyon Road is a highly engineered channel with a relatively uniform channel bottom ranging from 280 to 300 feet wide. A review of numerous soil borings and other geotechnical information collected by the USACE as part of its design of the Santa Ana River Mainstem Project (SARM) in this reach showed that the geologic conditions are favorable with generally permeable sediments in the upper 10 to 20 feet of the SAR channel.

Two types of RFS could be constructed in this reach. The first is a gravity system and the second is a pumped system. The advantage of a gravity system is it is relatively simple with no pumping-related infrastructure required. The disadvantage is that the flow generated by the system is constrained by the elevation difference from the collection point to the discharge location. In addition, larger pipe diameters are required to ensure that there are no constraints to the flows that can be generated. The surface area of the SAR channel from Imperial Highway to Weir Canyon Road, a stretch approximately 14,000 feet long (2.7 miles), is approximately 90 acres. For the Demonstration RFS, the maximum flow of 17.5 cfs was produced when all the collectors were open within the 10-acre footprint of the Demonstration RFS. Assuming a similar production rate of 1.8 cfs/acre in the upper SAR channel, an RFS covering the entire 90 acres could generate up to 157 cfs by gravity flow.

The portion of the SAR channel between Weir Canyon Road and the Imperial Rubber Dam has an elevation change of 314 ft msl to 265 ft msl (WGS84) over a distance of 17,350 ft, which yields a slope of 0.0028. Given this slope, Table 12 lists the potential flow rates that could be conveyed by gravity using different diameter HDPE pipes and rectangular concrete pipe. Note that the flows presented in Table 12 do not account for the percolation capacity of river channel sediments.

**Table 12: Estimated Gravity RFS Conveyance Dimensions and Maximum Flow Rates**

Material	Diameter (ft)	Flowrate (cfs)
HDPE	4	99
	5	180

	Width (ft)	Height (ft)	Flowrate (cfs)
Concrete	6	2	65
	4	3	71
	5	3	94
	6	3	118

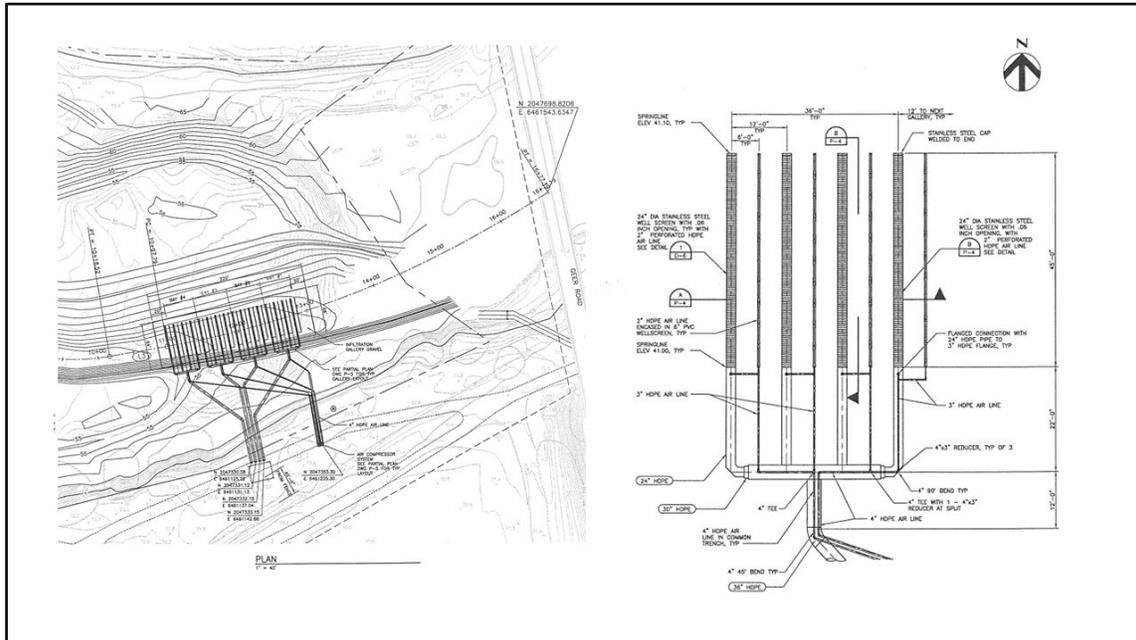
In addition to a gravity flow RFS, an RFS that is supplied by pumped water could also be considered. The Turlock Irrigation District (TID) constructed an infiltration gallery in the Tuolumne River downstream of La Grange Dam to recapture releases made to promote salmon habitat. The system was designed as follows:

1. 16 horizontal laterals in groups of four
2. The laterals are made up of 24-inch diameter wire-wrapped steel well screens
3. Each lateral has 45 feet of screen
4. Each group of four laterals is combined into a 30-inch header which then increases to a 36-inch collection line that connects to a wet well with a series of pumps.
5. The laterals were installed 5 ft below the river bottom
6. The laterals were encased in 4 feet of pea gravel (2 ft below and 2 ft above) with native material in the upper 3 feet
7. The footprint of the infiltration gallery covers 0.32 acres (220 ft x 64 ft).

Figure 31 shows some design details. Figure 32 is a photo taken during construction.

The system was designed to yield 100 cfs and during testing produced 108-110 cfs (Bill Penny, TID, personal communication July 24, 2023). Given a footprint of 0.32 acres and a design rate of 100 cfs, the unit yield is 309 cfs/acre. It is not expected that this yield could be achieved in the SAR channel given sediment conditions are different and the SAR has a higher sediment load. Nevertheless, the potential yield of a pumped RFS will be considerably higher than the 1.8 cfs/acre achieved using gravity flow.

Another advantage of the RFS is that it removes limitations associated with the inflatable rubber dams. Water is currently diverted from the SAR to the recharge system using two inflatable rubber dams. These dams are effective in diverting flows up to 1,000 cfs. At flow rates greater than 1,000 cfs, the dams must be deflated, which can limit the ability of the District to divert and capture stormwater. With the RFS, water could continue to be diverted from the SAR at flows greater than 1,000 cfs, when the rubber dams would ordinarily be deflated.



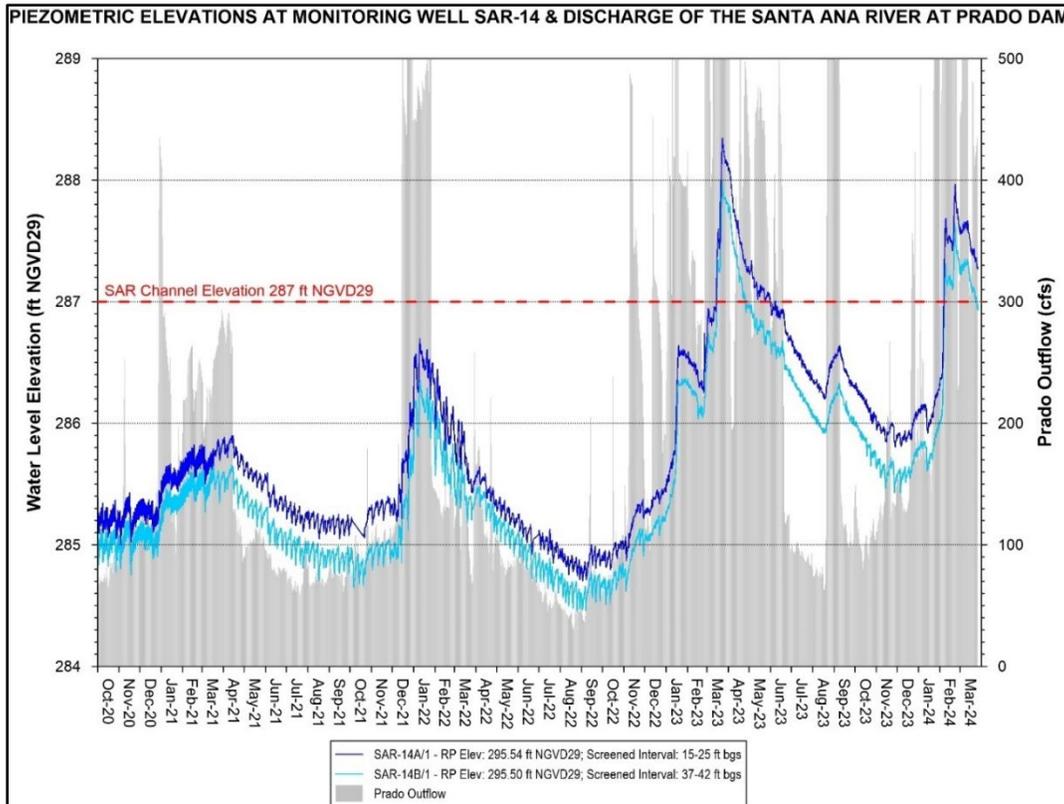
**Figure 31: Turlock Irrigation District Infiltration Gallery Design**



**Figure 32: Construction of Infiltration Gallery in Tuolumne River**

To obtain more information about hydrogeologic conditions in the SAR channel upstream of Imperial Highway, monitoring wells SAR-14 and SAR-14A were installed in Yorba Park adjacent to the SAR channel in 2019. The location SAR-14/14A is shown in Figure 30.

Figure 33 shows how groundwater levels change over time as well as the discharge rate from Prado Dam, which is located upstream. Figure 33 also shows the elevation of the SAR channel near the monitoring wells. These data suggest that water in the SAR channel is flowing away from the channel, except for when high flows cause water levels to rise higher than the SAR channel, which occurred in winter 2023 and 2024. Following these peaks, water groundwater levels rapidly declined, which is likely due to the draining of the groundwater back into the river. These data are consistent with a full alluvial aquifer and will be ideal for a large scale RFS.



**Figure 33: Groundwater Levels at SAR-14 and Flow in the SAR**

## 5.1 Potential Yield Estimates Using Recharge Facilities Model

The potential benefits of a future RFS were evaluated using OCWD's Recharge Facilities Model (RFM) (OCWD, 2009). OCWD worked with Jacobs Engineering, Inc. to update the RFM (Jacobs, 2023), extending the period of historical inflow and then running various scenarios simulating the benefits of a future RFS. The technical memorandum describing this work is presented in Appendix D. The baseline period for the modeling is the daily historical inflow to the recharge system from FY02-03 to FY19-20. It must be noted that using historical inflows is a conservative approach because the future availability of stormwater will increase as OCWD increases the volume of stormwater that can be temporarily impounded at Prado Dam using Forecast Informed Reservoir Operations (FIRO).

Six RFS alternatives were developed and two are presented here as follows:

Alternative 3a:

- Maximum RFS flow to Terminal Basin System: 450 cfs
- Flow in SAR greater than 450 cfs is conveyed to the Off-River System
- Maximum flow through Warner Transmission Pipeline: 170 cfs
- No clogging caused by recharge water

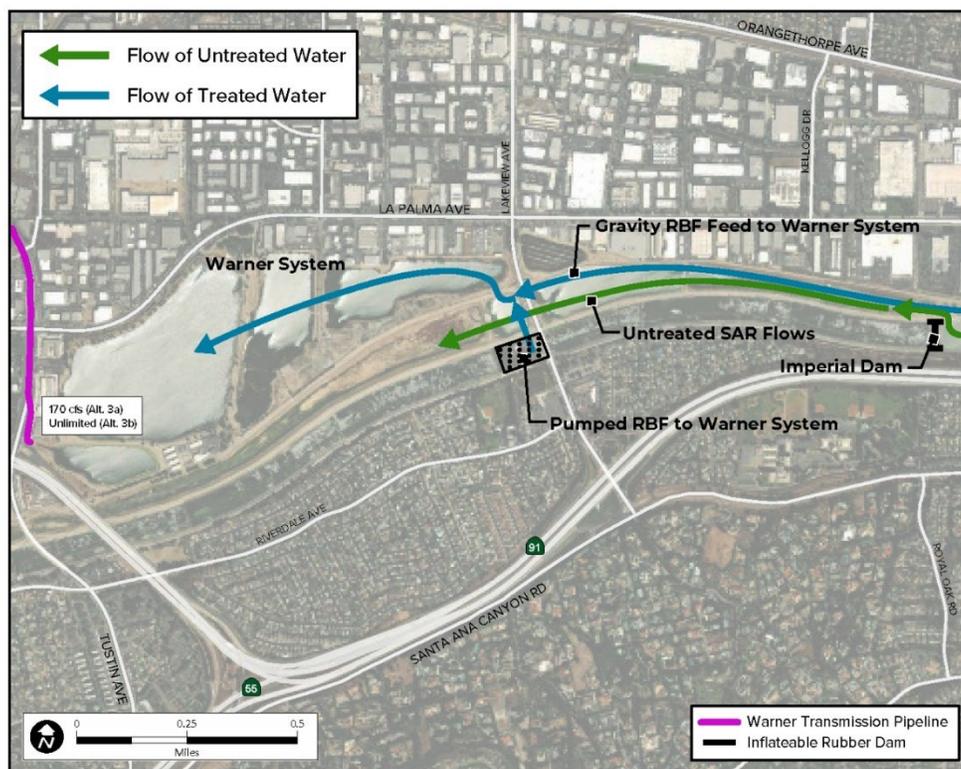
Alternative 3b:

- Same conditions as above, except:
- No max flow limit in Warner Transmission Pipeline

The purpose of Alternative 3a is to examine the potential benefit of maximizing the diversion of RFS water directly to the Warner System, which has a conveyance capacity of 400 cfs. Any additional untreated surface water (green line) available for diversion would be done with the existing facilities but would remain segregated from RFS flows (blue line) as shown in Figure 34. The details of how these flows would be conveyed or separated will be explored during a future phase of work. The maximum flow from the Warner System to the downstream facilities would be limited to the current maximum of 170 cfs. To examine the maximum potential of using RFS water, no clogging is assumed.

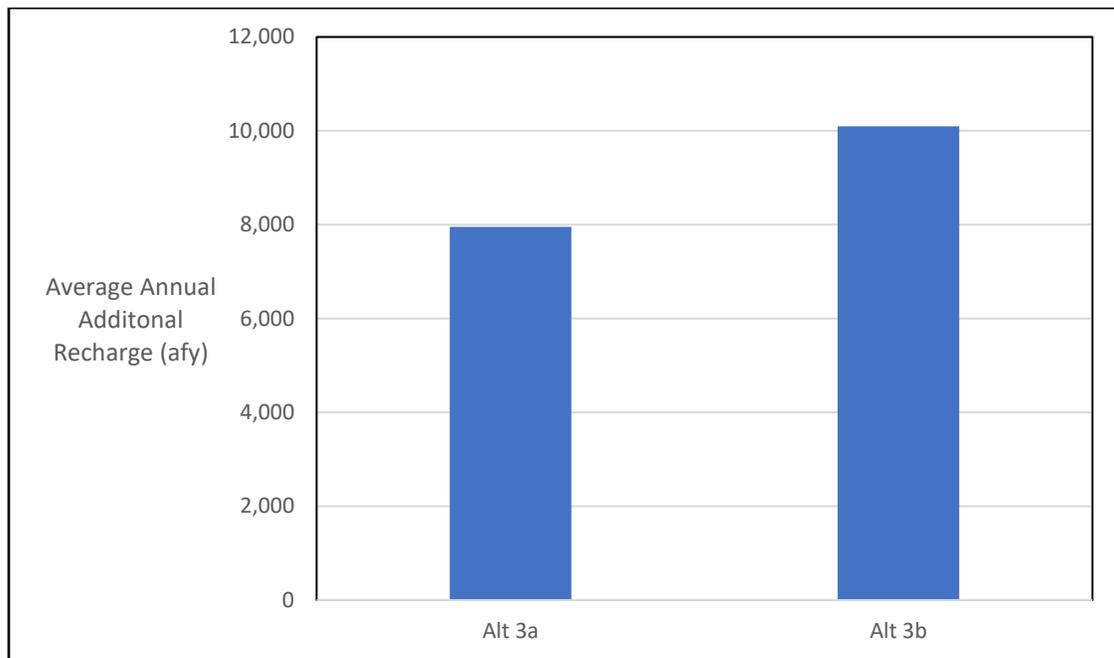
Alternative 3b is the same as Alternative 3a except the capacity of the Warner Transmission Pipeline is undefined in that it will supply whatever flows are needed in the downstream basins. This was done to see what the peak demand of the downstream basins is and as a starting point to optimize the capacity of this pipeline in a future phase of work. Figure 34 shows the conceptual flow of RFS (treated) and untreated SAR water through the recharge system and to the Terminal Recharge Basins. Figure 34 also shows conceptually how a gravity fed RFS located upstream of Imperial Rubber Dam and a smaller, pumped RFS could be constructed. Further study is required to find out which type of RFS or combination is most cost effective.

Figure 35 shows the increased annual recharge achieved using RFS water for Alternatives 3a and 3b. Alternative 3a shows that the additional recharge using RFS could be as high as 7,900 afy. When flow constraints are removed on the Warner Transmission Pipeline capacity in Alternative 3b, the annual additional recharge is approximately 10,000 afy. This indicates that with the RFS, removing the flow constraint of the Warner Transmission Pipeline could produce an additional 1,100 afy of recharge. Additional work needs to be done to evaluate the benefits of the additional recharge versus the cost of expanding the pipeline's capacity. This could also include a phased approach to constructing the RFS to assess the production capacity of each phase before moving to the next phase until the appropriate capacity is developed.



**Figure 34: Potential Conveyance of RFS Water to Terminal Basin System**

One of the benefits of using filtered water is a reduction in the number of times a basin needs to be cleaned, which reduces Operations and Maintenance (O&M) costs. Based on the modeling described above, there is a 40% reduction in the number of cleaning events needed for Alternatives 3a and 3b (see Table 2 in Jacobs, 2023, Appendix D).



**Figure 35: Average Annual Additional Recharge, Alternatives 3a and 3b**

## 5.2 Next Steps

The work conducted thus far shows that the RFS is effective at removing TSS from SAR water and has the potential to greatly increase OCWD's recharge capacity and potentially reduce future O&M costs. More work needs to be done to refine the potential configuration of a future RFS and develop more detailed cost and benefit estimates. Below is a list of potential next steps and additional work that may be required to better define and evaluate a potential full-scale RFS.

### Conduct hydraulic evaluation

- Define how much flow can be generated from a gravity fed system
- Define how much flow can be generated from a pumped system
- Define capacity of the Terminal Basin System using existing Warner Transmission Pipeline
- Evaluate potential cost and benefits of increasing the Warner Transmission Pipeline capacity
- Conduct hydrogeologic evaluation
  - What is the potential for mounding in receiving basins using RFS water
  - If mounding does occur, how much would it constrain recharge?
  - Develop a model of a shallow SAR channel to develop estimates of the potential yield of gravity and pumped RFS systems and design parameters

- Conduct engineering evaluation
  - Constructability analysis of gravity RFS in the SAR channel
  - Constructability analysis of pumped RFS in the SAR channel
- Constructability analysis of increasing the capacity of Warner Transmission Pipeline
- Permitting feasibility with USACE, OC Public Works and others.
- Conduct additional recharge modeling
  - Refine recharge estimates by including some level of basin clogging
  - Refine recharge estimates using future Prado Dam operations with a higher level of stormwater capture with FIRO
  - Develop cost estimates of O&M savings due to fewer basin cleanings
- Develop Preliminary Design
  - Develop cost estimate
  - Develop benefits based on modeling done in previous tasks

---

## 6.0 References

- Ausland, G., Stevik, T.K., Hanssen, J.F., Kohler, J.C. and Jenssen, P.D., 2002. Intermittent filtration of wastewater – removal of fecal coliforms and fecal streptococci. *Water Research*, 36: 3507-3516.
- Baveye, P., Vandevivere, P. Hoyle, B.L., DeLeo, P.C., and de Lozada, D.S., 1998. Environmental impact and mechanisms of the biological clogging of saturated soils and aquifer materials. *Critical Reviews in Environmental Science and Technology*. 28:123-191.
- Behnke, J.J., 1969. Clogging in surface spreading operations for artificial groundwater recharge. *Water Resources Research*. 5(4): 870-876.
- Bouwer, H. and Rice, R.C., 1989. Effect of water depth in groundwater recharge basins on infiltration. *Journal of Irrigation and Drainage Engineering*, ASCE, 115: 556-567.
- Bouwer, H., Ludke, J., and Rice, R.C., 2001. Sealing pond bottoms with muddy water. *Ecological Engineering*. 18:233-238.
- Bouwer, H. and Rice, R.C., 2001. Capturing flood waters for artificial recharge of groundwater. *Proceedings of 10th Biennial Symp. Artificial Recharge of Groundwater*, Tucson, AZ, AZ Hydrological Society, pp 99-106.
- Bouwer, H., 2002. Artificial recharge of groundwater: hydrogeology and engineering. *Hydrogeology Journal*. 10:121-142.
- GeoSystems Analysis, 2009. Orange County Water District (OCWD) Recharge Water Sediment Removal Feasibility Study-Under-Channel Lateral Drain System Pilot Study Results. Memo prepared for Scott Toland, HDR Engineering, June 5, 2009.
- Gerba, C.P. and Goyal, S.M., 1985. Pathogen removal from wastewater during groundwater recharge. In: *Groundwater Pollution Microbiology*. Asano, T. Butterworth Publishers, Boston, 283-317.
- Bouwer, H. 1991. Ground water recharge with sewage effluent. *Water Science and Technology* 23: 2099-2108.
- Guessab, M., Bize, J., Schwartzbrod, J., Mauri, A., Morlot, M., Nivault, N. and Schwartzbrod, L., 1993. Wastewater treatment by infiltration-percolation on sand: Results in Ben-Sergao, Morocco. *Water Science and Technology*, 27: 91-95.
- Hiscock, K. and T. Grischek, 2002. Attenuation of Groundwater Pollution by Riverbank Filtration, *Journal of Hydrology*, Vol. 266, p. 139-144.

- 
- Jacobs Engineering, Inc., 2023. OCWD Recharge Facilities 2023 Model Update Technical Memo (Final). Memo prepared for OCWD by Marcelo Reginato. August 29, 2023.
- Keller, J., M. Milczarek, G. Woodside, A. Hutchinson, 2010. The Orange County Water District Riverbed Filtration Pilot Project: Modeling of Lateral Drain Performance to Guide Project Design. Seventh International Symposium on Managed Aquifer Recharge, Abu Dhabi, UAE, October 9-12, 2010.
- Kuehn, W. and U. Mueller, 2000. Riverbank Filtration: An Overview, Journal AWWA, Vol. 92, No. 12, p. 60-69.
- Lacher, L.J., 1996. Recharge Characteristics of an Effluent Dominated Stream near Tucson, Arizona. Doctoral Dissertation. University of Arizona, Tucson, Arizona.
- Laws, B.V, Dickenson, E.R.V, Johnson, T.A, Snyder, S.A, and Drewes, J.E., 2011. Attenuation of contaminants of emerging concern during surface-spreading aquifer recharge. Science of the Total Environment 409: 1087-1094
- Mia, J., M. Ibekwe, M. Leddy, C. Yang, D Crowley, 2012. Assimilable organic carbon (AOC) in soil water extracts using *Vibrio harveyi* BB721 and its implication for microbial biomass. PLoS one. Vol 7e28519.
- Milczarek, M., J. Keller, G. Woodside, A. Hutchinson, R. Rice, A. Canfield, 2010. The Orange County Water District Riverbed Filtration Pilot Project: Water Quality and Recharge Improvements Using Induced Riverbed Filtration. Seventh International Symposium on Managed Aquifer Recharge, Abu Dhabi, UAE, October 9-12, 2010.
- Murray, M.I., 2020. Analysis of Aquifer and Operational Conditions for Successful Soil Aquifer Treatment of Treated Wastewater via Synthesis of Published full-scale and Laboratory-scale Studies. Thesis, California Polytechnic State University, San Luis Obispo, Master of Science in Civil and Environmental Engineering.
- National Research Council (NRC), Committee on Ground Water Recharge, 1994. Ground Water Recharge Using Waters of Impaired Quality. National Academy Press, Washington, D.C.
- OCWD, 2009. Orange County Water District Recharge Facilities Model - Development and Calibration of the Orange County Water District Recharge Facilities Model (OCWD RFM). Technical Memorandum prepared for OCWD by CH2M HILL, October 2009.
- Orange County Water District, 2010. Recharge Water Sediment Removal Feasibility Study, Final Report. Prepared for OCWD by HDR, Inc., February 2010.

---

Orange County Water District, 2015. Groundwater Management Plan 2015 Update. OCWD, June 17, 2015. [https://www.ocwd.com/wp-content/uploads/groundwatermanagementplan2015update\\_20150624.pdf](https://www.ocwd.com/wp-content/uploads/groundwatermanagementplan2015update_20150624.pdf)

Orange County Water District, 2017a. Basin 8-1 Alternative. Prepared by OCWD, City of La Habra, and Irvine Ranch Water District. Submitted to the California Department of Water Resources on January 1, 2017, to comply with the Sustainable Groundwater Management Act.

Orange County Water District, 2017b. Forebay Solids Monitoring Project, Final Report. Prepared by Don Phipps, and Grisel Rodriguez. August 2017.

Phipps, Donald W., Stephen Lyon, and Adam S. Hutchinson, 2007. Development of a percolation decay model to guide future optimization of surface water recharge basins. Management of Aquifer Recharge for Sustainability. Proceedings of the 6<sup>th</sup> International Symposium on Managed Aquifer Recharge, ISMAR-6, Phoenix, Arizona, October 28<sup>th</sup> to November 2, 2007. Edited by Peter Fox, Director - National Center for Sustainable Water Supply, Professor of Civil and Environmental Engineering, Arizona State University, Tempe, Arizona. Published by Acacia Publishing, Inc., Phoenix, Arizona. [www.acaciapublishing.com](http://www.acaciapublishing.com)

Quanrud, D.M., 1998. Efficiency and sustainability of soil aquifer treatment leading to wastewater reclamation and use. In: Water Reuse Conference, AWWA/WEF. Lake Buena Vista, Florida, 579-591.

Ray, C., T. Grischek, J. Schubert, J. Wang, T. Speth, 2002. A Perspective of Riverbank filtration. Journal AWWA, Vol. 94, No. 4, p. 149-160.

Rehg, K.J., Packman, A.I. and Ren, J., 2005. Effects of suspended sediment characteristics and bed sediment transport on streambed clogging. Hydrological Processes. 19:413–427.

Sallway, J., Jurado, A., Barquero, F., and Fahl, J., 2020. Enhanced removal of contaminants of emerging concern through hydraulic adjustments in soil. Water. 12: 1-19.

Schippers, J.C. and J. Verdouw, 1980. The modified fouling index, a method of determining the fouling characteristics of water. Desalination 32, pp. 137-148.

Schubert, J, 2004. Significance of hydrologic aspects on RBF performance. NATO Advanced Research Workshop, Samorin, Slovakia. September 7–10, 2004. <http://www.soulstatic.com/NATORBF/papers/schubert/hydrology.pdf>

Speth, TF, T. Merkel, and A.M. Gusses, 2002. Riverbank Filtration as a Pretreatment for Nanofiltration Membranes, Riverbank Filtration: Improving Source-Water Quality, C. Ray, G. Melin, and R.B. Linsky, editors, Dordrecht, The Netherlands: Kluwer Academic Publishers, pp. 261-266.

USBR, 2006. The Role of Riverbank Filtration in Reducing the Costs of Impaired Water Desalination. Desalination and Water Purification Research and Development Program Report No. 122. Prepared by Stephen Grooters, Carollo Engineers. April 2006.  
<https://www.usbr.gov/research/dwpr/reportpdfs/report122.pdf>.

Weiss, W., E. Bouwer, W, Ball, C. O'Melia, M. Lechevallier, H. Arora, and T. Speth, 2003. Riverbank Filtration – Fate of DBP Precursors and Selected Microorganisms. Journal AWWA, Vol. 95, No. 10, p. 68-81.

Yu, J.T., Bouwer, E.J., Coelhan, M., 2006. Occurrence and biodegradability studies of selected pharmaceuticals and personal care products in sewage effluent. Agricultural Water Management 86: 72-80.

## **Appendix A**

### Summary of Cloth Filtration Testing

## **Cloth Filtration Pilot Testing**

Cloth filter treatment units employ a series of large circular disks covered with a specially designed fabric. Water passes through the fabric, leaving sediment behind. When the fabric becomes clogged, the flow stops, and a backwash cycle begins where specially designed suction pads clean off the accumulated sediment and send it to waste. Once cleaned, the flow reverses, and treatment resumes.

For cloth filtration pilot testing, an AquaDisk cloth filter unit manufactured by Aqua-Aerobics Systems, Inc. was installed at Riverview Basin.

The cloth filter unit was tested over four stormwater “seasons” from 2012-13 to 2015-16. Key test results are as follows:

1. Sediment removal efficiency, as measured by the reduction in Total Suspended Solids (TSS) concentration, ranged from 16 to 71 percent.
2. TSS removal is most effective when total TSS concentrations fall within a relatively narrow range (10-30 mg/L).
3. A minimal increase in recharge in the Riverview Basin was observed.
4. Other than reduced TSS concentrations, the cloth filter produced minimal changes in water quality, which was expected.
5. The current cloth filter unit is undersized (5 cfs) relative to a maximum capacity of Riverview Basin (12 cfs).

In addition, modeling using the Recharge Facilities Model (RFM) indicated that future potential increases in recharge at Riverview Basin using the cloth filter were low and not cost-effective when considering the capital and operational costs associated with the cloth filter unit.

In summary, cloth filter testing showed that this method of treatment can only handle water with a relatively limited range of TSS concentrations (10-30 mg/L). This greatly restricts where it could be deployed within the District’s recharge system. For example, TSS concentrations in the SAR where it is diverted at Imperial Highway during the storm season average nearly 90 mg/L and can be as high as 4,200 mg/L (2008-2016), making it impractical to use a cloth filter at this location. This limited treatment range and concomitant minor improvement in recharge rates where it could potentially be deployed means that this technology is not considered cost-effective at this time.

## **Appendix B**

Water Quality Data

TABLE: Weir Pond 4 Water Quality Summary Data (2014-2019)

PARAMETER NAME	MEDIAN	MEAN	N=	MINIMUM	MAXIMUM	25th PERCENTILE	75th PERCENTILE	UNITS	MIN RDL	MAX RDL	# of NDs	# of DETECTS
<b>BIOLOGICAL</b>												
E. Coli (Membrane Filtration - CFU/100ml)	121.00	233.58	12.00	19.00	1340.00	50.75	194.75	CFU/100	1.00	1.00	0.00	12
E. Coli (by IDEXX (Colilert 18))	81.00	81.00	2.00	1.00	161.00	41.00	121.00	MPN	1.00	10.00	1.00	1
Enterococcus by IDEXX (Enterolert)	501.00	501.00	2.00	41.00	961.00	271.00	731.00	MPN	1.00	1.00	0.00	2
Enterococcus(Membrane Filtration-CFU/100ml)	140.00	134.14	7.00	4.00	390.00	17.50	185.00	CFU/100	1.00	1.00	0.00	7
Fecal Coliform (Membrane Filtration-CFU/100ml)	177.00	204.25	4.00	33.00	430.00	56.25	325.00	CFU/100	1.00	1.00	0.00	4
Fecal Coliform (Mult. Tube Fermentation)	38.00	38.00	2.00	27.00	49.00	32.50	43.50	MPN	1.80	1.80	0.00	2
Total Coliform (Membrane Filtration-CFU/100ml)	1900.00	4490.77	13.00	220.00	24000.00	900.00	3900.00	CFU/100	1.00	1.00	0.00	13
Total Coliform (Mult. Tube Fermentation)	615.00	615.00	2.00	310.00	920.00	462.50	767.50	MPN	1.80	1.80	0.00	2
Total Coliform by IDEXX (Colilert 18)	7359.00	7359.00	2.00	1722.00	12996.00	4540.50	10177.50	MPN	1.00	1.00	0.00	2
<b>FIELD MEASUREMENTS</b>												
Field Dissolved Oxygen	9.53	9.74	11.00	8.70	10.80	9.23	10.50	mg/L	0.00	0.01	0.00	11
Field Electrical Conductivity	813.00	791.18	11.00	456.00	1160.00	625.50	905.00	uS/cm	0.00	1.00	0.00	11
Field Oxidation-Reduction Potential	167.00	162.73	11.00	52.00	297.00	104.00	219.50	mV	-1000.00	-1000.00	0.00	11
Field Temperature	15.80	15.73	11.00	11.80	19.70	13.50	17.85	C	0.00	1.00	0.00	11
Field pH	8.00	7.92	11.00	7.50	8.30	7.75	8.05	UNITS	0.00	1.00	0.00	11
<b>INORGANIC</b>												
Alkalinity-Phenolphthalein	0.10	0.10	11.00	0.10	0.10	0.10	0.10	mg/L	1.00	1.00	11.00	0
Aluminum (dissolved)	13.10	20.12	11.00	5.90	51.00	8.30	31.50	ug/L	1.00	1.00	0.00	11
Ammonia Nitrogen	0.01	0.01	10.00	0.01	0.01	0.01	0.01	mg/L	0.10	0.10	10.00	0
Ammonia Nitrogen NH3-N	0.10	0.10	1.00	0.10	0.10	0.10	0.10	mg/L	0.10	0.10	0.00	1
Antimony (dissolved)	0.10	0.29	11.00	0.05	1.10	0.10	0.35	ug/L	0.50	1.00	8.00	3
Arsenic (dissolved)	1.90	1.85	11.00	0.10	3.20	1.15	2.80	ug/L	1.00	1.00	2.00	9
Barium (dissolved)	36.30	36.57	11.00	24.80	46.60	30.05	43.20	ug/L	1.00	1.00	0.00	11
Beryllium (dissolved)	0.10	0.09	11.00	0.05	0.10	0.08	0.10	ug/L	0.50	1.00	11.00	0
Bicarbonate (as CaCO3)	161.00	165.06	11.00	98.70	235.00	134.00	189.00	mg/L	1.00	1.00	0.00	11
Bicarbonate (as HCO3)	196.30	201.22	11.00	120.30	286.50	163.35	230.35	mg/L	1.20	1.20	0.00	11
Boron (dissolved)	0.20	0.19	11.00	0.10	0.30	0.15	0.20	mg/L	1.20	1.20	0.00	11
Bromide	0.13	0.12	11.00	0.01	0.29	0.06	0.17	mg/L	1.20	1.20	3.00	8
Cadmium (dissolved)	0.10	0.10	11.00	0.10	0.10	0.10	0.10	ug/L	1.00	1.00	11.00	0
Calcium (dissolved)	57.80	62.54	11.00	38.10	90.00	52.15	73.00	mg/L	1.20	1.20	0.00	11
Carbonate (as CaCO3)	0.10	0.10	11.00	0.10	0.10	0.10	0.10	mg/L	1.20	1.20	11.00	0
Cation-Anion meq balance	-0.82	-0.93	8.00	-4.32	2.79	-2.67	0.08	RATIO			0.00	8
Chloride	95.80	90.69	11.00	45.50	136.00	66.30	110.00	mg/L	0.50	2.00	0.00	11
Chromium (dissolved)	0.10	0.19	11.00	0.10	1.10	0.10	0.10	ug/L	1.00	1.00	10.00	1
Cobalt (dissolved)	0.10	0.10	11.00	0.10	0.10	0.10	0.10	ug/L	1.00	1.00	11.00	0
Copper (dissolved)	2.30	2.41	11.00	1.60	3.30	1.90	3.05	ug/L	1.00	1.00	0.00	11
Electrical Conductivity	796.00	790.45	11.00	462.00	1170.00	632.50	912.50	uS/cm	1.00	1.00	0.00	11
Fluoride	0.32	0.32	11.00	0.25	0.41	0.28	0.35	mg/L	0.10	0.10	0.00	11
Gadolinium (dissolved)	56.00	59.72	11.00	25.00	110.00	50.15	62.40	ng/L	10.00	10.00	0.00	11
Hydroxide (as CaCO3)	0.10	0.10	11.00	0.10	0.10	0.10	0.10	mg/L	1.00	1.00	11.00	0
Iron (dissolved)	27.50	38.21	11.00	12.80	92.50	20.70	52.55	ug/L	1.00	5.00	0.00	11
Lead (dissolved)	0.10	0.10	11.00	0.10	0.10	0.10	0.10	ug/L	1.00	1.00	11.00	0
Magnesium (dissolved)	14.10	15.12	11.00	8.50	23.00	12.30	18.10	mg/L	0.50	0.50	0.00	11
Manganese (dissolved)	30.90	34.35	11.00	0.10	93.50	11.00	53.30	ug/L	1.00	1.00	1.00	10
Mercury (dissolved)	0.10	0.07	11.00	0.01	0.10	0.01	0.10	ug/L	0.10	1.00	11.00	0
Nickel (dissolved)	2.20	2.21	11.00	0.10	4.80	1.70	2.60	ug/L	1.00	1.00	1.00	10
Nitrate	8.20	8.54	11.00	1.10	19.20	4.50	12.25	mg/L	0.40	0.40	0.00	11
Nitrate + Nitrite Nitrogen	1.92	1.98	11.00	0.27	4.39	1.07	2.84	mg/L	0.10	0.10	0.00	11
Nitrate Nitrogen	1.85	1.93	11.00	0.24	4.34	1.02	2.78	mg/L	0.10	0.10	0.00	11
Nitrite	0.13	0.15	11.00	0.10	0.23	0.11	0.21	mg/L	0.00	0.01	0.00	11
Nitrite Nitrogen	0.04	0.05	11.00	0.03	0.08	0.04	0.07	mg/L	0.00	0.00	0.00	11
Organic Nitrogen	0.80	0.73	11.00	0.30	1.30	0.50	0.85	mg/L	0.10	0.10	0.00	11
Phosphate Phosphorus (orthophosphate)	0.59	0.70	11.00	0.41	1.32	0.54	0.77	mg/L	0.01	0.01	0.00	11
Potassium (dissolved)	10.10	10.49	11.00	7.90	14.40	8.75	11.80	mg/L	0.50	0.50	0.00	11
Selenium (dissolved)	0.10	0.10	11.00	0.10	0.10	0.10	0.10	ug/L	1.00	1.00	11.00	0
Silica	13.00	13.50	11.00	5.40	21.70	11.00	16.35	mg/L	1.00	1.00	0.00	11
Silver (dissolved)	0.10	0.10	11.00	0.10	0.10	0.10	0.10	ug/L	1.00	1.00	11.00	0
Sodium (dissolved)	77.80	72.73	11.00	37.50	108.00	53.75	87.30	mg/L	0.50	0.50	0.00	11
Sulfate	87.10	85.94	11.00	47.10	128.00	74.35	102.00	mg/L	0.50	2.00	0.00	11
Suspended Solids	22.00	29.17	7.00	9.20	66.00	16.50	37.00	mg/L	1.00	2.50	0.00	7
Temperature (Laboratory)	21.80	21.70	3.00	21.00	22.30	21.40	22.05	C	1.00	1.00	0.00	3
Thallium (dissolved)	0.10	0.09	11.00	0.05	0.10	0.08	0.10	ug/L	0.50	1.00	11.00	0
Title 22 Total Anions	8.00	7.80	11.00	4.29	11.43	6.27	9.07	meq/L			0.00	11
Total Alkalinity (as CaCO3)	161.00	165.06	11.00	98.70	235.00	134.00	189.00	mg/L	1.00	5.00	0.00	11
Total Anions	7.47	7.66	8.00	4.31	11.47	5.80	9.25	meq/L	0.00	0.00	0.00	8

TABLE: Weir Pond 4 Water Quality Summary Data (2014-2019)

PARAMETER NAME	MEDIAN	MEAN	N=	MINIMUM	MAXIMUM	25th PERCENTILE	75th PERCENTILE	UNITS	MIN RDL	MAX RDL	# of NDs	# of DETECTS
Total Cations	7.22	7.59	8.00	4.43	11.40	5.74	9.24	meq/L	0.00	0.00	0.00	8
Total Dissolved Solids	514.00	476.73	11.00	282.00	674.00	394.00	528.00	mg/L	1.00	2.50	0.00	11
Total Hardness (as CaCO3) (dissolved)	202.00	218.45	11.00	130.00	320.00	181.00	257.00	mg/L	1.00	1.00	0.00	11
Total Kjeldahl Nitrogen	0.80	0.82	11.00	0.40	1.40	0.60	0.95	mg/L	0.20	0.20	0.00	11
Total Nitrogen	2.80	2.80	11.00	1.12	5.50	1.73	3.73	mg/L	0.20	0.20	0.00	11
Total Organic Carbon (Unfiltered)	6.47	7.40	11.00	5.49	10.90	6.21	8.47	mg/L	0.05	0.05	0.00	11
Turbidity	34.00	31.05	11.00	8.30	85.00	13.00	37.00	NTU	0.10	0.10	0.00	11
UV Absorbance/TOC (unfiltered) ratio	0.03	0.03	11.00	0.02	0.05	0.03	0.04	L/mg-cm	0.00	0.00	0.00	11
Ultraviolet (absorbance)	0.24	0.24	11.00	0.14	0.38	0.17	0.29	1/cm	0.01	0.01	0.00	11
Vanadium (dissolved)	3.80	3.95	11.00	3.10	5.10	3.60	4.15	ug/L	1.00	1.00	0.00	11
Zinc (dissolved)	6.60	11.80	11.00	3.30	60.60	5.65	8.20	ug/L	1.00	1.00	0.00	11
pH	8.00	8.05	11.00	7.80	8.30	8.00	8.20	UNITS	1.00	1.00	0.00	11
<b>ORGANIC</b>												
17a-Estradiol	0.10	0.10	1.00	0.10	0.10	0.10	0.10	ng/L	1.00	1.00	1.00	0
17a-Ethinylestradiol	1.00	1.00	1.00	1.00	1.00	1.00	1.00	ng/L	10.00	10.00	1.00	0
17b-Estradiol	0.20	0.20	1.00	0.20	0.20	0.20	0.20	ng/L	2.00	2.00	1.00	0
4-Androstene-3,17-dione	0.20	0.20	2.00	0.20	0.20	0.20	0.20	ng/L	2.00	2.00	2.00	0
4-n-Octylphenol	0.02	0.02	2.00	0.02	0.02	0.02	0.02	ug/L	0.20	0.20	2.00	0
4-tert-Octylphenol	0.02	0.02	2.00	0.02	0.02	0.02	0.02	ug/L	0.20	0.20	2.00	0
Aspartame	10.00	10.00	8.00	10.00	10.00	10.00	10.00	ng/L	100.00	100.00	8.00	0
Atenolol	11.80	14.43	8.00	0.50	33.40	6.88	21.85	ng/L	5.00	10.00	1.00	7
Bisphenol A	0.02	0.02	2.00	0.02	0.02	0.02	0.02	ug/L	0.20	0.20	2.00	0
Diclofenac	0.50	0.50	8.00	0.50	0.50	0.50	0.50	ng/L	5.00	5.00	8.00	0
Diethylstilbestrol	0.20	0.20	1.00	0.20	0.20	0.20	0.20	ng/L	2.00	2.00	1.00	0
Dilantin	37.85	37.43	8.00	14.90	60.10	29.75	43.43	ng/L	10.00	10.00	0.00	8
Dissolved Organic Carbon	6.47	6.75	11.00	4.31	9.85	5.78	7.31	mg/L	0.05	0.05	0.00	11
Epitestosterone (cis-Testosterone)	0.55	0.55	2.00	0.10	1.00	0.33	0.78	ng/L	1.00	10.00	2.00	0
Equilin	0.50	0.50	1.00	0.50	0.50	0.50	0.50	ng/L	5.00	5.00	1.00	0
Estriol	0.20	0.20	1.00	0.20	0.20	0.20	0.20	ng/L	2.00	2.00	1.00	0
Estrone	0.10	0.10	1.00	0.10	0.10	0.10	0.10	ng/L	1.00	1.00	1.00	0
Fluoxetine	0.50	0.50	8.00	0.50	0.50	0.50	0.50	ng/L	5.00	5.00	8.00	0
Iohexol	1645.00	1981.25	8.00	1100.00	3680.00	1165.00	2565.00	ng/L	20.00	200.00	0.00	8
Iopromide	116.00	114.49	8.00	77.60	146.00	87.78	142.25	ng/L	10.00	10.00	0.00	8
Linuron	0.00	0.00	8.00	0.00	0.00	0.00	0.00	ug/L	0.01	0.01	8.00	0
Meprobamate	63.55	84.29	8.00	22.90	200.00	47.53	102.50	ng/L	5.00	10.00	0.00	8
Naproxen	6.25	10.80	8.00	0.50	41.70	0.50	15.08	ng/L	5.00	10.00	4.00	4
Neotame	1.00	1.00	8.00	1.00	1.00	1.00	1.00	ng/L	10.00	10.00	8.00	0
Nonylphenol	0.02	0.02	2.00	0.02	0.02	0.02	0.02	ug/L	0.20	0.20	2.00	0
PhenylPhenol	0.02	0.02	2.00	0.02	0.02	0.02	0.02	ug/L	0.20	0.20	2.00	0
Progesterone	0.55	0.55	2.00	0.10	1.00	0.33	0.78	ng/L	1.00	10.00	2.00	0
Sucralose	20650.00	19896.25	8.00	8470.00	30800.00	13025.00	26525.00	ng/L	100.00	1000.00	0.00	8
Testosterone (trans-Testosterone)	0.55	0.55	2.00	0.10	1.00	0.33	0.78	ng/L	1.00	10.00	2.00	0
Tetrabromobisphenol A	0.02	0.02	2.00	0.02	0.02	0.02	0.02	ug/L	0.20	0.20	2.00	0
Total Organic Halogen	72.50	73.83	6.00	44.00	110.00	53.00	91.25	ug/L	20.00	40.00	0.00	6
Trimethoprim	0.50	0.56	8.00	0.50	1.00	0.50	0.50	ng/L	5.00	10.00	8.00	0
Tris-2-chloroethyl phosphate	105.00	105.48	8.00	52.80	190.00	84.60	112.50	ng/L	5.00	10.00	0.00	8
para-Chlorobenzene sulfonic acid	20.00	20.00	8.00	20.00	20.00	20.00	20.00	ng/L	200.00	200.00	8.00	0
<b>SEMI-ORGANIC</b>												
Acetaminophen	5.00	21.04	8.00	0.50	65.40	3.88	38.83	ng/L	5.00	50.00	5.00	3
Atrazine	0.00	0.00	8.00	0.00	0.01	0.00	0.00	ug/L	0.00	0.00	1.00	7
Azithromycin	1.00	2.00	8.00	1.00	5.00	1.00	2.00	ng/L	10.00	50.00	8.00	0
Caffeine	130.00	179.51	8.00	72.70	380.00	98.35	242.50	ng/L	3.00	3.00	0.00	8
Carbamazepine	67.90	67.74	8.00	36.80	100.00	49.93	84.30	ng/L	1.00	1.00	0.00	8
Diuron	0.21	0.36	8.00	0.03	1.25	0.05	0.46	ug/L	0.01	0.01	0.00	8
Erythromycin	0.10	0.60	8.00	0.10	4.10	0.10	0.10	ng/L	1.00	1.00	7.00	1
Gemfibrozil	6.85	9.48	8.00	1.30	28.10	3.18	11.00	ng/L	1.00	1.00	0.00	8
Ibuprofen	14.70	17.44	8.00	1.00	35.70	5.95	30.40	ng/L	1.00	10.00	1.00	7
N,N-diethyl-m-toluamide	26.30	28.29	8.00	20.70	39.20	23.78	32.78	ng/L	1.00	1.00	0.00	8
Pentachlorophenol (PCP)	0.02	0.02	2.00	0.02	0.02	0.02	0.02	ug/L	0.20	0.20	2.00	0
Primidone	38.30	41.50	8.00	5.00	79.20	24.03	64.13	ng/L	1.00	100.00	2.00	6
Simazine	0.02	0.02	8.00	0.01	0.05	0.01	0.04	ug/L	0.01	0.01	0.00	8
Sulfamethoxazole	44.50	53.50	8.00	17.50	130.00	36.05	57.08	ng/L	1.00	1.00	0.00	8
Triclosan	0.30	0.55	8.00	0.10	1.30	0.10	1.05	ng/L	1.00	5.00	5.00	3

TABLE: Olive Basin Water Quality Summary Data (2014-2019)

PARAMETER NAME	MEDIAN	MEAN	N=	MINIMUM	MAXIMUM	25th PERCENTILE	75th PERCENTILE	UNITS	MIN RDL	MAX RDL	# of NDS	# of DETECTS
<b>BIOLOGICAL</b>												
E. Coli (Membrane Filtration - CFU/100ml)	1.00	3.29	8.00	0.10	17.00	0.10	2.75	CFU/100	1	1	3	5
Enterococcus(Membrane Filtration-CFU/100ml)	2.00	1.70	3.00	0.10	3.00	1.05	2.50	CFU/100	1	1	1	2
Fecal Coliform (Membrane Filtration-CFU/100ml)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	CFU/100	1	1	0	1
Total Coliform (Membrane Filtration-CFU/100ml)	36.00	80.63	8.00	1.00	300.00	14.50	92.50	CFU/100	1	1	0	8
<b>FIELD MEASUREMENTS</b>												
Field Dissolved Oxygen	5.34	5.70	8.00	3.78	7.59	4.70	6.97	mg/L	0	0.01	0	8
Field Electrical Conductivity	873.00	855.50	8.00	643.00	1180.00	716.00	907.25	uS/cm	0	1	0	8
Field Oxidation-Reduction Potential	169.50	159.25	8.00	24.00	251.00	124.75	203.75	mV	-1000	-1000	0	8
Field Temperature	16.45	16.59	8.00	13.00	20.80	13.55	19.45	C	0	1	0	8
Field pH	7.75	7.74	8.00	7.50	8.00	7.68	7.80	UNITS	0	1	0	8
<b>INORGANIC</b>												
Alkalinity-Phenolphthalein	0.10	0.10	8.00	0.10	0.10	0.10	0.10	mg/L	1	1	8	0
Aluminum (dissolved)	2.30	2.54	8.00	1.10	6.20	1.65	2.60	ug/L	1	1	0	8
Ammonia Nitrogen	0.01	0.01	8.00	0.01	0.01	0.01	0.01	mg/L	0.1	0.1	8	0
Antimony (dissolved)	0.10	0.10	8.00	0.10	0.10	0.10	0.10	ug/L	1	1	8	0
Arsenic (dissolved)	2.40	2.36	8.00	1.20	3.80	1.83	2.75	ug/L	1	1	0	8
Barium (dissolved)	37.30	37.68	8.00	24.70	53.00	32.03	43.20	ug/L	1	1	0	8
Beryllium (dissolved)	0.10	0.10	8.00	0.10	0.10	0.10	0.10	ug/L	1	1	8	0
Bicarbonate (as CaCO3)	182.50	182.75	8.00	142.00	238.00	149.75	203.50	mg/L	1	1	0	8
Bicarbonate (as HCO3)	222.45	222.78	8.00	173.10	290.10	182.58	248.10	mg/L	1.2	1.2	0	8
Boron (dissolved)	0.20	0.21	8.00	0.20	0.30	0.20	0.20	mg/L	0.1	0.1	0	8
Bromide	0.15	0.14	8.00	0.10	0.24	0.13	0.16	mg/L	0.1	0.1	1	7
Cadmium (dissolved)	0.10	0.10	8.00	0.10	0.10	0.10	0.10	ug/L	1	1	8	0
Calcium (dissolved)	67.50	66.46	8.00	46.20	91.40	57.65	72.68	mg/L	0.5	0.5	0	8
Carbonate (as CaCO3)	0.10	0.10	8.00	0.10	0.10	0.10	0.10	mg/L	1	1	8	0
Cation-Anion meq balance	-4.37	-4.39	5.00	-10.26	-0.44	-6.32	-0.55	RATIO			0	5
Chloride	99.85	96.96	8.00	66.20	144.00	74.55	106.50	mg/L	0.5	2	0	8
Chromium (dissolved)	0.10	0.69	8.00	0.10	3.90	0.10	0.33	ug/L	1	1	6	2
Cobalt (dissolved)	0.10	0.10	8.00	0.10	0.10	0.10	0.10	ug/L	1	1	8	0
Copper (dissolved)	3.65	3.70	8.00	2.80	4.30	3.50	4.05	ug/L	1	1	0	8
Electrical Conductivity	871.50	858.13	8.00	622.00	1200.00	722.50	919.50	uS/cm	1	1	0	8
Fluoride	0.36	0.34	8.00	0.25	0.43	0.31	0.37	mg/L	0.1	0.1	0	8
Gadolinium (dissolved)	52.60	52.15	8.00	10.90	79.60	43.53	66.65	ng/L	10	10	0	8
Hydroxide (as CaCO3)	0.10	0.10	8.00	0.10	0.10	0.10	0.10	mg/L	1	1	8	0
Iron (dissolved)	4.65	5.81	8.00	0.10	15.00	3.45	7.58	ug/L	1	5	1	7
Lead (dissolved)	0.10	0.10	8.00	0.10	0.10	0.10	0.10	ug/L	1	1	8	0
Magnesium (dissolved)	16.40	16.60	8.00	11.50	23.30	14.53	18.18	mg/L	0.5	0.5	0	8
Manganese (dissolved)	0.10	0.78	8.00	0.10	5.50	0.10	0.10	ug/L	1	1	7	1
Mercury (dissolved)	0.10	0.09	8.00	0.01	0.10	0.10	0.10	ug/L	0.1	1	8	0
Nickel (dissolved)	2.55	2.16	8.00	0.10	4.00	1.38	2.70	ug/L	1	1	1	7
Nitrate	8.80	9.83	8.00	5.80	17.00	7.55	10.50	mg/L	0.4	0.4	0	8
Nitrate + Nitrite Nitrogen	1.99	2.23	8.00	1.36	3.85	1.71	2.39	mg/L	0.1	0.1	0	8
Nitrate Nitrogen	1.99	2.22	8.00	1.31	3.85	1.70	2.38	mg/L	0.1	0.1	0	8
Nitrite	0.02	0.04	8.00	0.01	0.15	0.02	0.03	mg/L	0.007	0.007	0	8
Nitrite Nitrogen	0.01	0.01	8.00	0.00	0.05	0.01	0.01	mg/L	0.002	0.002	0	8
Organic Nitrogen	0.30	0.29	8.00	0.20	0.40	0.28	0.30	mg/L	0.1	0.1	0	8
Phosphate Phosphorus (orthophosphate)	0.69	0.67	8.00	0.55	0.78	0.59	0.72	mg/L	0.01	0.01	0	8
Potassium (dissolved)	10.60	10.36	8.00	8.00	12.80	9.18	11.15	mg/L	0.5	0.5	0	8
Selenium (dissolved)	0.10	0.10	8.00	0.10	0.10	0.10	0.10	ug/L	1	1	8	0
Silica	14.40	13.94	8.00	8.40	18.00	11.60	17.43	mg/L	1	1	0	8
Silver (dissolved)	0.10	0.10	8.00	0.10	0.10	0.10	0.10	ug/L	1	1	8	0
Sodium (dissolved)	78.95	78.74	8.00	54.40	111.00	65.43	86.38	mg/L	0.5	0.5	0	8
Sulfate	95.15	96.19	8.00	62.80	147.00	82.75	103.00	mg/L	0.5	2	0	8
Suspended Solids	0.25	0.21	4.00	0.10	0.25	0.21	0.25	mg/L	1	2.5	4	0
Temperature (Laboratory)	22.10	21.87	3.00	21.00	22.50	21.55	22.30	C	1	1	0	3
Thallium (dissolved)	0.10	0.10	8.00	0.10	0.10	0.10	0.10	ug/L	1	1	8	0
Title 22 Total Anions	8.53	8.57	8.00	6.17	12.14	6.97	9.37	meq/L			0	8
Total Alkalinity (as CaCO3)	182.50	182.75	8.00	142.00	238.00	149.75	203.50	mg/L	1	5	0	8
Total Anions	8.21	8.74	5.00	6.20	12.17	6.95	10.15	meq/L	0	0	0	5
Total Cations	8.17	8.34	5.00	5.82	11.65	6.91	9.16	meq/L	0	0	0	5
Total Dissolved Solids	480.00	500.75	8.00	368.00	734.00	417.00	539.00	mg/L	1	2.5	0	8

**TABLE: Olive Basin Water Quality Summary Data (2014-2019)**

PARAMETER NAME	MEDIAN	MEAN	N=	MINIMUM	MAXIMUM	25th PERCENTILE	75th PERCENTILE	UNITS	MIN RDL	MAX RDL	# of NDS	# of DETECTS
Total Hardness (as CaCO3) (dissolved)	236.00	234.25	8.00	163.00	324.00	203.75	256.00	mg/L	1	1	0	8
Total Kjeldahl Nitrogen	0.30	0.30	8.00	0.20	0.40	0.30	0.30	mg/L	0.2	0.2	0	8
Total Nitrogen	2.30	2.55	8.00	1.80	4.20	2.03	2.68	mg/L	0.2	0.2	0	8
Total Organic Carbon (Unfiltered)	3.52	3.45	8.00	2.77	3.93	3.34	3.58	mg/L	0.05	0.05	0	8
Turbidity	0.30	0.35	8.00	0.10	0.60	0.28	0.50	NTU	0.1	0.1	0	8
UV Absorbance/TOC (unfiltered) ratio	0.03	0.03	8.00	0.02	0.04	0.03	0.03	L/mg-cm	0.0001	0.0001	0	8
Ultraviolet (absorbance)	0.10	0.10	8.00	0.07	0.12	0.10	0.11	1/cm	0.005	0.005	0	8
Vanadium (dissolved)	4.85	5.01	8.00	3.50	7.60	4.43	5.25	ug/L	1	1	0	8
Zinc (dissolved)	8.75	8.53	8.00	1.70	19.10	4.50	10.88	ug/L	1	1	0	8
pH	7.90	7.89	8.00	7.60	8.00	7.88	8.00	UNITS	1	1	0	8
<b>ORGANIC</b>												
Aspartame	10.00	10.00	5.00	10.00	10.00	10.00	10.00	ng/L	100	100	5	0
Atenolol	0.50	0.50	5.00	0.50	0.50	0.50	0.50	ng/L	5	5	5	0
Diclofenac	0.50	0.50	5.00	0.50	0.50	0.50	0.50	ng/L	5	5	5	0
Dilantin	28.60	28.28	5.00	12.30	41.10	27.00	32.40	ng/L	10	10	0	5
Dissolved Organic Carbon	3.45	3.35	8.00	2.69	3.79	3.24	3.58	mg/L	0.05	0.05	0	8
Fluoxetine	0.50	0.50	5.00	0.50	0.50	0.50	0.50	ng/L	5	5	5	0
Iohexol	152.00	255.00	5.00	77.00	690.00	146.00	210.00	ng/L	20	20	0	5
Iopromide	12.60	11.36	5.00	1.00	27.30	1.00	14.90	ng/L	10	10	2	3
Linuron	0.00	0.00	5.00	0.00	0.00	0.00	0.00	ug/L	0.005	0.005	5	0
Meprobamate	19.70	21.30	5.00	5.60	41.40	16.60	23.20	ng/L	5	10	0	5
Naproxen	0.50	0.60	5.00	0.50	1.00	0.50	0.50	ng/L	5	10	5	0
Neotame	1.00	1.00	5.00	1.00	1.00	1.00	1.00	ng/L	10	10	5	0
Sucralose	16700.00	15980.00	5.00	10900.00	22600.00	12200.00	17500.00	ng/L	100	1000	0	5
Total Organic Halogen	50.00	46.33	3.00	38.00	51.00	44.00	50.50	ug/L	20	20	0	3
Trimethoprim	0.50	0.50	5.00	0.50	0.50	0.50	0.50	ng/L	5	5	5	0
Tris-2-chloroethyl phosphate	40.50	41.18	5.00	18.50	62.10	27.60	57.20	ng/L	5	5	0	5
para-Chlorobenzene sulfonic acid	20.00	20.00	5.00	20.00	20.00	20.00	20.00	ng/L	200	200	5	0
<b>SEMI-ORGANIC</b>												
Acetaminophen	0.50	0.50	5.00	0.50	0.50	0.50	0.50	ng/L	5	5	5	0
Atrazine	0.00	0.00	5.00	0.00	0.01	0.00	0.00	ug/L	0.001	0.001	0	5
Azithromycin	1.00	2.60	5.00	1.00	5.00	1.00	5.00	ng/L	10	50	5	0
Caffeine	6.90	6.70	5.00	3.70	8.80	5.50	8.60	ng/L	3	3	0	5
Carbamazepine	60.50	65.20	5.00	39.70	87.70	59.50	78.60	ng/L	1	1	0	5
Diuron	0.03	0.05	5.00	0.01	0.09	0.02	0.09	ug/L	0.005	0.01	0	5
Erythromycin	0.10	0.10	5.00	0.10	0.10	0.10	0.10	ng/L	1	1	5	0
Gemfibrozil	0.10	0.10	5.00	0.10	0.10	0.10	0.10	ng/L	1	1	5	0
Ibuprofen	0.10	0.18	5.00	0.10	0.50	0.10	0.10	ng/L	1	5	5	0
N,N-diethyl-m-toluamide	8.70	8.28	5.00	3.40	11.70	7.30	10.30	ng/L	1	1	0	5
Primidone	43.30	36.44	5.00	5.00	65.20	10.00	58.70	ng/L	1	100	2	3
Simazine	0.02	0.03	5.00	0.01	0.05	0.02	0.03	ug/L	0.005	0.005	0	5
Sulfamethoxazole	50.20	58.06	5.00	25.60	110.00	38.40	66.10	ng/L	1	1	0	5
Triclosan	0.10	0.18	5.00	0.10	0.50	0.10	0.10	ng/L	1	5	5	0

TABLE: AM-51 Well Water Quality Summary Data (2013-2023)

PARAMETER NAME	MEDIAN	MEAN	N=	MINIMUM	MAXIMUM	25th PERCENTILE	75th PERCENTILE	UNITS	MIN RDL	MAX RDL	# of NDs	# of DETECTS
<b>BIOLOGICAL</b>												
E. Coli (Membrane Filtration - CFU/100ml)	0.10	0.10	10.00	0.10	0.10	0.10	0.10	CFU/100	1.00	1.00	0.00	10.00
Enterococcus(Membrane Filtration-CFU/100ml)	0.10	0.10	10.00	0.10	0.10	0.10	0.10	CFU/100	1.00	1.00	0.00	10.00
Fecal Coliform (Membrane Filtration-CFU/100ml)	0.10	0.10	2.00	0.10	0.10	0.10	0.10	CFU/100	1.00	1.00	0.00	2.00
Heterotrophic Plate Count (pour plate-CFU/1ml)	37.00	56.29	7.00	31.00	104.00	34.00	77.00	CFU/1 ml	1.00	1.00	0.00	7.00
Total Coliform (Membrane Filtration-CFU/100ml)	0.10	1.28	10.00	0.10	11.00	0.10	0.10	CFU/100	1.00	1.00	0.00	10.00
<b>FIELD MEASUREMENTS</b>												
Field Electrical Conductivity	1080.00	1047.47	30.00	609.00	1260.00	988.75	1165.00	uS/cm	0.00	1.00	0.00	30.00
Field Oxidation-Reduction Potential	84.00	66.73	30.00	-189.00	221.00	35.25	121.50	mV	-1000.00	-1000.00	0.00	30.00
Field Temperature	20.55	20.49	30.00	15.70	27.20	18.65	21.68	C	0.00	1.00	0.00	30.00
Field pH	7.40	7.41	30.00	6.30	7.90	7.30	7.50	UNITS	0.00	1.00	0.00	30.00
<b>INORGANIC</b>												
Aggressive Index	12.49	12.46	6.00	12.14	12.76	12.36	12.55	A.I.			0.00	6.00
Alkalinity-Phenolphthalein	0.10	0.10	28.00	0.10	0.10	0.10	0.10	mg/L	1.00	1.00	0.00	28.00
Aluminum (dissolved)	1.50	1.84	22.00	0.10	8.40	1.15	2.00	ug/L	1.00	1.00	0.00	22.00
Ammonia Nitrogen	0.01	0.01	22.00	0.01	0.01	0.01	0.01	mg/L	0.10	0.10	0.00	22.00
Antimony (dissolved)	0.10	0.10	22.00	0.05	0.50	0.06	0.10	ug/L	0.50	1.00	0.00	22.00
Arsenic (dissolved)	4.65	4.60	22.00	3.20	5.80	4.15	5.00	ug/L	1.00	1.00	0.00	22.00
Barium (dissolved)	73.30	68.45	22.00	36.30	91.90	52.48	81.35	ug/L	1.00	1.00	0.00	22.00
Beryllium (dissolved)	0.10	0.08	22.00	0.05	0.10	0.05	0.10	ug/L	0.50	1.00	0.00	22.00
Bicarbonate (as CaCO3)	218.00	209.93	28.00	145.00	246.00	207.50	225.75	mg/L	1.00	1.00	0.00	28.00
Bicarbonate (as HCO3)	265.70	255.91	28.00	176.80	299.90	252.98	275.20	mg/L	1.20	1.20	0.00	28.00
Boron	0.29	0.28	6.00	0.23	0.31	0.27	0.31	mg/L	0.10	0.10	0.00	6.00
Boron (dissolved)	0.30	0.26	22.00	0.20	0.30	0.20	0.30	mg/L	0.10	0.10	0.00	22.00
Bromate	0.50	0.50	1.00	0.50	0.50	0.50	0.50	ug/L	5.00	5.00	0.00	1.00
Bromide	0.20	0.18	28.00	0.01	0.30	0.16	0.21	mg/L	0.01	0.10	0.00	28.00
Cadmium (dissolved)	0.10	0.10	22.00	0.10	0.10	0.10	0.10	ug/L	1.00	1.00	0.00	22.00
Calcium	86.20	87.25	6.00	80.40	95.50	84.95	89.55	mg/L	0.50	0.50	0.00	6.00
Calcium (dissolved)	85.40	80.60	22.00	42.30	102.00	68.83	93.70	mg/L	0.50	0.50	0.00	22.00
Carbonate (as CaCO3)	0.10	0.10	28.00	0.10	0.10	0.10	0.10	mg/L	1.00	1.00	0.00	28.00
Cation-Anion meq balance	-1.23	-1.01	19.00	-5.86	3.89	-3.31	1.27	RATIO			0.00	19.00
Chlorate	10.80	10.80	1.00	10.80	10.80	10.80	10.80	ug/L	10.00	10.00	0.00	1.00
Chloride	132.00	123.08	28.00	61.70	150.00	115.00	140.25	mg/L	0.50	2.00	0.00	28.00
Chromium (dissolved)	0.10	0.24	22.00	0.10	1.30	0.10	0.10	ug/L	1.00	1.00	0.00	22.00
Cobalt (dissolved)	0.10	0.19	22.00	0.10	1.10	0.10	0.10	ug/L	1.00	1.00	0.00	22.00
Copper (dissolved)	2.85	3.00	22.00	1.80	4.20	2.53	3.58	ug/L	1.00	1.00	0.00	22.00
Cyanide	0.50	0.50	1.00	0.50	0.50	0.50	0.50	ug/L	5.00	5.00	0.00	1.00
Electrical Conductivity	1075.00	1029.46	28.00	633.00	1240.00	985.25	1150.00	uS/cm	1.00	1.00	0.00	28.00
Fluoride	0.34	0.36	22.00	0.29	0.45	0.32	0.39	mg/L	0.10	0.10	0.00	22.00
Gadolinium (dissolved)	26.60	29.91	22.00	10.80	63.70	22.90	31.85	ng/L	10.00	10.00	0.00	22.00
Hexavalent Chromium	0.30	0.30	1.00	0.30	0.30	0.30	0.30	ug/L	0.20	0.20	0.00	1.00
Hydroxide (as CaCO3)	0.10	0.14	28.00	0.10	0.50	0.10	0.10	mg/L	1.00	5.00	6.00	22.00
Iron (dissolved)	0.50	1.13	22.00	0.10	8.20	0.10	1.75	ug/L	1.00	5.00	0.00	22.00
Lead (dissolved)	0.10	0.10	22.00	0.10	0.10	0.10	0.10	ug/L	1.00	1.00	0.00	22.00
Magnesium	22.55	22.60	6.00	20.80	24.40	22.03	23.23	mg/L	0.50	0.50	0.00	6.00
Magnesium (dissolved)	22.00	21.09	22.00	11.10	27.00	18.30	24.63	mg/L	0.50	0.50	0.00	22.00
Manganese (dissolved)	0.10	2.32	22.00	0.10	16.70	0.10	0.10	ug/L	1.00	1.00	0.00	22.00
Mercury (dissolved)	0.06	0.06	22.00	0.01	0.10	0.01	0.10	ug/L	0.10	1.00	0.00	22.00
Nickel (dissolved)	2.35	2.59	22.00	1.10	4.30	2.00	3.25	ug/L	1.00	1.00	0.00	22.00
Nitrate	7.15	7.28	28.00	0.80	13.60	5.13	9.23	mg/L	0.40	0.40	0.00	28.00
Nitrate + Nitrite Nitrogen	1.66	1.69	23.00	0.70	3.08	1.23	2.16	mg/L	0.10	0.10	0.00	23.00
Nitrate Nitrogen	1.63	1.65	28.00	0.18	3.08	1.16	2.09	mg/L	0.10	0.10	0.00	28.00
Nitrite	0.00	0.00	23.00	0.00	0.01	0.00	0.00	mg/L	0.00	0.01	17.00	6.00
Nitrite Nitrogen	0.00	0.00	23.00	0.00	0.00	0.00	0.00	mg/L	0.00	0.00	0.00	23.00
Organic Nitrogen	0.01	0.10	22.00	0.01	0.30	0.01	0.20	mg/L	0.10	0.10	0.00	22.00
Perchlorate	0.25	0.24	20.00	0.20	0.25	0.25	0.25	ug/L	2.00	2.50	0.00	20.00
Phosphate Phosphorus (orthophosphate)	0.60	0.61	22.00	0.55	0.74	0.57	0.64	mg/L	0.01	0.01	0.00	22.00
Potassium	12.40	12.40	6.00	10.80	14.00	11.15	13.65	mg/L	0.50	0.50	0.00	6.00
Potassium (dissolved)	10.75	10.60	22.00	7.40	14.10	9.13	11.88	mg/L	0.50	0.50	0.00	22.00
Selenium (dissolved)	0.10	0.31	22.00	0.10	1.10	0.10	0.10	ug/L	1.00	1.00	0.00	22.00
Silica	17.50	17.38	22.00	13.70	21.80	15.85	18.83	mg/L	1.00	1.00	0.00	22.00
Silver (dissolved)	0.10	0.10	22.00	0.10	0.10	0.10	0.10	ug/L	1.00	1.00	0.00	22.00
Sodium	103.50	101.60	6.00	88.60	110.00	100.75	104.00	mg/L	0.50	0.50	0.00	6.00
Sodium (dissolved)	99.55	96.40	22.00	67.50	115.00	84.65	110.50	mg/L	0.50	0.50	0.00	22.00
Sulfate	128.00	126.23	28.00	66.50	182.00	104.00	150.75	mg/L	0.50	2.00	0.00	28.00
Surfactants	0.00	0.00	1.00	0.00	0.00	0.00	0.00	mg/L	0.02	0.02	0.00	1.00
Suspended Solids	0.10	0.13	14.00	0.10	0.25	0.10	0.10	mg/L	1.00	2.50	0.00	14.00
Temperature (Laboratory)	21.30	21.36	7.00	20.20	22.20	20.85	22.05	C	1.00	1.00	0.00	7.00
Thallium (dissolved)	0.10	0.08	22.00	0.05	0.10	0.05	0.10	ug/L	0.50	1.00	0.00	22.00
Title 22 Total Anions	10.84	10.26	22.00	6.16	12.55	8.85	11.74	meq/L			0.00	22.00
Title 22 Total Cations	11.09	10.95	6.00	10.25	11.61	10.50	11.30	meq/L			0.00	6.00
Total Alkalinity (as CaCO3)	218.00	209.96	28.00	145.00	246.00	207.50	225.75	mg/L	1.00	5.00	0.00	28.00
Total Anions	10.99	10.60	19.00	6.85	12.58	9.89	12.04	meq/L	0.00	0.00	0.00	19.00

TABLE: AM-51 Well Water Quality Summary Data (2013-2023)

PARAMETER NAME	MEDIAN	MEAN	N=	MINIMUM	MAXIMUM	25th PERCENTILE	75th PERCENTILE	UNITS	MIN RDL	MAX RDL	# of NDs	# of DETECTS
Total Cations	10.86	10.51	19.00	6.55	12.60	9.42	12.01	meq/L	0.00	0.00	0.00	19.00
Total Dissolved Solids	648.00	616.09	22.00	338.00	778.00	513.00	723.00	mg/L	1.00	2.50	0.00	22.00
Total Hardness (as CaCO3) (dissolved)	304.00	288.14	22.00	151.00	365.00	247.75	335.25	mg/L	1.00	1.00	0.00	22.00
Total Kjeldahl Nitrogen	0.02	0.07	22.00	0.02	0.30	0.02	0.02	mg/L	0.20	0.20	0.00	22.00
Total Nitrogen	1.63	1.72	22.00	0.79	3.10	1.20	2.15	mg/L	0.10	0.20	0.00	22.00
Total Organic Carbon (Unfiltered)	1.63	1.70	28.00	0.98	2.41	1.44	1.99	mg/L	0.05	0.05	0.00	28.00
Turbidity	0.15	0.21	22.00	0.01	1.10	0.01	0.28	NTU	0.10	0.10	0.00	22.00
UV Absorbance/TOC (unfiltered) ratio	0.02	0.03	22.00	0.02	0.04	0.02	0.03	L/mg-cm	0.00	0.00	0.00	22.00
Ultraviolet (absorbance)	0.04	0.04	22.00	0.02	0.06	0.03	0.05	1/cm	0.01	0.01	0.00	22.00
Vanadium (dissolved)	7.35	7.23	22.00	5.00	10.90	6.53	8.00	ug/L	1.00	1.00	0.00	22.00
Zinc (dissolved)	1.50	6.73	22.00	0.10	115.00	0.10	2.53	ug/L	1.00	1.00	0.00	22.00
pH	7.80	7.82	28.00	7.50	8.10	7.80	7.90	UNITS	1.00	1.00	0.00	28.00
<b>ORGANIC</b>												
1,1,1,2-Tetrachloroethane	0.05	0.05	20.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	20.00	0.00
1,1,1-Trichloroethane	0.05	0.05	20.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	20.00	0.00
1,1,2,2-Tetrachloroethane	0.05	0.05	20.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	20.00	0.00
1,1,2-Trichloroethane	0.05	0.05	20.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	20.00	0.00
1,1-Dichloroethane	0.05	0.05	20.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	20.00	0.00
1,1-Dichloroethene	0.05	0.05	20.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	20.00	0.00
1,1-Dichloropropene	0.05	0.05	20.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	20.00	0.00
1,2,3-Trichlorobenzene	0.05	0.05	20.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	20.00	0.00
1,2,3-Trichloropropane	0.05	0.03	34.00	0.00	0.05	0.00	0.05	ug/L	0.01	0.50	34.00	0.00
1,2,4-Trichlorobenzene	0.05	0.05	20.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	20.00	0.00
1,2,4-Trimethylbenzene	0.05	0.05	20.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	20.00	0.00
1,2-Dibromo-3-chloropropane	0.05	0.03	34.00	0.00	0.05	0.00	0.05	ug/L	0.01	0.50	34.00	0.00
1,2-Dibromoethane	0.05	0.03	34.00	0.00	0.05	0.00	0.05	ug/L	0.01	0.50	34.00	0.00
1,2-Dichlorobenzene	0.05	0.05	20.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	20.00	0.00
1,2-Dichloroethane	0.05	0.05	20.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	20.00	0.00
1,2-Dichloropropane	0.05	0.05	20.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	20.00	0.00
1,3,5-Trimethylbenzene	0.05	0.05	20.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	20.00	0.00
1,3-Dichlorobenzene	0.05	0.05	20.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	20.00	0.00
1,3-Dichloropropane	0.05	0.05	20.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	20.00	0.00
1,4-Dichlorobenzene	0.05	0.05	20.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	20.00	0.00
1,4-Dioxane	0.10	0.09	20.00	0.05	0.10	0.10	0.10	ug/L	0.50	1.00	20.00	0.00
11-chloroicosafafluoro-3-oxaundecane-1-sulfonic acid	0.20	0.20	1.00	0.20	0.20	0.20	0.20	ng/L	2.00	2.00	1.00	0.00
17a-Estradiol	0.10	0.10	9.00	0.10	0.10	0.10	0.10	ng/L	1.00	1.00	9.00	0.00
17a-Ethinylestradiol	0.20	0.29	9.00	0.20	1.00	0.20	0.20	ng/L	2.00	10.00	9.00	0.00
17b-Estradiol	0.20	0.20	9.00	0.20	0.20	0.20	0.20	ng/L	2.00	2.00	9.00	0.00
2,2-Dichloropropane	0.05	0.05	20.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	20.00	0.00
2,4-Dinitrotoluene	0.01	0.01	1.00	0.01	0.01	0.01	0.01	ug/L	0.10	0.10	1.00	0.00
2,6-Dinitrotoluene	0.01	0.01	1.00	0.01	0.01	0.01	0.01	ug/L	0.10	0.10	1.00	0.00
2-Chloroethylvinyl ether	0.10	0.10	13.00	0.10	0.10	0.10	0.10	ug/L	1.00	1.00	13.00	0.00
2-Chlorotoluene	0.05	0.05	20.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	20.00	0.00
2-Hexanone	1.00	1.00	13.00	1.00	1.00	1.00	1.00	ug/L	10.00	10.00	13.00	0.00
4,8-dioxa-3H-perfluorononanoic acid	0.20	0.20	1.00	0.20	0.20	0.20	0.20	ng/L	2.00	2.00	1.00	0.00
4-Androstene-3,17-dione	0.20	0.20	7.00	0.20	0.20	0.20	0.20	ng/L	2.00	2.00	7.00	0.00
4-Chlorotoluene	0.05	0.05	20.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	20.00	0.00
4-Isopropyltoluene	0.05	0.05	20.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	20.00	0.00
4-n-Octylphenol	0.02	0.02	10.00	0.02	0.02	0.02	0.02	ug/L	0.20	0.20	10.00	0.00
4-tert-Octylphenol	0.02	0.02	10.00	0.02	0.02	0.02	0.02	ug/L	0.20	0.20	10.00	0.00
9-chlorohexadecafluoro-3-oxanone-1-sulfonic acid	0.20	0.20	1.00	0.20	0.20	0.20	0.20	ng/L	2.00	2.00	1.00	0.00
Acetone	1.00	1.00	20.00	1.00	1.00	1.00	1.00	ug/L	10.00	10.00	20.00	0.00
Acrolein	1.00	0.93	15.00	0.50	1.00	1.00	1.00	ug/L	5.00	10.00	15.00	0.00
Acrylonitrile	1.00	0.89	15.00	0.20	1.00	1.00	1.00	ug/L	2.00	10.00	15.00	0.00
Aspartame	10.00	10.00	18.00	10.00	10.00	10.00	10.00	ng/L	100.00	100.00	18.00	0.00
Atenolol	0.50	0.50	18.00	0.50	0.50	0.50	0.50	ng/L	5.00	5.00	18.00	0.00
Benzene	0.05	0.05	20.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	20.00	0.00
Bisphenol A	0.02	0.02	10.00	0.02	0.05	0.02	0.02	ug/L	0.20	0.50	10.00	0.00
Bromobenzene	0.05	0.05	20.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	20.00	0.00
Bromochloromethane	0.05	0.05	20.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	20.00	0.00
Bromodichloromethane	0.05	0.05	20.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	20.00	0.00
Bromoform	0.05	0.05	20.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	20.00	0.00
Bromomethane	0.05	0.05	20.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	20.00	0.00
Carbon Disulfide	0.05	0.05	20.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	20.00	0.00
Carbon tetrachloride	0.05	0.05	20.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	20.00	0.00
Chlorobenzene	0.05	0.05	20.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	20.00	0.00
Chlorodifluoromethane	0.05	0.05	20.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	20.00	0.00
Chloroethane	0.05	0.05	20.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	20.00	0.00
Chloroform	0.05	0.15	20.00	0.05	0.80	0.05	0.25	ug/L	0.50	0.50	13.00	7.00
Chloromethane	0.05	0.05	20.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	20.00	0.00
Chlorotrifluoroethene	0.50	0.50	4.00	0.50	0.50	0.50	0.50	ug/L	5.00	5.00	4.00	0.00
Dacthal Acid Metabolites	0.03	0.03	1.00	0.03	0.03	0.03	0.03	ug/L	0.25	0.25	1.00	0.00
Dibromochloromethane	0.05	0.05	20.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	20.00	0.00
Dibromomethane	0.05	0.05	20.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	20.00	0.00

TABLE: AM-51 Well Water Quality Summary Data (2013-2023)

PARAMETER NAME	MEDIAN	MEAN	N=	MINIMUM	MAXIMUM	25th PERCENTILE	75th PERCENTILE	UNITS	MIN RDL	MAX RDL	# of NDs	# of DETECTS
Dichlorodifluoromethane	0.05	0.05	20.00	0.05	0.05	0.05	0.05	ug/L	0.50	5.00	20.00	0.00
Diclofenac	0.50	0.50	18.00	0.50	0.50	0.50	0.50	ng/L	5.00	5.00	18.00	0.00
Diethylstilbestrol	0.20	0.20	9.00	0.20	0.20	0.20	0.20	ng/L	2.00	2.00	9.00	0.00
Diflubenzuron	0.10	0.10	1.00	0.10	0.10	0.10	0.10	ug/L	1.00	1.00	1.00	0.00
Diisopropyl ether	0.10	0.10	20.00	0.10	0.10	0.10	0.10	ug/L	1.00	1.00	20.00	0.00
Dilantin	19.60	21.34	18.00	1.00	47.20	17.35	28.20	ng/L	10.00	10.00	2.00	16.00
Dissolved Organic Carbon	1.75	1.75	22.00	1.28	2.42	1.40	2.07	mg/L	0.05	0.05	0.00	22.00
Endosulfan II	0.01	0.01	2.00	0.00	0.01	0.00	0.01	ug/L	0.01	0.10	2.00	0.00
Epitestosterone (cis-Testosterone)	0.10	0.10	10.00	0.10	0.10	0.10	0.10	ng/L	1.00	1.00	10.00	0.00
Equilin	0.50	0.50	6.00	0.50	0.50	0.50	0.50	ng/L	5.00	5.00	6.00	0.00
Estriol	0.20	0.20	9.00	0.20	0.20	0.20	0.20	ng/L	2.00	2.00	9.00	0.00
Estrone	0.10	0.10	9.00	0.10	0.10	0.10	0.10	ng/L	1.00	1.00	9.00	0.00
Ethyl tert-butyl ether	0.10	0.10	20.00	0.10	0.10	0.10	0.10	ug/L	1.00	1.00	20.00	0.00
Ethylbenzene	0.05	0.05	20.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	20.00	0.00
Fluometuron	0.10	0.10	1.00	0.10	0.10	0.10	0.10	ug/L	1.00	1.00	1.00	0.00
Fluoxetine	0.50	0.50	18.00	0.50	0.50	0.50	0.50	ng/L	5.00	5.00	18.00	0.00
Freon 123a	0.05	0.05	20.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	20.00	0.00
HCH-alpha (Alpha-BHC)	0.01	0.01	2.00	0.00	0.01	0.00	0.01	ug/L	0.02	0.10	2.00	0.00
HCH-beta (Beta-BHC)	0.01	0.01	2.00	0.00	0.01	0.00	0.01	ug/L	0.02	0.10	2.00	0.00
HCH-delta (Delta-BHC)	0.01	0.01	2.00	0.00	0.01	0.00	0.01	ug/L	0.02	0.10	2.00	0.00
Hexachlorobutadiene	0.05	0.05	20.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	20.00	0.00
Hexafluoropropylene oxide dimer acid (GenX)	0.20	0.20	1.00	0.20	0.20	0.20	0.20	ng/L	2.00	2.00	1.00	0.00
Iohexol	2.00	12.49	18.00	2.00	66.80	2.00	2.00	ng/L	20.00	20.00	14.00	4.00
Iopromide	1.00	1.00	18.00	1.00	1.00	1.00	1.00	ng/L	10.00	10.00	18.00	0.00
Isophorone	0.01	0.01	1.00	0.01	0.01	0.01	0.01	ug/L	0.10	0.10	1.00	0.00
Isopropylbenzene	0.05	0.05	20.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	20.00	0.00
Linuron	0.00	0.01	19.00	0.00	0.10	0.00	0.00	ug/L	0.01	1.00	19.00	0.00
Meprobamate	0.50	1.49	18.00	0.50	10.20	0.50	0.50	ng/L	5.00	10.00	16.00	2.00
Methyl Ethyl Ketone (MEK)	0.50	0.46	20.00	0.25	0.50	0.50	0.50	ug/L	2.50	5.00	20.00	0.00
Methyl Isobutyl Ketone (MIBK)	0.50	0.46	20.00	0.25	0.50	0.50	0.50	ug/L	2.50	5.00	20.00	0.00
Methyl tert-butyl ether	0.02	0.02	20.00	0.02	0.02	0.02	0.02	ug/L	0.20	0.20	20.00	0.00
Methylene Chloride	0.05	0.05	20.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	20.00	0.00
Methylisothiocyanate	0.00	0.00	13.00	0.00	0.01	0.00	0.01	ug/L	0.01	0.10	13.00	0.00
Metolachlor	0.05	0.05	2.00	0.01	0.08	0.03	0.06	ug/L	0.10	0.80	2.00	0.00
N-Nitrosomorpholine	1.00	1.00	1.00	1.00	1.00	1.00	1.00	ng/L	10.00	10.00	1.00	0.00
N-ethyl perfluorooctanesulfonamide acid	0.20	0.20	1.00	0.20	0.20	0.20	0.20	ng/L	2.00	2.00	1.00	0.00
N-methyl perfluorooctanesulfonamide acid	0.20	0.20	1.00	0.20	0.20	0.20	0.20	ng/L	2.00	2.00	1.00	0.00
Naphthalene	0.05	0.05	21.00	0.01	0.05	0.05	0.05	ug/L	0.10	0.50	21.00	0.00
Naproxen	0.50	0.81	18.00	0.50	5.00	0.50	0.50	ng/L	5.00	50.00	18.00	0.00
Neotame	1.00	1.00	18.00	1.00	1.00	1.00	1.00	ng/L	10.00	10.00	18.00	0.00
Nitrobenzene	0.50	0.50	13.00	0.50	0.50	0.50	0.50	ug/L	5.00	5.00	13.00	0.00
Nonylphenol	0.02	0.02	10.00	0.02	0.02	0.02	0.02	ug/L	0.20	0.20	10.00	0.00
PCB-1016	0.05	0.05	1.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	1.00	0.00
PCB-1221	0.05	0.05	1.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	1.00	0.00
PCB-1232	0.05	0.05	1.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	1.00	0.00
PCB-1242	0.05	0.05	1.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	1.00	0.00
PCB-1248	0.05	0.05	1.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	1.00	0.00
PCB-1254	0.05	0.05	1.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	1.00	0.00
PCB-1260	0.05	0.05	1.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	1.00	0.00
PFOA + PFOS	21.00	21.00	2.00	14.30	27.70	17.65	24.35	ng/L	2.00	4.00	0.00	2.00
Perfluoro butane sulfonic acid	13.25	13.25	2.00	13.10	13.40	13.18	13.33	ng/L	2.00	4.00	0.00	2.00
Perfluoro heptanoic acid	1.95	1.95	2.00	0.40	3.50	1.18	2.73	ng/L	2.00	4.00	1.00	1.00
Perfluoro hexane sulfonic acid	8.65	8.65	2.00	6.30	11.00	7.48	9.83	ng/L	2.00	4.00	0.00	2.00
Perfluoro nonanoic acid	1.40	1.40	2.00	0.40	2.40	0.90	1.90	ng/L	2.00	4.00	1.00	1.00
Perfluoro octane sulfonic acid	13.05	13.05	2.00	9.30	16.80	11.18	14.93	ng/L	2.00	4.00	0.00	2.00
Perfluoro octanoic acid	7.95	7.95	2.00	5.00	10.90	6.48	9.43	ng/L	2.00	4.00	0.00	2.00
Perfluorodecanoic acid	0.20	0.20	1.00	0.20	0.20	0.20	0.20	ng/L	2.00	2.00	1.00	0.00
Perfluorododecanoic acid	0.20	0.20	1.00	0.20	0.20	0.20	0.20	ng/L	2.00	2.00	1.00	0.00
Perfluorohexanoic acid	8.90	8.90	1.00	8.90	8.90	8.90	8.90	ng/L	2.00	2.00	0.00	1.00
Perfluorotetradecanoic acid	0.20	0.20	1.00	0.20	0.20	0.20	0.20	ng/L	2.00	2.00	1.00	0.00
Perfluorotridecanoic acid	0.20	0.20	1.00	0.20	0.20	0.20	0.20	ng/L	2.00	2.00	1.00	0.00
Perfluoroundecanoic acid	0.20	0.20	1.00	0.20	0.20	0.20	0.20	ng/L	2.00	2.00	1.00	0.00
PhenylPhenol	0.02	0.02	10.00	0.02	0.02	0.02	0.02	ug/L	0.20	0.20	10.00	0.00
Progesterone	0.10	0.10	10.00	0.10	0.10	0.10	0.10	ng/L	1.00	1.00	10.00	0.00
Propanil	0.10	0.10	1.00	0.10	0.10	0.10	0.10	ug/L	1.00	1.00	1.00	0.00
Propylbenzene	0.05	0.05	20.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	20.00	0.00
Siduron	0.10	0.10	1.00	0.10	0.10	0.10	0.10	ug/L	1.00	1.00	1.00	0.00
Styrene	0.05	0.05	20.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	20.00	0.00
Sucralose	11750.00	11988.89	18.00	4830.00	20300.00	7825.00	16225.00	ng/L	100.00	1000.00	0.00	18.00
Terbufos Sulfone	0.01	0.01	1.00	0.01	0.01	0.01	0.01	ug/L	0.10	0.10	1.00	0.00
Tert-amyl methyl ether	0.10	0.10	20.00	0.10	0.10	0.10	0.10	ug/L	1.00	1.00	20.00	0.00
Testosterone (trans-Testosterone)	0.10	0.10	10.00	0.10	0.10	0.10	0.10	ng/L	1.00	1.00	10.00	0.00
Tetrabromobisphenol A	0.02	0.02	10.00	0.02	0.02	0.02	0.02	ug/L	0.20	0.20	10.00	0.00

TABLE: AM-51 Well Water Quality Summary Data (2013-2023)

PARAMETER NAME	MEDIAN	MEAN	N=	MINIMUM	MAXIMUM	25th PERCENTILE	75th PERCENTILE	UNITS	MIN RDL	MAX RDL	# of NDs	# of DETECTS
Tetrachloroethene	0.05	0.05	20.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	20.00	0.00
Thidiazuron	0.10	0.10	1.00	0.10	0.10	0.10	0.10	ug/L	1.00	1.00	1.00	0.00
Toluene	0.05	0.05	20.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	20.00	0.00
Total 1,3-Dichloropropene	0.05	0.05	20.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	20.00	0.00
Total Organic Halogen	28.50	29.50	18.00	2.00	57.00	22.50	34.75	ug/L	20.00	20.00	1.00	17.00
Total Trihalomethanes	0.05	0.15	20.00	0.05	0.80	0.05	0.25	ug/L	0.50	0.50	13.00	7.00
Total Xylenes (m,p,&o)	0.05	0.05	20.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	20.00	0.00
Trichloroethene	0.05	0.05	20.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	20.00	0.00
Trichlorofluoromethane (Freon 11)	0.05	0.05	20.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	20.00	0.00
Trichlorotrifluoroethane (Freon 113)	0.05	0.05	20.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	20.00	0.00
Trimethoprim	0.50	0.50	18.00	0.50	0.50	0.50	0.50	ng/L	5.00	5.00	18.00	0.00
Tris-2-chloroethyl phosphate	0.50	9.21	18.00	0.50	67.50	0.50	1.00	ng/L	5.00	10.00	14.00	4.00
Vinyl Acetate	1.00	1.00	13.00	1.00	1.00	1.00	1.00	ug/L	10.00	10.00	13.00	0.00
Vinyl chloride	0.05	0.05	20.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	20.00	0.00
bis (2-chloroethyl) ether	0.50	0.46	20.00	0.25	0.50	0.50	0.50	ug/L	2.50	5.00	20.00	0.00
cis-1,2-Dichloroethene	0.05	0.05	20.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	20.00	0.00
cis-1,3-Dichloropropene	0.05	0.05	20.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	20.00	0.00
m,p-Xylene	0.05	0.05	20.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	20.00	0.00
n-Butylbenzene	0.05	0.05	20.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	20.00	0.00
n-Nitrosodimethylamine	0.20	0.20	1.00	0.20	0.20	0.20	0.20	ng/L	2.00	2.00	1.00	0.00
o-Xylene	0.05	0.05	20.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	20.00	0.00
para-Chlorobenzene sulfonic acid	20.00	20.00	18.00	20.00	20.00	20.00	20.00	ng/L	200.00	200.00	18.00	0.00
sec-Butylbenzene	0.05	0.05	20.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	20.00	0.00
tert-Butylbenzene	0.05	0.05	20.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	20.00	0.00
tert-butyl alcohol	0.20	0.20	20.00	0.20	0.20	0.20	0.20	ug/L	2.00	2.00	20.00	0.00
trans-1,2 Dichloroethene	0.05	0.05	20.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	20.00	0.00
trans-1,3-Dichloropropene	0.05	0.05	20.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	20.00	0.00
<b>SEMI-ORGANIC</b>												
1-Naphthol	0.50	0.50	1.00	0.50	0.50	0.50	0.50	ug/L	5.00	5.00	1.00	0.00
2,2',3',4,6-Pentachlorobiphenyl	0.01	0.01	1.00	0.01	0.01	0.01	0.01	ug/L	0.10	0.10	1.00	0.00
2,2',3',3',4,4',6-Heptachlorobiphenyl	0.01	0.01	1.00	0.01	0.01	0.01	0.01	ug/L	0.10	0.10	1.00	0.00
2,2',3',3',4,4',5,6,6'-Octachlorobiphenyl	0.01	0.01	1.00	0.01	0.01	0.01	0.01	ug/L	0.10	0.10	1.00	0.00
2,2',4,4',5,6'-Hexachlorobiphenyl	0.01	0.01	1.00	0.01	0.01	0.01	0.01	ug/L	0.10	0.10	1.00	0.00
2,2',4,4'-Tetrachlorobiphenyl	0.01	0.01	1.00	0.01	0.01	0.01	0.01	ug/L	0.10	0.10	1.00	0.00
2,3-Dichlorobiphenyl	0.01	0.01	1.00	0.01	0.01	0.01	0.01	ug/L	0.10	0.10	1.00	0.00
2,4,5-TP (Silvex)	0.05	0.05	1.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	1.00	0.00
2,4,5-Trichlorobiphenyl	0.01	0.01	1.00	0.01	0.01	0.01	0.01	ug/L	0.10	0.10	1.00	0.00
2,4-Dichlorophenoxyacetic Acid	0.05	0.05	1.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	1.00	0.00
2-Chlorobiphenyl	0.01	0.01	1.00	0.01	0.01	0.01	0.01	ug/L	0.10	0.10	1.00	0.00
3-Hydroxycarbofuran	0.20	0.20	1.00	0.20	0.20	0.20	0.20	ug/L	2.00	2.00	1.00	0.00
4,4'-DDD	0.01	0.01	2.00	0.00	0.01	0.00	0.01	ug/L	0.01	0.10	2.00	0.00
4,4'-DDE	0.01	0.01	2.00	0.00	0.01	0.00	0.01	ug/L	0.01	0.10	2.00	0.00
4,4'-DDT	0.01	0.01	2.00	0.00	0.01	0.00	0.01	ug/L	0.01	0.10	2.00	0.00
Acenaphthene	0.01	0.01	1.00	0.01	0.01	0.01	0.01	ug/L	0.10	0.10	1.00	0.00
Acenaphthylene	0.01	0.01	1.00	0.01	0.01	0.01	0.01	ug/L	0.10	0.10	1.00	0.00
Acetaminophen	0.50	0.75	18.00	0.50	5.00	0.50	0.50	ng/L	5.00	50.00	18.00	0.00
Acetochlor	0.01	0.01	1.00	0.01	0.01	0.01	0.01	ug/L	0.10	0.10	1.00	0.00
Acifluorfen	0.05	0.05	1.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	1.00	0.00
Alachlor	0.01	0.02	3.00	0.01	0.05	0.01	0.03	ug/L	0.10	0.50	3.00	0.00
Aldicarb	0.10	0.10	1.00	0.10	0.10	0.10	0.10	ug/L	1.00	1.00	1.00	0.00
Aldicarb sulfone	0.20	0.20	1.00	0.20	0.20	0.20	0.20	ug/L	2.00	2.00	1.00	0.00
Aldicarb sulfoxide	0.20	0.20	1.00	0.20	0.20	0.20	0.20	ug/L	2.00	2.00	1.00	0.00
Aldrin	0.01	0.01	2.00	0.00	0.01	0.00	0.01	ug/L	0.03	0.10	2.00	0.00
Ametryn	0.01	0.01	1.00	0.01	0.01	0.01	0.01	ug/L	0.10	0.10	1.00	0.00
Anthracene	0.01	0.01	1.00	0.01	0.01	0.01	0.01	ug/L	0.10	0.10	1.00	0.00
Atrazine	0.00	0.00	20.00	0.00	0.01	0.00	0.00	ug/L	0.00	0.10	8.00	12.00
Azithromycin	1.00	1.50	18.00	1.00	5.00	1.00	1.00	ng/L	10.00	50.00	18.00	0.00
Baygon	0.10	0.10	1.00	0.10	0.10	0.10	0.10	ug/L	1.00	1.00	1.00	0.00
Bentazon	0.10	0.10	1.00	0.10	0.10	0.10	0.10	ug/L	1.00	1.00	1.00	0.00
Benzo(a)anthracene	0.01	0.01	1.00	0.01	0.01	0.01	0.01	ug/L	0.10	0.10	1.00	0.00
Benzo(a)pyrene	0.01	0.01	1.00	0.01	0.01	0.01	0.01	ug/L	0.10	0.10	1.00	0.00
Benzo(b)fluoranthene	0.01	0.01	1.00	0.01	0.01	0.01	0.01	ug/L	0.10	0.10	1.00	0.00
Benzo(g,h,i)perylene	0.01	0.01	1.00	0.01	0.01	0.01	0.01	ug/L	0.10	0.10	1.00	0.00
Benzo[k]fluoranthene	0.01	0.01	1.00	0.01	0.01	0.01	0.01	ug/L	0.10	0.10	1.00	0.00
Bromacil	0.03	0.03	2.00	0.01	0.05	0.02	0.04	ug/L	0.10	0.50	2.00	0.00
Butachlor	0.02	0.02	2.00	0.01	0.04	0.02	0.03	ug/L	0.10	0.38	2.00	0.00
Butylate	0.01	0.01	1.00	0.01	0.01	0.01	0.01	ug/L	0.10	0.10	1.00	0.00
Butylbenzyl phthalate	0.20	0.20	1.00	0.20	0.20	0.20	0.20	ug/L	2.00	2.00	1.00	0.00
Caffeine	0.30	2.61	20.00	0.30	30.00	0.30	0.60	ng/L	3.00	300.00	19.00	1.00
Captan	0.01	0.01	1.00	0.01	0.01	0.01	0.01	ug/L	0.10	0.10	1.00	0.00
Carbamazepine	75.85	68.06	18.00	36.80	92.10	52.60	84.75	ng/L	1.00	5.00	0.00	18.00
Carbaryl	0.20	0.20	1.00	0.20	0.20	0.20	0.20	ug/L	2.00	2.00	1.00	0.00

TABLE: AM-51 Well Water Quality Summary Data (2013-2023)

PARAMETER NAME	MEDIAN	MEAN	N=	MINIMUM	MAXIMUM	25th PERCENTILE	75th PERCENTILE	UNITS	MIN RDL	MAX RDL	# of NDs	# of DETECTS
Carbofuran	0.10	0.10	1.00	0.10	0.10	0.10	0.10	ug/L	1.00	1.00	1.00	0.00
Chlordane	0.01	0.01	1.00	0.01	0.01	0.01	0.01	ug/L	0.10	0.10	1.00	0.00
Chlordane-alpha	0.01	0.01	2.00	0.00	0.01	0.00	0.01	ug/L	0.01	0.10	2.00	0.00
Chlordane-gamma	0.01	0.01	2.00	0.00	0.01	0.00	0.01	ug/L	0.01	0.10	2.00	0.00
Chlorobenzilate	0.01	0.01	2.00	0.01	0.01	0.01	0.01	ug/L	0.05	0.10	2.00	0.00
Chloroneb	0.03	0.03	2.00	0.01	0.04	0.02	0.03	ug/L	0.10	0.40	2.00	0.00
Chlorothalonil	0.26	0.26	2.00	0.01	0.50	0.13	0.38	ug/L	0.10	5.00	2.00	0.00
Chlorpropham	0.01	0.01	1.00	0.01	0.01	0.01	0.01	ug/L	0.10	0.10	1.00	0.00
Chlorpyrifos	0.01	0.01	2.00	0.01	0.01	0.01	0.01	ug/L	0.10	0.10	2.00	0.00
Chrysene	0.01	0.01	1.00	0.01	0.01	0.01	0.01	ug/L	0.10	0.10	1.00	0.00
Cycloate	0.01	0.01	1.00	0.01	0.01	0.01	0.01	ug/L	0.10	0.10	1.00	0.00
DCPA-Dacthal	0.01	0.01	2.00	0.01	0.01	0.01	0.01	ug/L	0.05	0.10	2.00	0.00
Dalapon	0.10	0.10	1.00	0.10	0.10	0.10	0.10	ug/L	1.00	1.00	1.00	0.00
Di-n-butylphthalate	0.20	0.20	1.00	0.20	0.20	0.20	0.20	ug/L	2.00	2.00	1.00	0.00
Di-n-octyl phthalate	0.20	0.20	1.00	0.20	0.20	0.20	0.20	ug/L	2.00	2.00	1.00	0.00
Diazinon	0.01	0.01	1.00	0.01	0.01	0.01	0.01	ug/L	0.10	0.10	1.00	0.00
Dibenzo(a,h)anthracene	0.01	0.01	1.00	0.01	0.01	0.01	0.01	ug/L	0.10	0.10	1.00	0.00
Dicamba	0.01	0.01	1.00	0.01	0.01	0.01	0.01	ug/L	0.08	0.08	1.00	0.00
Dichlorvos	0.01	0.01	1.00	0.01	0.01	0.01	0.01	ug/L	0.10	0.10	1.00	0.00
Dieldrin	0.01	0.01	2.00	0.00	0.01	0.00	0.01	ug/L	0.02	0.10	2.00	0.00
Diethyl phthalate	0.20	0.20	1.00	0.20	0.20	0.20	0.20	ug/L	2.00	2.00	1.00	0.00
Dimethoate	0.26	0.26	2.00	0.01	0.50	0.13	0.38	ug/L	0.10	5.00	2.00	0.00
Dimethyl phthalate	0.20	0.20	1.00	0.20	0.20	0.20	0.20	ug/L	2.00	2.00	1.00	0.00
Dinoseb	0.05	0.05	1.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	1.00	0.00
Diphenamid	0.01	0.01	1.00	0.01	0.01	0.01	0.01	ug/L	0.10	0.10	1.00	0.00
Diquat	0.40	0.40	1.00	0.40	0.40	0.40	0.40	ug/L	4.00	4.00	1.00	0.00
Diuron	0.00	0.04	19.00	0.00	0.41	0.00	0.04	ug/L	0.01	1.00	12.00	7.00
EPTC	0.01	0.01	2.00	0.01	0.01	0.01	0.01	ug/L	0.10	0.10	2.00	0.00
Endosulfan I	0.01	0.01	2.00	0.01	0.01	0.01	0.01	ug/L	0.05	0.10	2.00	0.00
Endosulfan sulfate	0.01	0.01	2.00	0.01	0.01	0.01	0.01	ug/L	0.05	0.10	2.00	0.00
Endothal	4.50	4.50	1.00	4.50	4.50	4.50	4.50	ug/L	45.00	45.00	1.00	0.00
Endrin	0.01	0.01	2.00	0.00	0.01	0.00	0.01	ug/L	0.03	0.10	2.00	0.00
Endrin Aldehyde	0.01	0.01	2.00	0.01	0.01	0.01	0.01	ug/L	0.10	0.10	2.00	0.00
Endrin Ketone	0.01	0.01	1.00	0.01	0.01	0.01	0.01	ug/L	0.10	0.10	1.00	0.00
Erythromycin	0.10	0.12	18.00	0.10	0.50	0.10	0.10	ng/L	1.00	5.00	18.00	0.00
Ethion	0.01	0.01	2.00	0.01	0.01	0.01	0.01	ug/L	0.10	0.10	2.00	0.00
Ethoprop	0.01	0.01	1.00	0.01	0.01	0.01	0.01	ug/L	0.10	0.10	1.00	0.00
Etnidiazole	0.01	0.01	2.00	0.01	0.01	0.01	0.01	ug/L	0.05	0.10	2.00	0.00
Fenarimol	0.10	0.10	1.00	0.10	0.10	0.10	0.10	ug/L	1.00	1.00	1.00	0.00
Fluoranthene	0.01	0.01	1.00	0.01	0.01	0.01	0.01	ug/L	0.10	0.10	1.00	0.00
Fluorene	0.01	0.01	1.00	0.01	0.01	0.01	0.01	ug/L	0.10	0.10	1.00	0.00
Fluoridone	0.20	0.20	1.00	0.20	0.20	0.20	0.20	ug/L	2.00	2.00	1.00	0.00
Gemfibrozil	0.10	0.10	18.00	0.10	0.10	0.10	0.10	ng/L	1.00	1.00	18.00	0.00
Glyphosate	2.50	2.50	1.00	2.50	2.50	2.50	2.50	ug/L	25.00	25.00	1.00	0.00
HCH-gamma (Lindane)	0.01	0.01	2.00	0.01	0.01	0.01	0.01	ug/L	0.10	0.10	2.00	0.00
Heptachlor	0.01	0.01	2.00	0.00	0.01	0.00	0.01	ug/L	0.01	0.10	2.00	0.00
Heptachlor epoxide	0.01	0.01	2.00	0.00	0.01	0.00	0.01	ug/L	0.01	0.10	2.00	0.00
Hexachlorobenzene	0.03	0.03	2.00	0.01	0.05	0.02	0.04	ug/L	0.10	0.50	2.00	0.00
Hexachlorocyclopentadiene	0.03	0.03	2.00	0.01	0.05	0.02	0.04	ug/L	0.10	0.50	2.00	0.00
Hexazinone	0.01	0.01	1.00	0.01	0.01	0.01	0.01	ug/L	0.10	0.10	1.00	0.00
Ibuprofen	0.10	0.24	18.00	0.10	1.00	0.10	0.10	ng/L	1.00	10.00	18.00	0.00
Indeno(1,2,3-cd)pyrene	0.01	0.01	1.00	0.01	0.01	0.01	0.01	ug/L	0.10	0.10	1.00	0.00
MGK 264	0.01	0.01	1.00	0.01	0.01	0.01	0.01	ug/L	0.10	0.10	1.00	0.00
Malathion	0.60	0.60	1.00	0.60	0.60	0.60	0.60	ug/L	6.00	6.00	1.00	0.00
Methiocarb	0.40	0.40	1.00	0.40	0.40	0.40	0.40	ug/L	4.00	4.00	1.00	0.00
Methomyl	0.10	0.10	1.00	0.10	0.10	0.10	0.10	ug/L	1.00	1.00	1.00	0.00
Methoxychlor	0.06	0.06	2.00	0.01	0.10	0.03	0.08	ug/L	0.10	1.00	2.00	0.00
Methyl paraoxon	0.10	0.10	1.00	0.10	0.10	0.10	0.10	ug/L	1.00	1.00	1.00	0.00
Metribuzin	0.02	0.02	1.00	0.02	0.02	0.02	0.02	ug/L	0.20	0.20	1.00	0.00
Mevinphos	0.10	0.10	1.00	0.10	0.10	0.10	0.10	ug/L	1.00	1.00	1.00	0.00
Molinate	0.03	0.03	2.00	0.01	0.05	0.02	0.04	ug/L	0.10	0.50	2.00	0.00
N,N-diethyl-m-toluamide	0.10	0.89	18.00	0.10	7.40	0.10	0.50	ng/L	1.00	5.00	14.00	4.00
Napropamide	0.01	0.01	1.00	0.01	0.01	0.01	0.01	ug/L	0.10	0.10	1.00	0.00
Norflurazon	0.08	0.08	2.00	0.05	0.10	0.06	0.09	ug/L	0.50	1.00	2.00	0.00
Oxamyl	0.20	0.20	1.00	0.20	0.20	0.20	0.20	ug/L	2.00	2.00	1.00	0.00
Paraquat	0.40	0.40	1.00	0.40	0.40	0.40	0.40	ug/L	4.00	4.00	1.00	0.00
Parathion	0.05	0.05	1.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	1.00	0.00
Pebulate	0.01	0.01	1.00	0.01	0.01	0.01	0.01	ug/L	0.10	0.10	1.00	0.00
Pentachlorophenol (PCP)	0.02	0.03	12.00	0.01	0.10	0.02	0.02	ug/L	0.10	1.00	12.00	0.00
Permethrin-(total of cis/trans)	0.01	0.01	2.00	0.01	0.01	0.01	0.01	ug/L	0.10	0.10	2.00	0.00
Phenanthrene	0.01	0.01	1.00	0.01	0.01	0.01	0.01	ug/L	0.10	0.10	1.00	0.00
Picloram	0.05	0.05	1.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	1.00	0.00
Primidone	41.00	41.74	18.00	5.00	71.00	35.55	48.65	ng/L	1.00	100.00	2.00	16.00
Prometon	0.01	0.01	1.00	0.01	0.01	0.01	0.01	ug/L	0.10	0.10	1.00	0.00
Prometryn	0.01	0.01	2.00	0.01	0.01	0.01	0.01	ug/L	0.10	0.10	2.00	0.00
Pronamide	0.01	0.01	1.00	0.01	0.01	0.01	0.01	ug/L	0.10	0.10	1.00	0.00
Propachlor	0.05	0.04	3.00	0.01	0.05	0.03	0.05	ug/L	0.10	0.50	3.00	0.00
Propazine	0.01	0.01	2.00	0.01	0.01	0.01	0.01	ug/L	0.10	0.10	2.00	0.00
Pyrene	0.01	0.01	1.00	0.01	0.01	0.01	0.01	ug/L	0.10	0.10	1.00	0.00
Simazine	0.02	0.02	19.00	0.01	0.04	0.01	0.02	ug/L	0.01	0.10	2.00	0.00

TABLE: AM-51 Well Water Quality Summary Data (2013-2023)

PARAMETER NAME	MEDIAN	MEAN	N=	MINIMUM	MAXIMUM	25th PERCENTILE	75th PERCENTILE	UNITS	MIN RDL	MAX RDL	# of NDs	# of DETECTS
Simetryn	0.10	0.10	1.00	0.10	0.10	0.10	0.10	ug/L	1.00	1.00	1.00	0.00
Stirofos	0.20	0.20	1.00	0.20	0.20	0.20	0.20	ug/L	2.00	2.00	1.00	0.00
Sulfamethoxazole	44.60	51.42	18.00	14.90	120.00	35.70	55.13	ng/L	1.00	5.00	0.00	18.00
Tebuthiuron	0.15	0.15	2.00	0.10	0.20	0.13	0.18	ug/L	1.00	2.00	2.00	0.00
Terbacil	0.01	0.01	2.00	0.01	0.01	0.01	0.01	ug/L	0.10	0.10	2.00	0.00
Terbutryn	0.01	0.01	1.00	0.01	0.01	0.01	0.01	ug/L	0.10	0.10	1.00	0.00
Thiobencarb	0.03	0.03	2.00	0.01	0.05	0.02	0.04	ug/L	0.10	0.50	2.00	0.00
Toxaphene Mixture	0.10	0.10	1.00	0.10	0.10	0.10	0.10	ug/L	1.00	1.00	1.00	0.00
Triadimefon	0.10	0.10	1.00	0.10	0.10	0.10	0.10	ug/L	1.00	1.00	1.00	0.00
Triclosan	0.10	0.19	18.00	0.10	1.00	0.10	0.10	ng/L	1.00	10.00	18.00	0.00
Tricyclazole	0.20	0.20	1.00	0.20	0.20	0.20	0.20	ug/L	2.00	2.00	1.00	0.00
Trifluralin	0.01	0.01	2.00	0.01	0.01	0.01	0.01	ug/L	0.05	0.10	2.00	0.00
Trithion	0.01	0.01	1.00	0.01	0.01	0.01	0.01	ug/L	0.10	0.10	1.00	0.00
Vernolate	0.01	0.01	1.00	0.01	0.01	0.01	0.01	ug/L	0.10	0.10	1.00	0.00
bis (2-ethylhexyl) adipate	0.20	0.20	1.00	0.20	0.20	0.20	0.20	ug/L	2.00	2.00	1.00	0.00
bis (2-ethylhexyl) phthalate	0.20	0.20	1.00	0.20	0.20	0.20	0.20	ug/L	2.00	2.00	1.00	0.00
methyl-Parathion	0.05	0.05	1.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	1.00	0.00
trans-nonachlor	0.01	0.01	1.00	0.01	0.01	0.01	0.01	ug/L	0.10	0.10	1.00	0.00

TABLE: AM-51A Well Water Quality Summary Data (2014-2023)

PARAMETER NAME	MEDIAN	MEAN	N=	MINIMUM	MAXIMUM	25th PERCENTILE	75th PERCENTILE	UNITS	MIN RDL	MAX RDL	# of NDs	# of DETECTS
<b>BIOLOGICAL</b>												
E. Coli (Membrane Filtration - CFU/100ml)	0.10	0.10	2.00	0.10	0.10	0.10	0.10	CFU/100	1.00	1.00	0.00	2.00
Enterococcus (Membrane Filtration-CFU/100ml)	0.10	0.10	2.00	0.10	0.10	0.10	0.10	CFU/100	1.00	1.00	0.00	2.00
Total Coliform (Membrane Filtration-CFU/100ml)	0.10	0.10	2.00	0.10	0.10	0.10	0.10	CFU/100	1.00	1.00	0.00	2.00
<b>FIELD MEASUREMENTS</b>												
Field Dissolved Oxygen	5.59	5.02	15.00	0.52	8.03	3.87	6.64	mg/L	0.00	0.01	0.00	15.00
Field Electrical Conductivity	998.00	958.75	16.00	605.00	1270.00	823.25	1065.00	uS/cm	0.00	1.00	0.00	16.00
Field Oxidation-Reduction Potential	123.00	116.13	15.00	-40.00	256.00	65.00	160.00	mV	-1000.00	-1000.00	0.00	15.00
Field Temperature	19.90	20.43	16.00	14.70	25.60	19.28	21.48	C	0.00	1.00	0.00	16.00
Field pH	7.55	7.51	16.00	7.20	7.70	7.38	7.63	UNITS	0.00	1.00	0.00	16.00
<b>INORGANIC</b>												
Aggressive Index	12.43	12.49	7.00	12.28	12.66	12.42	12.61	A.I.			0.00	7.00
Alkalinity-Phenolphthalein	0.10	0.10	16.00	0.10	0.10	0.10	0.10	mg/L	1.00	1.00	0.00	16.00
Aluminum (dissolved)	2.30	2.86	9.00	1.20	5.50	1.70	4.00	ug/L	1.00	1.00	0.00	9.00
Ammonia Nitrogen	0.01	0.01	10.00	0.01	0.01	0.01	0.01	mg/L	0.10	0.10	0.00	10.00
Antimony (dissolved)	0.10	0.20	9.00	0.10	0.60	0.10	0.10	ug/L	0.50	1.00	0.00	9.00
Arsenic (dissolved)	2.90	2.78	9.00	1.90	4.30	2.20	3.00	ug/L	1.00	1.00	0.00	9.00
Barium (dissolved)	50.30	50.07	9.00	35.90	71.30	42.80	55.10	ug/L	1.00	1.00	0.00	9.00
Beryllium (dissolved)	0.10	0.09	9.00	0.05	0.10	0.10	0.10	ug/L	0.50	1.00	0.00	9.00
Bicarbonate (as CaCO3)	190.50	195.19	16.00	140.00	255.00	166.75	223.50	mg/L	1.00	1.00	0.00	16.00
Bicarbonate (as HCO3)	232.25	237.94	16.00	170.70	310.80	203.30	272.43	mg/L	1.20	1.20	0.00	16.00
Boron	0.30	0.30	7.00	0.23	0.34	0.30	0.32	mg/L	0.10	0.10	0.00	7.00
Boron (dissolved)	0.20	0.19	9.00	0.10	0.20	0.20	0.20	mg/L	0.10	0.10	0.00	9.00
Bromide	0.17	0.16	16.00	0.01	0.23	0.13	0.18	mg/L	0.01	0.10	0.00	16.00
Cadmium (dissolved)	0.10	0.10	9.00	0.10	0.10	0.10	0.10	ug/L	1.00	1.00	0.00	9.00
Calcium	88.40	86.21	7.00	59.00	103.00	83.20	93.35	mg/L	0.50	0.50	0.00	7.00
Calcium (dissolved)	68.10	65.97	9.00	44.90	84.10	58.10	78.60	mg/L	0.50	0.50	0.00	9.00
Carbonate (as CaCO3)	0.10	0.10	16.00	0.10	0.10	0.10	0.10	mg/L	1.00	1.00	0.00	16.00
Cation-Anion meq balance	1.14	0.04	6.00	-3.96	3.61	-2.57	1.86	RATIO			0.00	6.00
Chloride	118.00	114.18	16.00	61.00	158.00	92.40	144.25	mg/L	0.50	2.00	0.00	16.00
Chromium (dissolved)	0.10	0.37	9.00	0.10	1.40	0.10	0.10	ug/L	1.00	1.00	0.00	9.00
Cobalt (dissolved)	0.10	0.10	9.00	0.10	0.10	0.10	0.10	ug/L	1.00	1.00	0.00	9.00
Copper (dissolved)	3.70	3.80	9.00	2.80	4.70	3.40	4.30	ug/L	1.00	1.00	0.00	9.00
Electrical Conductivity	989.50	960.81	16.00	632.00	1230.00	854.75	1087.50	uS/cm	1.00	1.00	0.00	16.00
Fluoride	0.31	0.32	9.00	0.29	0.37	0.30	0.35	mg/L	0.10	0.10	0.00	9.00
Gadolinium (dissolved)	35.70	42.86	9.00	27.30	80.60	32.20	50.20	ng/L	10.00	10.00	0.00	9.00
Hydroxide (as CaCO3)	0.10	0.18	16.00	0.10	0.50	0.10	0.10	mg/L	1.00	5.00	6.00	10.00
Iron (dissolved)	2.80	2.73	9.00	0.50	6.00	0.50	4.20	ug/L	1.00	5.00	0.00	9.00
Lead (dissolved)	0.10	0.10	9.00	0.10	0.10	0.10	0.10	ug/L	1.00	1.00	0.00	9.00
Magnesium	22.30	21.99	7.00	15.40	26.10	20.90	24.15	mg/L	0.50	0.50	0.00	7.00
Magnesium (dissolved)	17.90	17.07	9.00	11.90	21.10	15.10	20.30	mg/L	0.50	0.50	0.00	9.00
Manganese (dissolved)	0.10	0.10	9.00	0.10	0.10	0.10	0.10	ug/L	1.00	1.00	0.00	9.00
Mercury (dissolved)	0.10	0.07	9.00	0.01	0.10	0.01	0.10	ug/L	0.10	1.00	0.00	9.00
Nickel (dissolved)	2.40	2.39	9.00	1.00	4.40	1.70	2.50	ug/L	1.00	1.00	0.00	9.00
Nitrate	8.45	8.71	16.00	1.00	27.60	4.30	11.15	mg/L	0.40	0.40	0.00	16.00
Nitrate + Nitrite Nitrogen	1.98	2.32	11.00	0.74	6.23	1.30	2.76	mg/L	0.10	0.10	0.00	11.00
Nitrate Nitrogen	1.90	1.97	16.00	0.22	6.23	0.98	2.51	mg/L	0.10	0.10	0.00	16.00
Nitrite	0.00	0.00	11.00	0.00	0.02	0.00	0.00	mg/L	0.00	0.01	7.00	4.00
Nitrite Nitrogen	0.00	0.00	11.00	0.00	0.01	0.00	0.00	mg/L	0.00	0.00	0.00	11.00
Organic Nitrogen	0.20	0.19	10.00	0.01	0.30	0.13	0.30	mg/L	0.10	0.10	0.00	10.00
Perchlorate	0.23	0.23	8.00	0.20	0.25	0.20	0.25	ug/L	2.00	2.50	0.00	8.00
Phosphate Phosphorus (orthophosphate)	0.58	0.59	10.00	0.54	0.72	0.57	0.59	mg/L	0.01	0.01	0.00	10.00
Potassium	13.40	12.70	7.00	8.80	14.80	11.75	14.20	mg/L	0.50	0.50	0.00	7.00
Potassium (dissolved)	9.90	9.94	9.00	7.10	12.60	8.50	11.40	mg/L	0.50	0.50	0.00	9.00
Selenium (dissolved)	0.10	0.10	9.00	0.10	0.10	0.10	0.10	ug/L	1.00	1.00	0.00	9.00
Silica	12.90	13.68	9.00	10.50	17.60	12.40	15.20	mg/L	1.00	1.00	0.00	9.00
Silver (dissolved)	0.10	0.10	9.00	0.10	0.10	0.10	0.10	ug/L	1.00	1.00	0.00	9.00
Sodium	113.00	107.57	7.00	81.00	115.00	107.50	114.50	mg/L	0.50	0.50	0.00	7.00
Sodium (dissolved)	79.20	79.22	9.00	59.30	95.40	69.00	89.30	mg/L	0.50	0.50	0.00	9.00
Sulfate	105.50	109.28	16.00	72.10	176.00	93.05	119.50	mg/L	0.50	2.00	0.00	16.00
Suspended Solids	1.68	4.78	6.00	0.25	19.00	0.25	5.13	mg/L	1.00	2.50	0.00	6.00
Temperature (Laboratory)	21.70	21.47	7.00	20.50	22.10	21.05	21.95	C	1.00	1.00	0.00	7.00
Thallium (dissolved)	0.10	0.09	9.00	0.05	0.10	0.10	0.10	ug/L	0.50	1.00	0.00	9.00
Title 22 Total Anions	8.25	8.34	9.00	6.18	10.24	7.51	9.63	meq/L			0.00	9.00
Title 22 Total Cations	11.53	11.12	7.00	7.96	12.67	10.86	11.97	meq/L			0.00	7.00
Total Alkalinity (as CaCO3)	190.50	195.19	16.00	140.00	255.00	166.75	223.50	mg/L	1.00	5.00	0.00	16.00
Total Anions	8.22	8.36	6.00	6.66	9.89	7.69	9.29	meq/L	0.00	0.00	0.00	6.00
Total Cations	8.40	8.39	6.00	6.40	10.09	7.50	9.47	meq/L	0.00	0.00	0.00	6.00
Total Dissolved Solids	492.00	501.80	10.00	350.00	676.00	460.50	554.00	mg/L	1.00	2.50	0.00	10.00
Total Hardness (as CaCO3)	211.00	211.00	1.00	211.00	211.00	211.00	211.00	mg/L	1.00	1.00	0.00	1.00
Total Hardness (as CaCO3) (dissolved)	244.00	234.89	9.00	161.00	296.00	207.00	280.00	mg/L	1.00	1.00	0.00	9.00
Total Kjeldahl Nitrogen	0.20	0.19	10.00	0.02	0.30	0.07	0.30	mg/L	0.20	0.20	0.00	10.00
Total Nitrogen	2.05	2.40	10.00	0.90	6.20	1.51	2.74	mg/L	0.10	0.20	0.00	10.00

TABLE: AM-51A Well Water Quality Summary Data (2014-2023)

PARAMETER NAME	MEDIAN	MEAN	N=	MINIMUM	MAXIMUM	25th PERCENTILE	75th PERCENTILE	UNITS	MIN RDL	MAX RDL	# of NDs	# of DETECTS
Total Organic Carbon (Unfiltered)	2.37	2.47	16.00	1.39	3.59	2.14	2.78	mg/L	0.05	0.05	0.00	16.00
Turbidity	0.60	1.93	9.00	0.20	8.00	0.30	2.80	NTU	0.10	0.10	0.00	9.00
UV Absorbance/TOC (unfiltered) ratio	0.03	0.03	9.00	0.02	0.03	0.02	0.03	L/mg-cm	0.00	0.00	0.00	9.00
Ultraviolet (absorbance)	0.07	0.07	9.00	0.05	0.10	0.06	0.08	1/cm	0.01	0.01	0.00	9.00
Vanadium (dissolved)	5.60	5.66	9.00	4.20	7.00	5.30	6.20	ug/L	1.00	1.00	0.00	9.00
Zinc (dissolved)	2.10	4.10	9.00	0.10	18.90	1.30	4.50	ug/L	1.00	1.00	0.00	9.00
pH	7.90	7.84	16.00	7.60	8.00	7.78	7.90	UNITS	1.00	1.00	0.00	16.00
<b>ORGANIC</b>												
1,1,1,2-Tetrachloroethane	0.05	0.05	8.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	8.00	0.00
1,1,1-Trichloroethane	0.05	0.05	8.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	8.00	0.00
1,1,2,2-Tetrachloroethane	0.05	0.05	8.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	8.00	0.00
1,1,2-Trichloroethane	0.05	0.05	8.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	8.00	0.00
1,1-Dichloroethane	0.05	0.05	8.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	8.00	0.00
1,1-Dichloroethene	0.05	0.05	8.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	8.00	0.00
1,1-Dichloropropene	0.05	0.05	8.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	8.00	0.00
1,2,3-Trichlorobenzene	0.05	0.05	8.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	8.00	0.00
1,2,3-Trichloropropane	0.05	0.03	13.00	0.00	0.05	0.00	0.05	ug/L	0.01	0.50	13.00	0.00
1,2,4-Trichlorobenzene	0.05	0.05	8.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	8.00	0.00
1,2,4-Trimethylbenzene	0.05	0.05	8.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	8.00	0.00
1,2-Dibromo-3-chloropropane	0.05	0.03	13.00	0.00	0.05	0.00	0.05	ug/L	0.01	0.50	13.00	0.00
1,2-Dibromoethane	0.05	0.03	13.00	0.00	0.05	0.00	0.05	ug/L	0.01	0.50	13.00	0.00
1,2-Dichlorobenzene	0.05	0.05	8.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	8.00	0.00
1,2-Dichloroethane	0.05	0.05	8.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	8.00	0.00
1,2-Dichloropropane	0.05	0.05	8.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	8.00	0.00
1,3,5-Trimethylbenzene	0.05	0.05	8.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	8.00	0.00
1,3-Dichlorobenzene	0.05	0.05	8.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	8.00	0.00
1,3-Dichloropropane	0.05	0.05	8.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	8.00	0.00
1,4-Dichlorobenzene	0.05	0.05	8.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	8.00	0.00
1,4-Dioxane	0.08	0.08	8.00	0.05	0.10	0.05	0.10	ug/L	0.50	1.00	8.00	0.00
11-chloroeicosafluoro-3-oxaundecane-1-sulfonic acid	0.20	0.20	1.00	0.20	0.20	0.20	0.20	ng/L	2.00	2.00	1.00	0.00
2,2-Dichloropropane	0.05	0.05	8.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	8.00	0.00
2-Chloroethylvinyl ether	0.10	0.10	5.00	0.10	0.10	0.10	0.10	ug/L	1.00	1.00	5.00	0.00
2-Chlorotoluene	0.05	0.05	8.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	8.00	0.00
2-Hexanone	1.00	1.00	1.00	1.00	1.00	1.00	1.00	ug/L	10.00	10.00	1.00	0.00
4,8-dioxa-3H-perfluorononanoic acid	0.20	0.20	1.00	0.20	0.20	0.20	0.20	ng/L	2.00	2.00	1.00	0.00
4-Androstene-3,17-dione	0.20	0.20	1.00	0.20	0.20	0.20	0.20	ng/L	2.00	2.00	1.00	0.00
4-Chlorotoluene	0.05	0.05	8.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	8.00	0.00
4-Isopropyltoluene	0.05	0.05	8.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	8.00	0.00
4-n-Octylphenol	0.02	0.02	1.00	0.02	0.02	0.02	0.02	ug/L	0.20	0.20	1.00	0.00
4-tert-Octylphenol	0.02	0.02	1.00	0.02	0.02	0.02	0.02	ug/L	0.20	0.20	1.00	0.00
9-chlorohexadecafluoro-3-oxanone-1-sulfonic acid	0.20	0.20	1.00	0.20	0.20	0.20	0.20	ng/L	2.00	2.00	1.00	0.00
Acetone	1.00	1.00	8.00	1.00	1.00	1.00	1.00	ug/L	10.00	10.00	8.00	0.00
Acrolein	0.50	0.67	3.00	0.50	1.00	0.50	0.75	ug/L	5.00	10.00	3.00	0.00
Acrylonitrile	0.20	0.47	3.00	0.20	1.00	0.20	0.60	ug/L	2.00	10.00	3.00	0.00
Aspartame	10.00	10.00	6.00	10.00	10.00	10.00	10.00	ng/L	100.00	100.00	6.00	0.00
Atenolol	0.50	0.50	6.00	0.50	0.50	0.50	0.50	ng/L	5.00	5.00	6.00	0.00
Benzene	0.05	0.05	8.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	8.00	0.00
Bisphenol A	0.02	0.02	1.00	0.02	0.02	0.02	0.02	ug/L	0.20	0.20	1.00	0.00
Bromobenzene	0.05	0.05	8.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	8.00	0.00
Bromochloromethane	0.05	0.05	8.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	8.00	0.00
Bromodichloromethane	0.05	0.05	8.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	8.00	0.00
Bromoform	0.05	0.05	8.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	8.00	0.00
Bromomethane	0.05	0.05	8.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	8.00	0.00
Carbon Disulfide	0.05	0.05	8.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	8.00	0.00
Carbon tetrachloride	0.05	0.05	8.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	8.00	0.00
Chlorobenzene	0.05	0.05	8.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	8.00	0.00
Chlorodifluoromethane	0.05	0.05	8.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	8.00	0.00
Chloroethane	0.05	0.05	8.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	8.00	0.00
Chloroform	0.25	0.21	8.00	0.05	0.50	0.05	0.25	ug/L	0.50	0.50	3.00	5.00
Chloromethane	0.05	0.05	8.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	8.00	0.00
Chlorotrifluoroethene	0.50	0.50	1.00	0.50	0.50	0.50	0.50	ug/L	5.00	5.00	1.00	0.00
Dibromochloromethane	0.05	0.05	8.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	8.00	0.00
Dibromomethane	0.05	0.05	8.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	8.00	0.00
Dichlorodifluoromethane	0.05	0.05	8.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	8.00	0.00
Diclofenac	0.50	0.50	6.00	0.50	0.50	0.50	0.50	ng/L	5.00	5.00	6.00	0.00
Diisopropyl ether	0.10	0.10	8.00	0.10	0.10	0.10	0.10	ug/L	1.00	1.00	8.00	0.00
Dilantin	22.95	21.50	6.00	1.00	38.00	14.45	30.10	ng/L	10.00	10.00	1.00	5.00
Dissolved Organic Carbon	2.59	2.63	9.00	1.83	3.56	2.21	2.96	mg/L	0.05	0.05	0.00	9.00
Epitestosterone (cis-Testosterone)	0.10	0.10	1.00	0.10	0.10	0.10	0.10	ng/L	1.00	1.00	1.00	0.00
Ethyl tert-butyl ether	0.10	0.10	8.00	0.10	0.10	0.10	0.10	ug/L	1.00	1.00	8.00	0.00
Ethylbenzene	0.05	0.05	8.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	8.00	0.00
Fluoxetine	0.50	0.50	6.00	0.50	0.50	0.50	0.50	ng/L	5.00	5.00	6.00	0.00
Freon 123a	0.05	0.05	8.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	8.00	0.00
Hexachlorobutadiene	0.05	0.05	8.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	8.00	0.00

TABLE: AM-51A Well Water Quality Summary Data (2014-2023)

PARAMETER NAME	MEDIAN	MEAN	N=	MINIMUM	MAXIMUM	25th PERCENTILE	75th PERCENTILE	UNITS	MIN RDL	MAX RDL	# of NDs	# of DETECTS
Hexafluoropropylene oxide dimer acid (GenX)	0.20	0.20	1.00	0.20	0.20	0.20	0.20	ng/L	2.00	2.00	1.00	0.00
Iohexol	26.65	48.90	6.00	2.00	195.00	7.63	38.03	ng/L	20.00	20.00	2.00	4.00
Iopromide	1.00	2.52	6.00	1.00	10.10	1.00	1.00	ng/L	10.00	10.00	5.00	1.00
Isopropylbenzene	0.05	0.05	8.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	8.00	0.00
Linuron	0.00	0.00	6.00	0.00	0.00	0.00	0.00	ug/L	0.01	0.01	6.00	0.00
Meprobamate	0.50	7.37	6.00	0.50	41.20	0.50	0.88	ng/L	5.00	10.00	5.00	1.00
Methyl Ethyl Ketone (MEK)	0.50	0.41	8.00	0.25	0.50	0.25	0.50	ug/L	2.50	5.00	8.00	0.00
Methyl Isobutyl Ketone (MIBK)	0.50	0.41	8.00	0.25	0.50	0.25	0.50	ug/L	2.50	5.00	8.00	0.00
Methyl tert-butyl ether	0.02	0.02	8.00	0.02	0.02	0.02	0.02	ug/L	0.20	0.20	8.00	0.00
Methylene Chloride	0.05	0.05	8.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	8.00	0.00
Methylisothiocyanate	0.01	0.01	5.00	0.00	0.01	0.01	0.01	ug/L	0.01	0.10	5.00	0.00
N-ethyl perfluorooctanesulfonamidoacetic acid	0.20	0.20	1.00	0.20	0.20	0.20	0.20	ng/L	2.00	2.00	1.00	0.00
N-methyl perfluorooctanesulfonamidoacetic acid	0.20	0.20	1.00	0.20	0.20	0.20	0.20	ng/L	2.00	2.00	1.00	0.00
Naphthalene	0.05	0.05	8.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	8.00	0.00
Naproxen	0.50	0.58	6.00	0.50	1.00	0.50	0.50	ng/L	5.00	10.00	6.00	0.00
Neotame	1.00	1.00	6.00	1.00	1.00	1.00	1.00	ng/L	10.00	10.00	6.00	0.00
Nitrobenzene	0.50	0.50	1.00	0.50	0.50	0.50	0.50	ug/L	5.00	5.00	1.00	0.00
Nonylphenol	0.02	0.02	1.00	0.02	0.02	0.02	0.02	ug/L	0.20	0.20	1.00	0.00
PFOA + PFOS	20.10	20.10	1.00	20.10	20.10	20.10	20.10	ng/L	2.00	2.00	0.00	1.00
Perfluoro butane sulfonic acid	12.40	12.40	1.00	12.40	12.40	12.40	12.40	ng/L	2.00	2.00	0.00	1.00
Perfluoro heptanoic acid	6.90	6.90	1.00	6.90	6.90	6.90	6.90	ng/L	2.00	2.00	0.00	1.00
Perfluoro hexane sulfonic acid	7.90	7.90	1.00	7.90	7.90	7.90	7.90	ng/L	2.00	2.00	0.00	1.00
Perfluoro nonanoic acid	0.20	0.20	1.00	0.20	0.20	0.20	0.20	ng/L	2.00	2.00	1.00	0.00
Perfluoro octane sulfonic acid	9.90	9.90	1.00	9.90	9.90	9.90	9.90	ng/L	2.00	2.00	0.00	1.00
Perfluoro octanoic acid	10.20	10.20	1.00	10.20	10.20	10.20	10.20	ng/L	2.00	2.00	0.00	1.00
Perfluorodecanoic acid	0.20	0.20	1.00	0.20	0.20	0.20	0.20	ng/L	2.00	2.00	1.00	0.00
Perfluorododecanoic acid	0.20	0.20	1.00	0.20	0.20	0.20	0.20	ng/L	2.00	2.00	1.00	0.00
Perfluorohexanoic acid	14.00	14.00	1.00	14.00	14.00	14.00	14.00	ng/L	2.00	2.00	0.00	1.00
Perfluorotetradecanoic acid	0.20	0.20	1.00	0.20	0.20	0.20	0.20	ng/L	2.00	2.00	1.00	0.00
Perfluorotridecanoic acid	0.20	0.20	1.00	0.20	0.20	0.20	0.20	ng/L	2.00	2.00	1.00	0.00
Perfluoroundecanoic acid	0.20	0.20	1.00	0.20	0.20	0.20	0.20	ng/L	2.00	2.00	1.00	0.00
PhenylPhenol	0.02	0.02	1.00	0.02	0.02	0.02	0.02	ug/L	0.20	0.20	1.00	0.00
Progesterone	0.10	0.10	1.00	0.10	0.10	0.10	0.10	ng/L	1.00	1.00	1.00	0.00
Propylbenzene	0.05	0.05	8.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	8.00	0.00
Styrene	0.05	0.05	8.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	8.00	0.00
Sucralose	15200.00	13428.33	6.00	6780.00	18900.00	9442.50	16525.00	ng/L	100.00	1000.00	0.00	6.00
Tert-amyl methyl ether	0.10	0.10	8.00	0.10	0.10	0.10	0.10	ug/L	1.00	1.00	8.00	0.00
Testosterone (trans-Testosterone)	0.10	0.10	1.00	0.10	0.10	0.10	0.10	ng/L	1.00	1.00	1.00	0.00
Tetrabromobisphenol A	0.02	0.02	1.00	0.02	0.02	0.02	0.02	ug/L	0.20	0.20	1.00	0.00
Tetrachloroethene	0.05	0.05	8.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	8.00	0.00
Toluene	0.05	0.05	8.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	8.00	0.00
Total 1,3-Dichloropropene	0.05	0.05	8.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	8.00	0.00
Total Organic Halogen	38.00	39.00	4.00	36.00	44.00	36.75	40.25	ug/L	20.00	20.00	0.00	4.00
Total Trihalomethanes	0.25	0.21	8.00	0.05	0.50	0.05	0.25	ug/L	0.50	0.50	3.00	5.00
Total Xylenes (m,p,&o)	0.05	0.05	8.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	8.00	0.00
Trichloroethene	0.05	0.05	8.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	8.00	0.00
Trichlorofluoromethane (Freon 11)	0.05	0.05	8.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	8.00	0.00
Trichlorotrifluoroethane (Freon 113)	0.05	0.05	8.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	8.00	0.00
Trimethoprim	0.50	0.50	6.00	0.50	0.50	0.50	0.50	ng/L	5.00	5.00	6.00	0.00
Tris-2-chloroethyl phosphate	26.45	34.73	6.00	0.50	100.00	1.88	52.60	ng/L	5.00	10.00	2.00	4.00
Vinyl Acetate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	ug/L	10.00	10.00	1.00	0.00
Vinyl chloride	0.05	0.05	8.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	8.00	0.00
bis (2-chloroethyl) ether	0.50	0.66	8.00	0.25	2.50	0.25	0.50	ug/L	2.50	25.00	8.00	0.00
cis-1,2-Dichloroethene	0.05	0.05	8.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	8.00	0.00
cis-1,3-Dichloropropene	0.05	0.05	8.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	8.00	0.00
m,p-Xylene	0.05	0.05	8.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	8.00	0.00
n-Butylbenzene	0.05	0.05	8.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	8.00	0.00
o-Xylene	0.05	0.05	8.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	8.00	0.00
para-Chlorobenzene sulfonic acid	20.00	20.00	6.00	20.00	20.00	20.00	20.00	ng/L	200.00	200.00	6.00	0.00
sec-Butylbenzene	0.05	0.05	8.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	8.00	0.00
tert-Butylbenzene	0.05	0.05	8.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	8.00	0.00
tert-butyl alcohol	0.20	0.20	8.00	0.20	0.20	0.20	0.20	ug/L	2.00	2.00	8.00	0.00
trans-1,2 Dichloroethene	0.05	0.05	8.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	8.00	0.00
trans-1,3-Dichloropropene	0.05	0.05	8.00	0.05	0.05	0.05	0.05	ug/L	0.50	0.50	8.00	0.00
<b>SEMI-ORGANIC</b>												
Acetaminophen	0.50	1.25	6.00	0.50	5.00	0.50	0.50	ng/L	5.00	50.00	6.00	0.00
Atrazine	0.00	0.00	6.00	0.00	0.01	0.00	0.00	ug/L	0.00	0.00	1.00	5.00
Azithromycin	1.00	2.33	6.00	1.00	5.00	1.00	4.00	ng/L	10.00	50.00	6.00	0.00
Caffeine	0.90	3.63	6.00	0.30	15.00	0.30	3.68	ng/L	3.00	15.00	4.00	2.00
Carbamazepine	68.95	61.97	6.00	35.60	74.00	57.28	70.43	ng/L	1.00	1.00	0.00	6.00
Diuron	0.03	0.08	6.00	0.00	0.33	0.01	0.05	ug/L	0.01	0.01	1.00	5.00

**TABLE: AM-51A Well Water Quality Summary Data (2014-2023)**

PARAMETER NAME	MEDIAN	MEAN	N=	MINIMUM	MAXIMUM	25th PERCENTILE	75th PERCENTILE	UNITS	MIN RDL	MAX RDL	# of NDs	# of DETECTS
Erythromycin	0.10	0.10	6.00	0.10	0.10	0.10	0.10	ng/L	1.00	1.00	6.00	0.00
Gemfibrozil	0.10	0.10	6.00	0.10	0.10	0.10	0.10	ng/L	1.00	1.00	6.00	0.00
Ibuprofen	0.10	0.32	6.00	0.10	1.00	0.10	0.40	ng/L	1.00	10.00	6.00	0.00
N,N-diethyl-m-toluamide	1.60	3.62	6.00	0.10	12.20	0.10	5.35	ng/L	1.00	1.00	3.00	3.00
Pentachlorophenol (PCP)	0.02	0.02	1.00	0.02	0.02	0.02	0.02	ug/L	0.20	0.20	1.00	0.00
Primidone	47.30	35.32	6.00	5.00	51.30	19.13	50.28	ng/L	1.00	100.00	2.00	4.00
Simazine	0.02	0.02	6.00	0.01	0.04	0.01	0.03	ug/L	0.01	0.01	0.00	6.00
Sulfamethoxazole	54.35	61.57	6.00	16.50	110.00	34.38	93.45	ng/L	1.00	1.00	0.00	6.00
Triclosan	0.10	0.17	6.00	0.10	0.50	0.10	0.10	ng/L	1.00	5.00	6.00	0.00

## **Appendix C**

### RBF System Collector Testing

RBF system collector schematics showing results of variations in lateral configuration testing. Nineteen tests were conducted between December 2015- October 2017.

Collector Testing #1



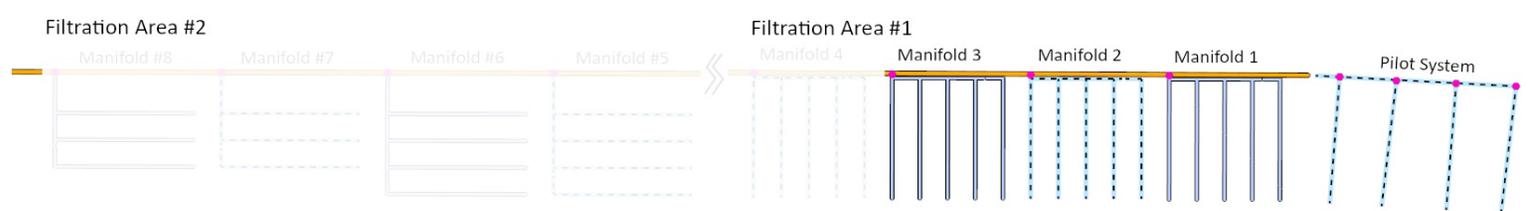
Date	# Open Sections	# of Combinations	Avg. Total Flow (cfs)	Avg Flow /Section (cfs)	Feet of Open Section	Avg flow /1000 ft
12/2015 to 1/2016	2	2	3.50	1.75	1,440	2.43

Collector Testing #2



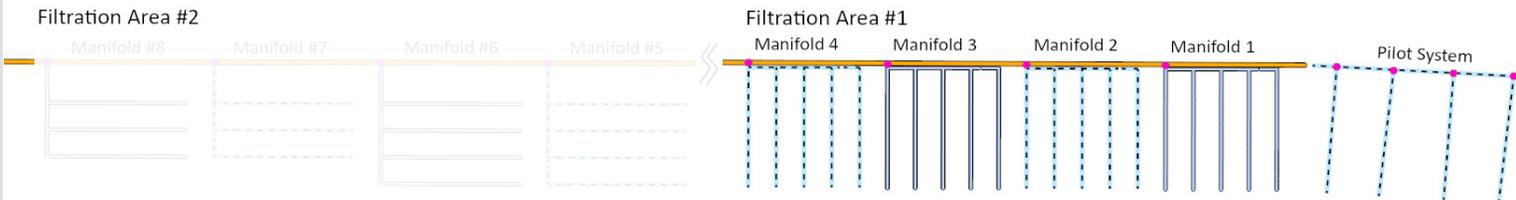
Date	# Open Sections	# of Combinations	Avg. Total Flow (cfs)	Avg Flow /Section (cfs)	Feet of Open Section	Avg flow /1000 ft
12/2015 to 1/2016	3	2	6.90	2.30	2,160	3.19

Collector Testing #3



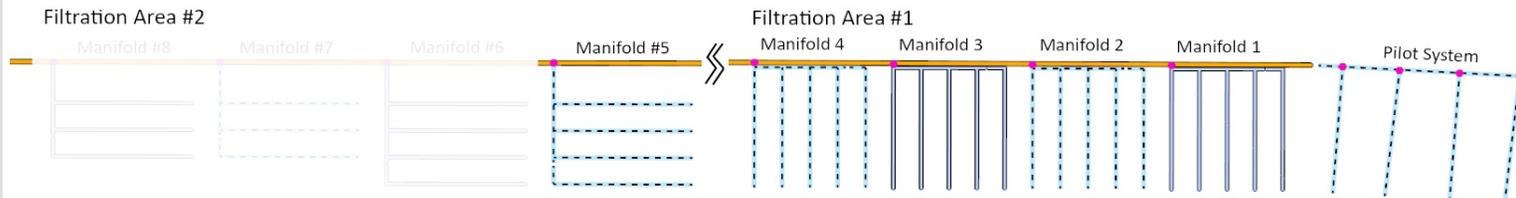
Date	# Open Sections	# of Combinations	Avg. Total Flow (cfs)	Avg Flow /Section (cfs)	Feet of Open Section	Avg flow /1000 ft
12/2015 to 1/2016	4	2	10.10	2.53	2,880	3.51

Collector Testing #4



Date	# Open Sections	# of Combinations	Avg. Total Flow (cfs)	Avg Flow/Section (cfs)	Feet of Open Section	Avg flow/1000 ft
12/2015 to 1/2016	5	2	12.60	2.52	3,600	3.50

Collector Testing #5



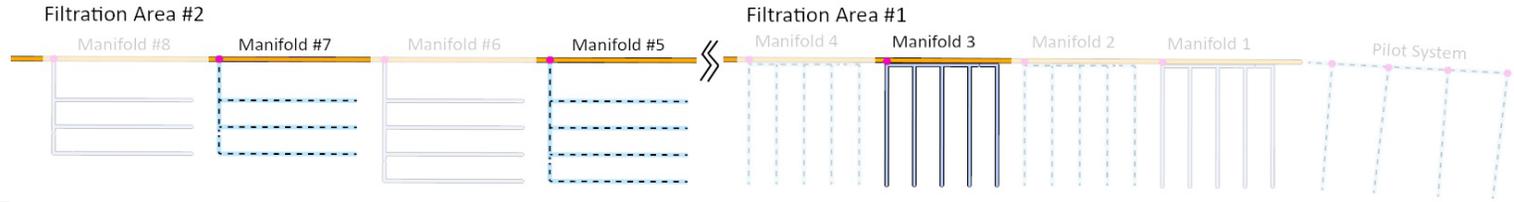
Date	# Open Sections	# of Combinations	Avg. Total Flow (cfs)	Avg Flow/Section (cfs)	Feet of Open Section	Avg flow/1000 ft
12/2015 to 1/2016	6	3	14.90	2.48	4,320	3.45

Collector Testing #6



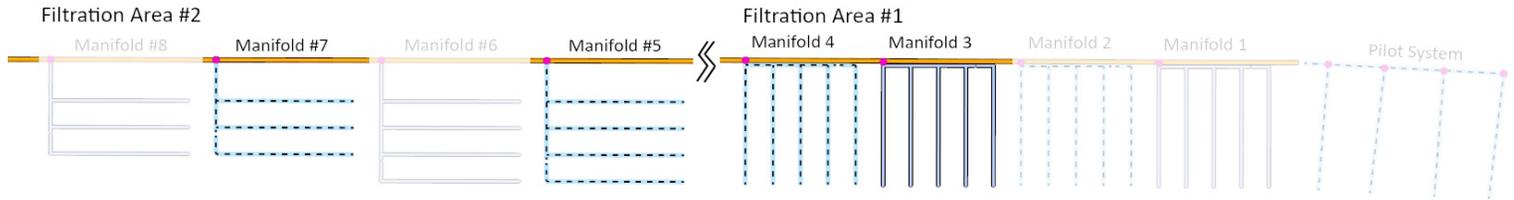
Date	# Open Sections	# of Combinations	Avg. Total Flow (cfs)	Avg Flow/Section (cfs)	Feet of Open Section	Avg flow/1000 ft
6/2016 to 8/2016	1	1	3.00	3.00	720	4.17

Collector Testing #7



Date	# Open Sections	# of Combinations	Avg. Total Flow (cfs)	Avg Flow /Section (cfs)	Feet of Open Section	Avg flow /1000 ft
6/2016 to 8/2016	3	2	9.50	3.17	1,980	4.80

Collector Testing #8



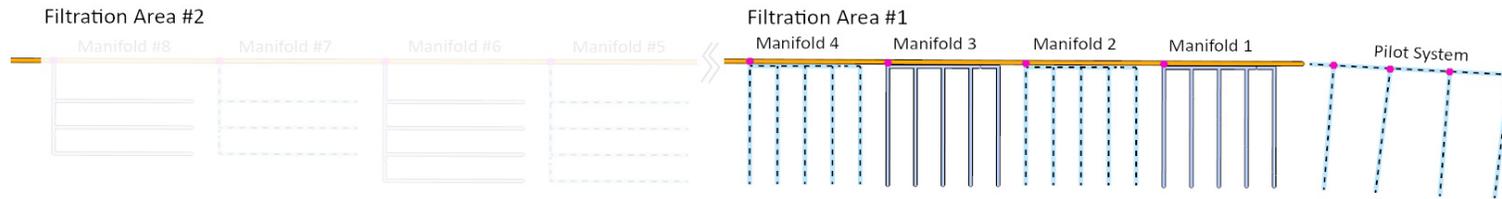
Date	# Open Sections	# of Combinations	Avg. Total Flow (cfs)	Avg Flow /Section (cfs)	Feet of Open Section	Avg flow /1000 ft
6/2016 to 8/2016	4	3	11.00	2.75	2,700	4.07

Collector Testing #9



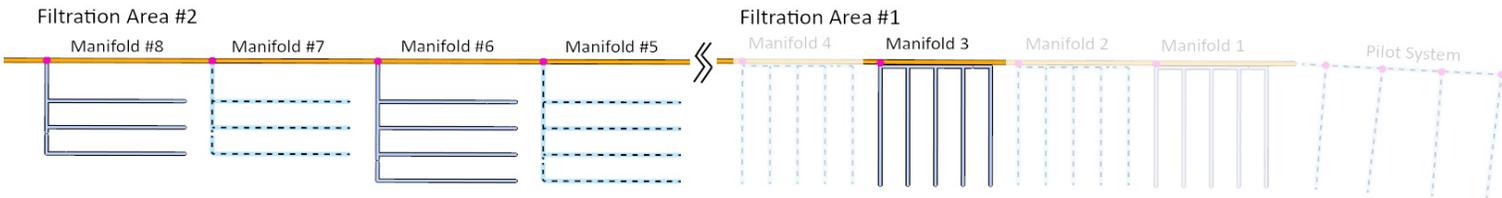
Date	# Open Sections	# of Combinations	Avg. Total Flow (cfs)	Avg Flow /Section (cfs)	Feet of Open Section	Avg flow /1000 ft
6/2016 to 8/2016	4	2	9.00	2.25	2,880	3.13

Collector Testing #10



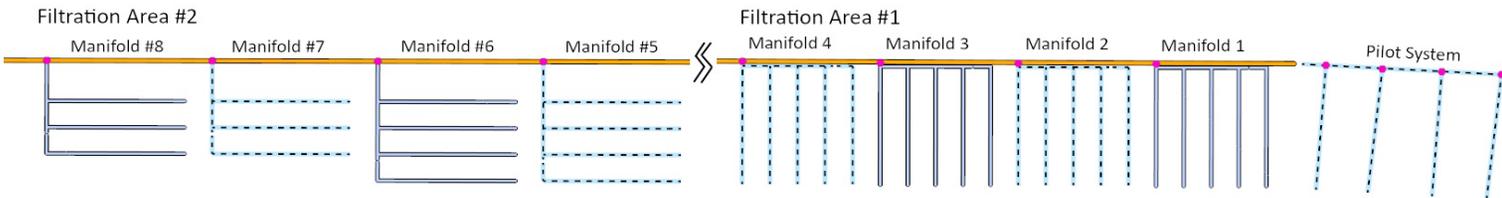
Date	# Open Sections	# of Combinations	Avg. Total Flow (cfs)	Avg Flow /Section (cfs)	Feet of Open Section	Avg flow /1000 ft
6/2016 to 8/2016	5	2	13.00	2.60	3,600	3.61

Collector Testing #11



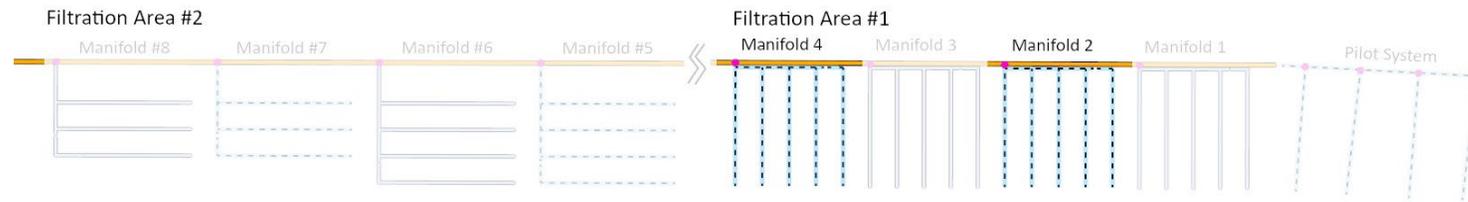
Date	# Open Sections	# of Combinations	Avg. Total Flow (cfs)	Avg Flow /Section (cfs)	Feet of Open Section	Avg flow /1000 ft
6/2016 to 8/2016	5	3	11.20	2.24	3,240	3.46

Collector Testing #12



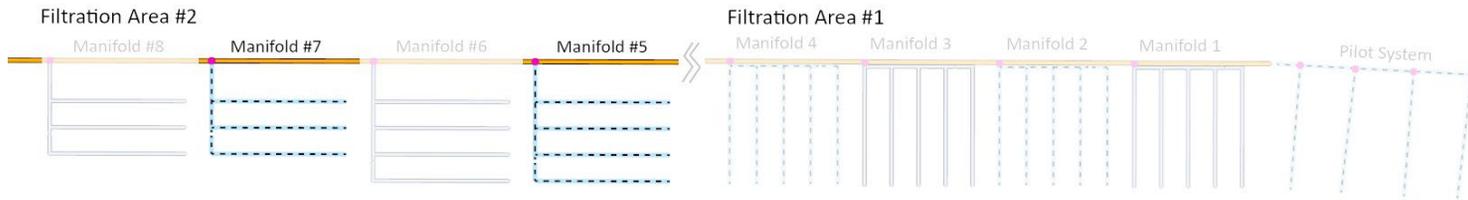
Date	# Open Sections	# of Combinations	Avg. Total Flow (cfs)	Avg Flow /Section (cfs)	Feet of Open Section	Avg flow /1000 ft
6/2016 to 8/2016	9	4	17.50	1.94	6,120	2.86

Collector Testing #13



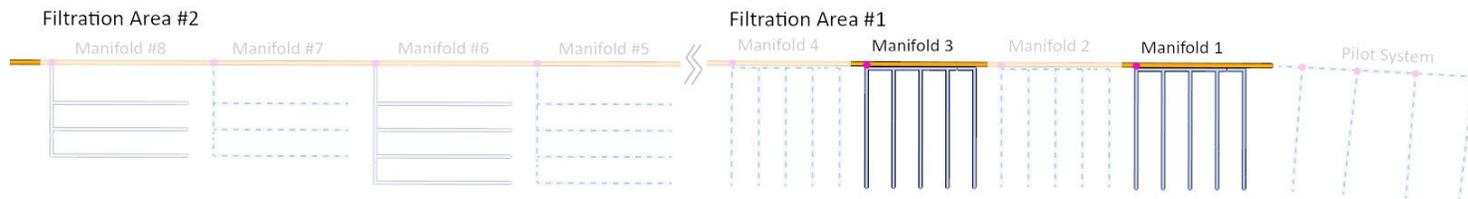
Date	# Open Sections	# of Combinations	Avg. Total Flow (cfs)	Avg Flow/Section (cfs)	Feet of Open Section	Avg flow/1000 ft
8/2017	2	1	7.00	3.50	1,440	4.86

Collector Testing #14



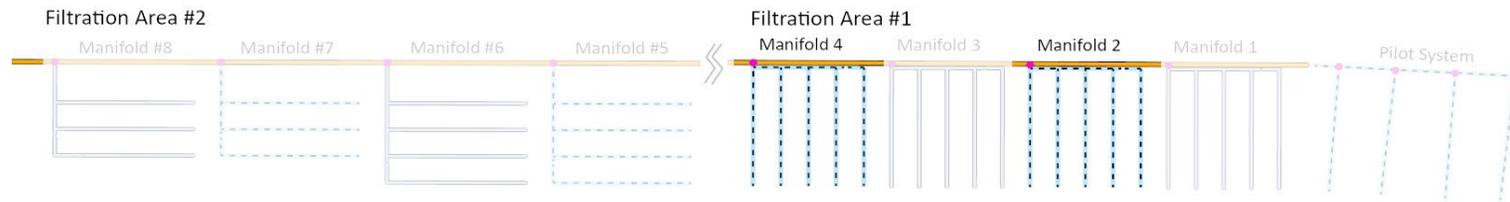
Date	# Open Sections	# of Combinations	Avg. Total Flow (cfs)	Avg Flow/Section (cfs)	Feet of Open Section	Avg flow/1000 ft
8/2017	2	1	5.00	2.50	1,260	3.97

Collector Testing #15



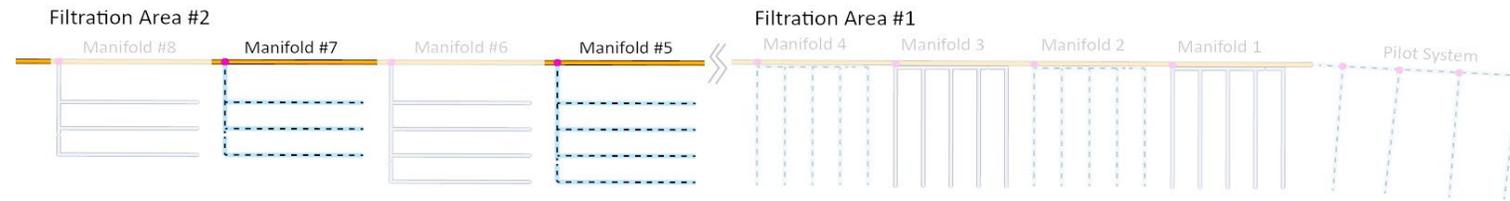
Date	# Open Sections	# of Combinations	Avg. Total Flow (cfs)	Avg Flow/Section (cfs)	Feet of Open Section	Avg flow/1000 ft
8/2017	2	1	5.90	2.95	1,440	4.10

Collector Testing #16



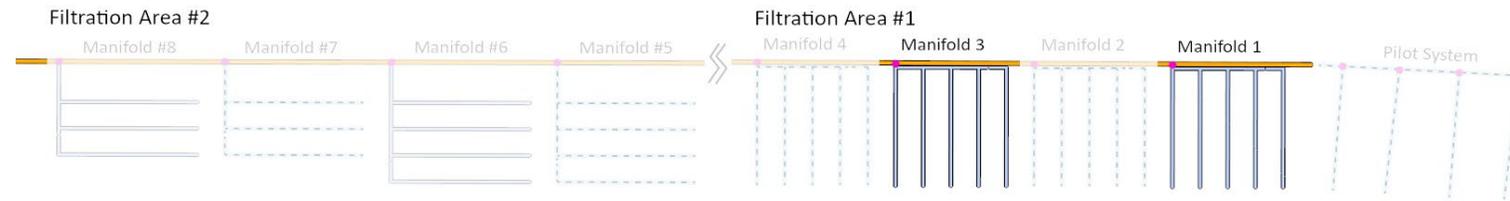
Date	# Open Sections	# of Combinations	Avg. Total Flow (cfs)	Avg Flow/Section (cfs)	Feet of Open Section	Avg flow /1000 ft
10/2017	2	1	5.10	2.55	1,440	3.54

Collector Testing #17

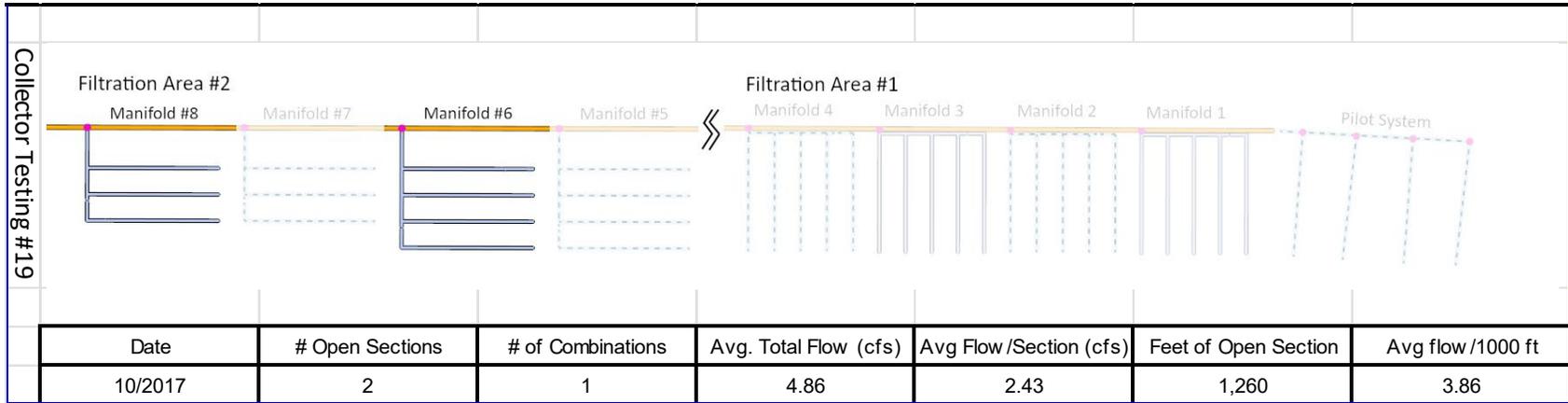


Date	# Open Sections	# of Combinations	Avg. Total Flow (cfs)	Avg Flow/Section (cfs)	Feet of Open Section	Avg flow /1000 ft
10/2017	2	1	3.94	1.97	1,260	3.13

Collector Testing #18



Date	# Open Sections	# of Combinations	Avg. Total Flow (cfs)	Avg Flow/Section (cfs)	Feet of Open Section	Avg flow /1000 ft
10/2017	2	1	5.60	2.80	1,260	4.44



RBF system collector schematic showing results of variations in lateral configuration testing; nineteen tests were conducted between December 2015- October 2017.

## **Appendix D**

Recharge Facilities Model Update and RFS Simulations (Jacobs, 2023)

## OCWD Recharge Facilities 2023 Model Update Technical Memo (Final)

<b>Date:</b>	August 29, 2023	<b>Jacobs Engineering Inc</b>
<b>Attention:</b>	Adam Hutchinson/OCWD	Suite 500, 5th Floor
<b>Client:</b>	Orange County Water District	2600 Michelson Drive
<b>Prepared By:</b>	Marcelo Reginato, Jacobs	Irvine, California 92612
<b>Reviewed By:</b>	Adam Hutchinson/OCWD	United States
<b>Document no:</b>	<i>[Document number]</i>	T +1 949.224.7500
<b>Revision No.</b>	3	www.jacobs.com

---

## 1. Introduction

In 2009, CH2M Hill developed a recharge facilities model (RFM) for the Orange County Water District (OCWD) managed aquifer recharge system (CH2M Hill 2009). Subsequently, OCWD has used the model to understand recharge benefits related to potential projects or changes in operations. The user interacts with the model via dashboards and model results can be retrieved also from dashboards or loaded into spreadsheet tools for further analysis.

This TM describes the model activities and changes implemented between May and September 2023. The activities focused on updating model inputs, reviewing logic, adding new logic, and updating dashboards for model control. The activities include a few model scenarios runs to understand benefits related to implemented changes. The model activities included:

- Update of historical Prado Dam releases time series.
- Update riverbed filtration system (RFS) logic.
- Update of model logic to pause infiltration decay when RFS is active.
- Model simulations to understand the benefits of a RFS under different operational scenarios.

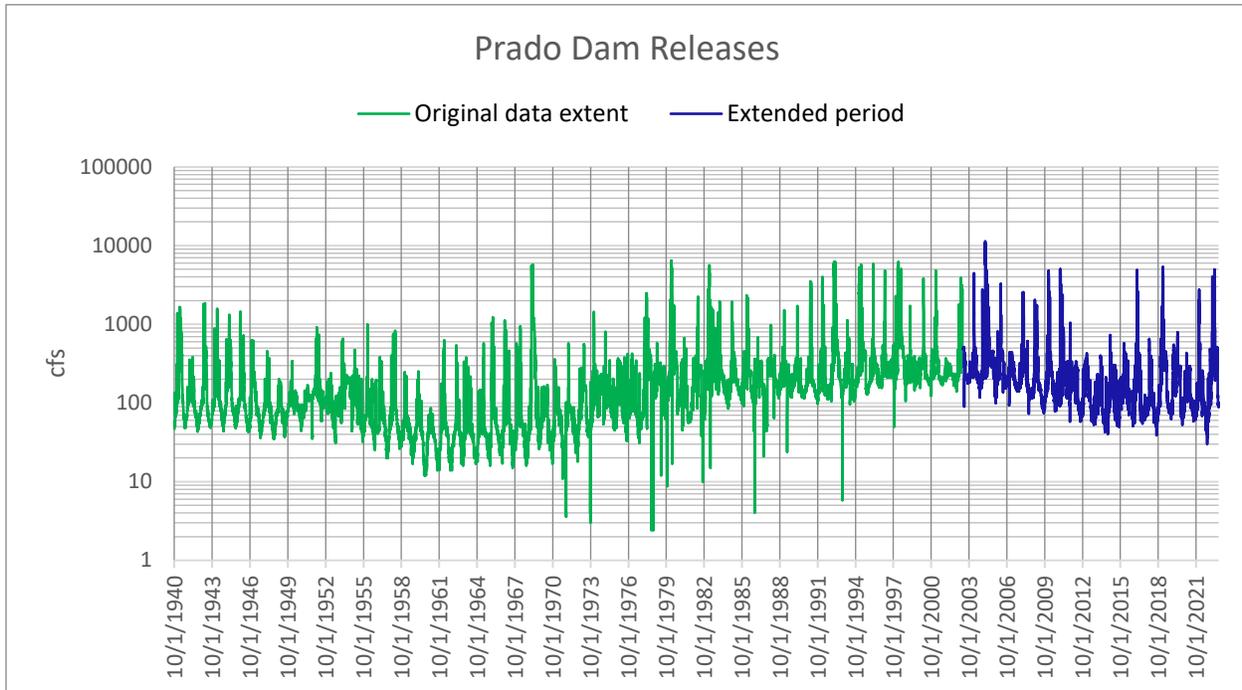
Attachment 1 includes the latest updated OCWD RFM model files that were used in this study. The files in attachment 1 were delivered electronically.

## 2. Model Updates

The Historical Prado Dam time series of water releases included in the original RFM extended from 10/1/1940 to 4/15/2013. During this current model update the time series were extended from 4/15/2013 to 7/18/2023. The flow data was downloaded from the United States Geological Survey (USGS) website (USGS 2023) for station USGS 11074000 SANTA ANA R BL PRADO DAM CA. The additional time series of Prado Dam releases allows model simulations to utilize historical Prado Dam releases up to 7/18/2023. shows the historical Prado Dam outflow data that can be used in the model as input to recharge basins. Historical Prado Dam releases is only one of many model options for inflow to the recharge system, other options include flows upstream Prado Dam with dynamic rules that operate the reservoir releases considering OCWD recharge basing status.

Prado Dam releases are a function of OCWD's recharge basins percolation status, therefore, simulations that have as main goal estimates of actual percolation volume should use a dynamic rule for Prado releases. The current model update is mainly concerned with the efficiency of a RFS; therefore, the historical record of Prado Dam releases is sufficient for this analysis. Future model runs may consider using historical or projected inflow rates and use the dynamic Prado Dam operations feature.

Figure 1. USGS 11074000 SANTA ANA R BL PRADO DAM CH Historical flow data



The RFS is a concept that would divert flows from the Santa Ana River (SAR) using a collection gallery constructed under the bed of the SAR. This system, if implemented, is supposed to have a few advantages over the current rubber dam diversion system:

- Filtration of SAR water that would otherwise flow into the OCWD recharge basins and eventually clog recharge basins.
- Ability to divert flows even when rubber dam is deflated due to high flow conditions in the SAR.
- Ability to divert flows even when sediment concentration in the SAR is elevated and would be otherwise avoided since it would rapidly clog recharge basins.

To estimate the benefits of a RFS, a few model changes were necessary. Additional dashboard options were added so that the model user can select the following options for model scenarios:

- Current rubber dam diversion only
- RFS diversion only
- Rubber dam diversion and RFS only if rubber dam is down.
- Rubber dam diversion and RFS with rubber dam diverting only when RFS is at maximum capacity and diverting only to off-river system (Olive Basin and downstream basins).

The RFS capacity is a user input and estimated at 450 cfs for the current model simulations. This capacity is above the maximum pipe capacities in the Warner and Anaheim systems.

An additional model logic was implemented that pauses the infiltration decay of the percolation basins in the Warner and Anaheim systems if flows are being diverted from the RFS. The original model percolation decay is a feature with many options that was built into the first model version (CH2M Hill 2009).

A number of model simulation scenarios were created to understand the benefit of a RFS in creating additional recharge for the system. The model scenarios are described in the following section.

### 3. Modeling Simulations

The total eight model scenarios run in this study was to understand the benefits of a RFS. The simulation run for a total of 18 years, from Fiscal year 2003 to 2020 in a daily time step.

During the simulation period the model assumed historical Prado Dam releases. This is not the closest to reality since Prado Dam releases can be a function of OCWD recharge basin conditions, however this assumption allows a more consistent comparison of benefits across scenarios. This simplification was applied to all scenarios and that would show, conservatively, how much more recharge the system would be able to achieve given a consistent set of inflows (same for all scenarios). Future simulations using the dynamic Prado Dam operations will provide a more realistic estimate of benefits.

The baseline scenario selected (from where all other scenarios originated) was the calibration scenario from year 2010. This scenario was replicating similar historical recharge basin operations however this scenario does not include the recent expanded Groundwater Replenishment System (GWRS) flows, except for a short period between January and July of 2008, and recent added basins (Miraloma and La Palma). Figure 2 shows the percolation model results for the baseline model run in comparison with historical measured percolation. The historical data is available up to year 2008.

**Figure 2. Baseline percolation comparison against available historical percolation up to year 2008**

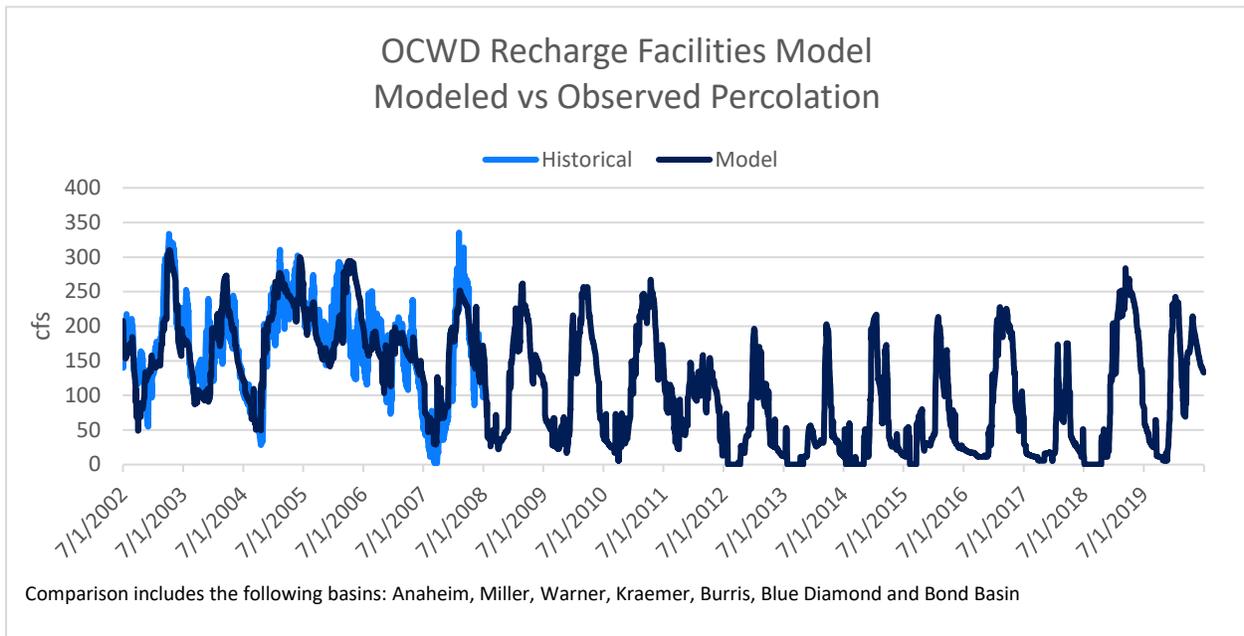
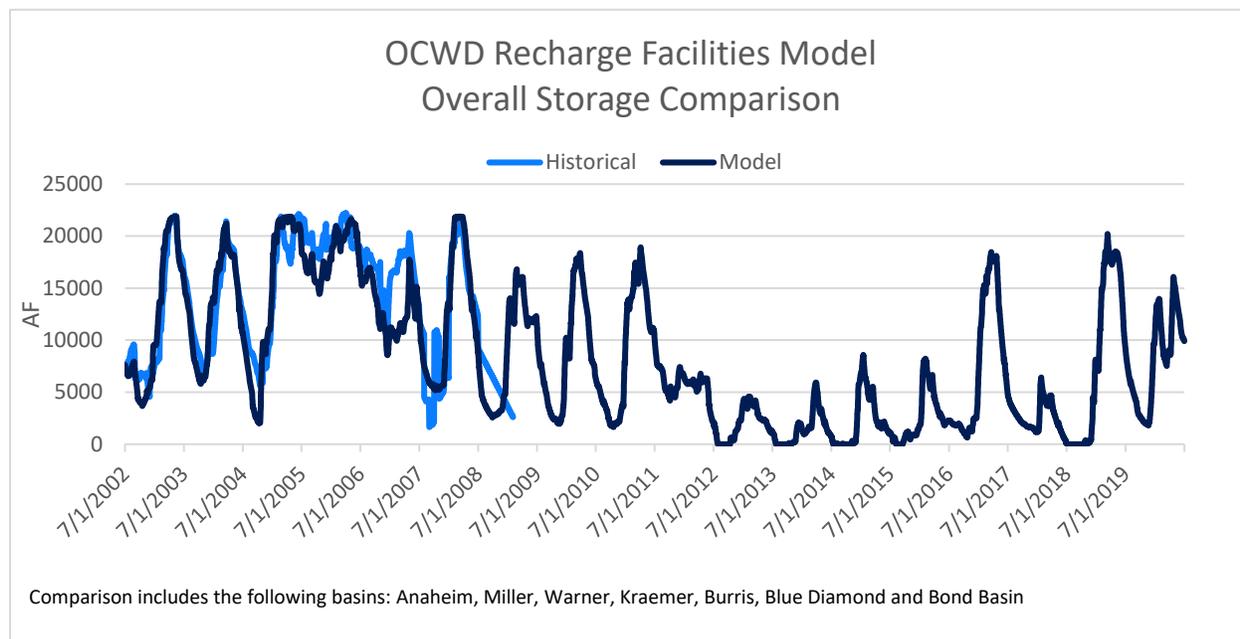


Figure 3 shows the system storage for a selection of basins. The figure compares model results for the baseline model against historical measured storage. The historical data is available up to year 2008.

Figure 3. Baseline storage comparison against available historical storage up to year 2008



A total of seven additional model scenarios were created in addition to the Baseline. The seven model scenarios were created to evaluate the recharge benefits of aRFS. Following is a brief description of the model scenarios:

**Base Calibration (Olive Basin ON)** the Baseline calibration scenario uses the same assumptions of the calibration model scenario except that the Olive Basin is turned on with percolation capacity of 20 cfs.

**Alt1a -RB** This scenario includes the RFS as a replacement for the Rubber dam system. The difference in yield is due to the fact the RFS can divert water when the rubber dam is deflated.

**Alt1b -RB Holding decay** Same assumptions of Alt1b, however this scenario stops the percolation decay of the Warner and Anaheim systems basins.

**Alt2a -RB OR RD** This scenario allows the use of the RFS or the rubber dam but not both systems at the same time. The RFS is activated only if the rubber dam is deflated due to high flows in the river.

**Alt2b -RB OR RD Holding decay** Same assumptions of Alt2b, however the percolation decay of the basins that fed by the RFS (Anaheim and Warner basins) is paused when being fed water from the RFS.

**Alt3a -RB AND RD** This scenario allows the use of both the RFS and rubber dam diversions at the same time, however, the rubber dam system will only divert after the RFS is maxed out and will divert only to off river system (Olive Basin and downstream basins). This scenario stops the percolation decay for Anaheim and Warner basins since it assumes that only water from the RFS supplies these basins.

**Alt3b -RB AND RD incr. WTP capacity** Same assumptions of scenario Alt3a but with increase of the Warner Transmission Pipeline (WTP) from 170 cfs to unlimited and removing capacity constraints between WTP and the RFS. The unlimited value would show the maximum flows needed to supply basins downstream of the WTP.

A summary of the model variables that changed across all the scenarios are presented in Table 1.

**Table 1. Demand Assumptions for the Different Model Alternatives**

Scenarios	Model Variables			
	Rubber Dam diversions	Riverbed diversions	Hold Percolation Decay	Pipe capacity increased
Calibration (2010)	✓	x	x	x
Base Calibration (Olive Basin ON)	□	x	x	x
Alt1 a-RB	x	□	x	x
Alt1 b-RB Holding decay	x	x	□	x
Alt2a-RB OR RD	□	□	x	x
Alt2b-RB OR RD Holding decay	□	□	□	x
Alt3 a-RB AND RD	□	□	□	x
Alt3 b-RB AND RD incr. pipe capacity	□	□	□	□

The model results are summarized in Tables 2 and 3. Table 2 shows annual average percolation, average annual losses to the ocean, and average cleaning events over the simulation time. The table also shows the difference from Baseline scenario. Most of the scenario runs achieve higher percolation, reduced losses to the ocean and fewer basin cleaning events. The increased percolation ranges from approximately 650 AFY to a little over 10,000 AFY and there could be reductions in number of cleanings of up to 8 events per year.

Table 3 is focused on individual basins in the system and shows the average recharged in these basins in comparison with some historical averages. The implementation of a RFS would increase percolation in basins receiving this water.

For scenario Alt3b, where the WTP capacity was left unlimited, the maximum flow observed was 368 cfs.

## Technical Memorandum

---

**Table 2. Summary of model results presented as average over an 18-year simulation period.**

Scenario	18 years Annual Average Results			Difference From Calibration (2010)			Percentage Difference From Calibration (2010)		
	Average Percolation	Average Losses to Ocean	Average Cleaning Events	Average Percolation	Average Losses to Ocean	Average Cleaning Events	Average Percolation	Average Losses to Ocean	Average Cleaning Events
	AFY	AFY	Events/yr	AFY	AFY	Events/yr	%	%	%
Calibration (2010)	170,423	55,013	17	0	0	0	0.0%	0.0%	0.0%
Base Calibration (Olive Basin ON)	170,996	54,441	17	573	-572	0	0.3%	-1.0%	-0.3%
Alt1a-RB	172,427	52,994	17	2,004	-2,019	-1	1.2%	-3.7%	-3.2%
Alt1b-RB Holding decay	178,372	47,253	10	7,949	-7,760	-8	4.7%	-14.1%	-43.6%
Alt2a-RB OR RD	172,212	53,222	17	1,789	-1,791	-1	1.0%	-3.3%	-3.2%
Alt2b-RB OR RD Holding decay	172,378	53,069	17	1,955	-1,945	0	1.1%	-3.5%	-2.6%
Alt3a-RB AND RD	178,376	47,248	10	7,953	-7,765	-8	4.7%	-14.1%	-43.6%
Alt3b-RB AND RD incr. pipe capacity	180,519	45,144	10	10,097	-9,869	-7	5.9%	-17.9%	-42.9%

**Table 3: Historical versus model results for average annual system percolation**

System	Time Period	Historical Data				Model Results						
		Max Annual Recharge (afy)	Avg Annual Recharge (afy)	Calibration (2010)	Base Calibration (Olive Basin ON)	Alt1a-RB	Alt1b-RB Holding decay	Alt2a-RB OR RD	Alt2b-RB OR RD Holding decay	Alt3a-RB AND RD	Alt3b-RB AND RD incr. pipe capacity	
		AFY	AFY	AFY	AFY	AFY	AFY	AFY	AFY	AFY	AFY	
Desilting System	FY92/93 -FY12/13	3441	1,239	2,651	2,651	2,680	2,680	2,651	2,652	2,680	2,680	
SAR Channel	FY95/96-FY12/13**	76961	62,600	68,438	68,438	68,398	68,398	68,438	68,441	68,398	68,398	
Upper Off River Channel				340	348	416	204	417	395	204	144	
Lower Off River Channel				1,046	990	1,139	584	1,118	1,062	584	410	
Warner Basin System	FY88/89-FY12/13	33534	16,470	21,446	21,437	21,277	38,743	21,448	21,919	38,743	37,876	
Anaheim Lake*	FY88/89-FY12/13	42555	30,950	24,069	24,134	24,890	35,621	24,442	24,869	35,621	36,309	
Mini-Anaheim Lake*	FY97/98-FY12/13	5207	3,295	3,895	3,877	3,883	2,611	3,863	3,688	2,611	2,582	
Kraemer Basin*	FY88/89-FY12/13	45502	25,637	14,614	14,348	14,660	10,396	14,468	14,505	10,396	13,202	
Miller Basin*	FY88/89-FY12/13	27345	12,177	2,295	2,051	2,257	269	2,019	2,033	269	3,623	
La Jolla Basin*	FY08/09-FY12/13	8505	5,621	808	674	729	-	762	711	-	270	
Placentia Basin	FY88/89-FY12/13	3609	738	713	697	772	-	793	681	-	206	
Raymond Basin	FY88/89-FY12/13	3517	1,148	843	848	850	11	889	725	11	213	
Off-River Channel												
Olive Basin	FY08/09-FY12/13	3364	2,380	-	1,023	1,215	617	1,209	1,115	617	499	
Five Coves Basins	FY89/90-FY12/13	5316	2,153	2,305	2,371	2,291	1,586	2,350	2,350	1,586	1,316	
Lincoln Basin***	N/A		362	8	8	8	8	8	8	8	8	
Burriss Basin	FY89/90-FY12/13	15916	10,390	5,980	6,074	6,081	3,985	6,214	6,238	3,990	3,080	
River View Basin	FY04/05-FY12/13	3152	1,930	1	1	1	1	1	1	1	1	
Santiago Basins	FY95/96-FY12/13**	62250	38,800	18,830	18,895	18,778	11,237	18,994	18,766	11,237	8,606	
Santiago Creek Channel	FY98/99-FY12/13	5149	3,152	2,185	2,173	2,143	1,465	2,171	2,263	1,465	1,143	
<b>Total</b>		<b>345323</b>	<b>219,042</b>	<b>170,467</b>	<b>171,040</b>	<b>172,470</b>	<b>178,417</b>	<b>172,256</b>	<b>172,422</b>	<b>178,421</b>	<b>180,564</b>	
				Change from Calibration (2010)	572	2,003	7,950	1,788	1,954	7,954	10,097	

\*Max recharge for these basins elevated due to recharge with imported and/or GWRS water.

\*\*Early years excluded because different assumptions regarding storm flow and peak recharge were used.

\*\*\*Assumed 0.5 cfs of recharge capacity.

\*\*\*\* average of 18 years

## 4. Conclusions

A RFS could significantly increase recharge in receiving basins by reducing the total suspended solids (TSS) in the diverted flows from SAR. The different model scenarios estimate the magnitude of the recharge benefit based on different possible operations, mainly by increasing diversion at times the current rubber dam system would be unable to divert and holding the percolation decay when receiving water from the RFS.

This first analysis of RFS benefits does not assume any decay on basin percolation. Although a much lower clogging effect is expected from water produced by the RFS the no decay condition is likely over optimistic. Further work is needed to assign a reasonable clogging rate to bound the potential benefits of the RFS.

The simulations indicate a potential additional annual yield of up to 6 percent using historical Prado Dam outflow. The improvements in recharge represent reduced losses to the ocean and are highest during the wet years when losses to the ocean are greatest.

A significant reduction in basin cleaning events is also expected since filtered water from the RFS will result in less clogging. Model results indicates a reduction between 1 and 8 total cleaning operations per year considering all basins that receive water from the RFS.

Future model scenarios can be run with projected Prado inflows and using the dynamic Prado Dam operations with target water conservation elevations. Another improvement is applying a more realistic basin percolation decay. Both of these changes will offer a better estimate on the future potential recharge that the RFS would be able to achieve.

## 5. References

CH2M Hill. 2009. Orange County Water District Recharge Facilities Model - Development and Calibration of the Orange County Water District Recharge Facilities Model (OCWD RFM) October 2009.

USGS.2023.USGS 11074000 SANTA ANA R BL PRADO DAM CA flow time series Automated-retrieval info: <https://help.waterdata.usgs.gov/faq/automated-retrievals>. retrieved: 2023-07-19 14:17:13 EDT

**Attachment 1**  
**OCWD Recharge Facilities Model**



## Technical Memorandum

---

[OCWD\\_OPT\\_v1.63\\_v14\\_player.zip](#)